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~ MEFkon 2025 ~

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Svetlana Vukotić, PhD

Tehnical editors
Sanja Anastasija Marković, PhD
Vuk Mirčetić, PhD

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Strahinja Vidojević, BSc

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Foreword

Dear authors, readers, colleagues, students and enthusiasts eager for knowledge,

In front of you are the proceedings of the eleventh International Scientific and Professional Conference "Innovation as an initiator of the development" organised by the Faculty of Applied Management, Economics, and Finance, Belgrade, University Business Academy in Novi Sad.

The information age, in which we live, has imposed a constant flow of new ideas as a condition for the development of individual, company, and societal potential. Generating innovations contributes to progress, and according to Peter Drucker, real profit is only that obtained through innovation. Therefore, for more than a decade, at the beginning of December, we have been traditionally confirming through papers at the conference that innovations are all around us. It is precisely in this thematic comprehensiveness that the inspiration to analyse innovations from multiple angles lies.

This year, the proceedings bring together works by numerous authors, both from Serbia, the surrounding countries, and from other countries, showing that spatial boundaries do not limit innovations. On the path to re-examine innovations, eminent university professors, prominent researchers, experts and scientists gathered around a common goal. We are especially proud of our young researchers who will inevitably be the bearers of innovations in the future, but who have also analysed them in their studies at the present moment.

We are grateful to everyone for the trust and cooperation they have shown in our quest to explore innovations together, both now and in the future. Innovations will never cease to give us hope again and again.

In Belgrade, December, 2025

Editors

Gabrijela Popović, PhD

Darjan Karabašević, PhD

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INVITED PAPERS

Social Transformations and Changing Societies

Društvene transformacije i društva koja se menjaju

Venelin Terziev[1], Marusya Lyubcheva[2]

[1]*Trakia University, Stara Zagora, Bulgaria; Black Sea Institute, Bourgas, Bulgaria, vkterziev@gmail.com*
[2]*Black Sea Institute, Bourgas, Bulgaria, milyubcheff@gmail.com*

Abstract: *In this publication, we set ourselves the objectively complex task of analyzing the possibilities for making strategic decisions during a crisis, trying to partially analyse the ongoing crises caused by various circumstances. Crisis circumstances require societies to quickly rethink and develop adequate strategies and, accordingly, to formulate strategic goals and plan processes. In many cases, preliminary analysis and assessment are practically impossible, especially when it comes to natural disasters or other types of crises, such as military conflicts. All this puts entire systems and societies to the test, and those who are empowered to manage the process - under strong pressure from unforeseen circumstances and not always objective assessments. The oncoming social transformations are unpredictable, and people find themselves unprepared to deal with new and different challenges. Researching and analyzing these processes is a particular challenge, that cannot always be accomplished with traditional approaches and research methods. This paper presents the expert analysis of the authors, as well as their views and assessment of the ongoing processes.*
Keywords: *Entrepreneurship, legal aspects, organizational aspects, European Union, small and medium-sized enterprises, Bulgaria.*

Apstrakt: *U ovoj publikaciji, postavili smo sebi objektivno složen zadatak analize mogućnosti za donošenje strateških odluka tokom krize, pokušavajući da delimično analiziramo tekuće krize izazvane različitim okolnostima. Krizne okolnosti zahtevaju od društava da brzo preispitaju i razviju adekvatne strategije i, shodno tome, da formulišu strateške ciljeve i planiraju procese. U mnogim slučajevima, preliminarne analize i procene su praktično nemoguće, posebno kada su u pitanju prirodne katastrofe ili druge vrste kriza, poput vojnih sukoba. Sve ovo stavlja čitave sisteme i društva na test, a one koji su ovlašćeni da upravljaju procesom - pod snažan pritisak nepredviđenih okolnosti i ne uvek objektivnih procena. Predstojeće društvene transformacije su nepredvidive, a ljudi se nalaze nespremni da se nose sa novim i drugačijim izazovima. Istraživanje i analiza ovih procesa je poseban izazov, koji se ne može uvek ostvariti tradicionalnim pristupima i metodama istraživanja. Ovaj rad predstavlja stručnu analizu autora, kao i njihove stavove i procenu tekućih procesa.*
Ključne reči: *Preduzetništvo, pravni aspekti, organizacioni aspekti, Evropska unija, mala i srednja preduzeća, Bugarska.*

Introduction

Social systems are subjected to specific loads and this even questions their existence as such. these are extremely interesting processes from a scientific and research point of view. Their analysis, study and modeling would create conditions for a strategy for their management. Managing processes in such complex, sometimes unpredictable or crisis situations requires the preparation of the leaders of various institutions, organizations, countries. Overcoming crises, as well as eliminating their consequences, pose a particular challenge.

Setting goals and planning process actions in process management, and on a larger scale - strategic management during a crisis, is even more challenging. In accordance with the definitions of "crisis", in the broadest sense, crisis management is of strategic importance, since it is always about saving and surviving people, territories, objects, etc. On the one hand, crisis management corresponds to the

principles of general management, but on the other hand, it is quite complex, which arises from the fact of the rapidly and dynamically changing environment - both national and international. This is most often and clearly observed during crisis circumstances that affect a very large part of the population of a given country, region, continent or even the whole world. Crises have a diverse nature, both in scope and nature, and their management is related to this. Different options for developing strategies in crisis situations are considered, depending on whether they concern one administrative area, country, group of countries or cover the whole world.

1. The formation of the new social systems

Social systems have their own characteristics and they cannot exist by themselves. Regardless of the fact that different definitions and different interpretations are found in the scientific and popular literature, they are those that form the social attitudes of the individuals (people) in the environment. Countries can be seen as social systems, even the world can be seen as one social system.

A welfare state is a form of government in which the state (or a well-established network of social institutions) protects and promotes the economic and social well-being of its citizens, based upon the principles of equal opportunity, equitable distribution of wealth, and public responsibility for citizens unable to avail themselves of the minimal provisions for a good life (2024).

There is substantial variability in the form and trajectory of the welfare state across countries and regions (Béland et al., 2021). All welfare states entail some degree of private–public partnerships wherein the administration and delivery of at least some welfare programs occur through private entities (Béland & Morgan, 2021). Welfare state services are also provided at varying territorial levels of government (Béland & Morgan, 2021).

Early features of the welfare state, such as public pensions and social insurance, developed from the 1880s onwards in industrializing Western countries (Skocpol, 1995; Béland et al., 2021; Koehler-Derrick & Lee, 2023). World War I, the Great Depression, and World War II have been characterized as important events that ushered in the expansion of the welfare state (Skocpol, 1995; O'Hara, 1999). The fullest forms of the welfare state were developed after World War II (Béland et al., 2021).

The German term sozialstaat (“social state”) has been used since 1870 to describe state support programs devised by German sozialpolitiker ("social politicians") and implemented as part of Otto von Bismarck's conservative reforms (Fay, 1950).

The literal English equivalent “social state” did not catch on in Anglophone countries (Smith, 1901). However, during the Second World War, Anglican Archbishop William Temple, author of the book Christianity and the Social Order (1942), popularized the concept using the phrase “welfare state” (Gough, 1989) Bishop Temple's use of “welfare state” has been connected to Benjamin Disraeli's 1845 novel Sybil: or the Two Nations (in other words, the rich and the poor), where he writes “power has only one duty – to secure the social welfare of the PEOPLE” (Disraeli, 2024). At the time he wrote Sybil, Disraeli (later a prime minister) belonged to Young England, a conservative group of youthful Tories who disagreed with how the Whigs dealt with the conditions of the industrial poor. Members of Young England attempted to garner support among the privileged classes to assist the less fortunate and to recognize the dignity of labor that they imagined had characterized England during the Feudal Middle Ages (Alexander: Medievalism).

Before looking in detail at the ongoing processes in social systems, it is good to clarify the concept of social structure.

Social structure is a term used in sociology and the social sciences to denote characteristically constructed social formations that make society as a whole and that determine to some extent the actions of individuals socialized in that structure.

The meaning of the term social structure has different applicability. In macro sociology, it is a system of socioeconomic stratification, social institutions, or certain relations between large social groups. In meso-sociology, it is a social network structure that creates connections between individuals or organizations. In macro sociology, it can also be how norms determine the behavior of individuals in a social system.

Social systems function under the organization of certain rules. These rules are created to satisfy certain needs of the individuals who participate in a given social system. The development of social systems leads to a distortion of the set of existing rules, which becomes unacceptable to individuals. This is one of the prerequisites for implementing change in social systems or their destruction. The period of transformation of one social system into another is usually accompanied by cataclysms that societies experience.

Historians speak of cyclicality in the change of social systems, which has only some accuracy in such logic. However, it should be emphasized that the changes that occur in social systems are caused by certain circumstances and factors that have an impact on the system itself. The turbulence that precedes certain transformations in the social system is a signal that the period of system change is soon.

Signals of changing social systems are a large set of events and actions that occur in a certain sequence. Such can be the frequent regional military conflicts and tensions in certain communities that create discomfort in the coexistence of a certain group of people and many others.

A significant problem is the divergence in action between those who manage social systems and those who participate in social systems. When the expectations of the one and the other are in different directions, the rupture in this social system is completely predictable and expectedly possible.

All the elements of a state of tension of existing social systems are present. The internal and external environments function in a series of defect processes. This not only creates a sense of failure in their existence but also foreshadows many transformations to come. The rules created for the normal functioning of these social systems have exhausted their essence and must be replaced by other rules that satisfy the existence of the new social systems.

Even a basic survey of the behavior of the leaders of the existing social societies speaks unequivocally that a dramatic change is coming, in which all participants will be subjected to certain loads, even tensions during this period of active transformations.

The changes that will have to be accepted by the individuals participating in these new public social systems may turn out to be overwhelming for some of them, for others - unacceptable, and for others - an objective impossibility to physically survive this transformation.

They are looking for the creation of new social systems, which will condition new rules of interaction in them, which will also form new types of social relations. Undoubtedly, the newly formed social leaders will play a key role in these transformations.

This process of active and preferential influence of social leaders is known historically. The dominant influence of strong social leaders was also evident after the end of the two world wars. Their decisions affect both large and small social systems. The rules of functioning of the transformed social systems are set and partially shaped by the new social leaders of the historical moment.

The inevitability of such a process is almost impossible to predict with absolute accuracy, but considering that such processes take approximately several years, it can be said that we are already in a stage of the period of active social transformations.

The lack of research in this direction and the possibility of planning and forecasting these processes is puzzling. Even if we assume that some of them are under the guise of protecting national security, the deepening of research in this direction must happen quickly enough and with the possibility of the participation of researchers with high expertise in various fields.

2. Formation of the new social centers

The changes that are taking place of a geopolitical nature also imply social changes in social systems. Many analysts predict drastic changes in social relations, which will lead to the formation of new spheres of influence. Whether this will happen and especially when it will happen is a question from the point of view of a specific strategic analysis. Despite the impossibility of analyzing with a certain precision the multidirectional information in this plane, it can be concluded with a great deal of objectivity that several main centers of influence. These centers have the economic, financial, military, political, and cultural capacity to influence social systems. They have a high power of influence that they can even model them. To a certain extent, this gives us an objective possibility of predictability, and on the other hand, it also predicts uncertainty in the direction of development of these processes.

2.1. World financial centers formed

We can consider financial centers as one of those that can significantly influence the ongoing transformations in social systems.

New York retains the top spot in the ranking of global financial centers by the Z/Yen Group. London and Singapore also retain their positions in second and third place respectively in the 33rd edition of The Global Financial Centers Index (GFCI).

The 33rd edition of the Global Financial Center Index (GFCI 33) provides future competitiveness assessments and rankings for 120 financial centers around the world. GFCI serves as a reference for policy and investment decision-makers.

The China Development Institute (CDI) in Shenzhen and Z/Yen Partners in London are collaborating on the development of the GFCI. GFCI is updated and published every March and September and receives considerable attention from the global financial community.

130 financial centers are surveyed for GFCI 33, of which 120 are in the main index. The GFCI is compiled using 153 instrumental factors. These quantitative measures are provided by third parties, including the World Bank, the Economist Intelligence Unit (EIU), the Organization for Economic Co-operation and Development (OECD), and the United Nations.

Instrumental factors are combined with financial center ratings provided by respondents to the GFCI online questionnaire. GFCI 33 uses 61,449 ratings from 10,252 respondents (2024a).

2.2. World economic centers formed

The formed world economic centers, even in the presence of divergent assessments of their capacity, define the USA, the European Union and Asia as such. Usually, the main indicator that is predominantly used is the Gross Domestic Product per capita. However, this only shows part of the economic picture in determining these centers.

2.3. World military centers formed

The military power of the states is determined by a number of indicators, with a significant advantage given by high-tech armament and preparedness. Five countries have the largest armed forces, as follows: China (2,255,000), USA (1,420,000), India (1,414,000), Russia (1,120,000), Democratic People's Republic of Korea -1,106,000 The countries - South Korea, Pakistan, Iran, Turkey, Vietnam - also have a large number of armed forces (2024b).

2.4. World political centers

The influence on the formation of public relations on a global scale is undoubtedly exerted by several political centers. Washington (USA), which in the last decades was the undisputed leader in almost all respects and had an irresistible opportunity to determine to a large extent the public policies of many countries, even to change them and redirect them to different spheres of its influence. The forceful

imposition of certain policies was part of this hegemon behavior. Of course, it has always been limited or contested by other contenders.

The dynamic development of the processes determines the definition of several main centers, such as Moscow (Russian Federation) and Beijing (People's Republic of China). In no case can their influence be defined as only regional. Their behavior in the last few years has determined that they hold major political influence. We should note that both countries in different historical periods had one.

Several more political centers can be identified on the various continents, whose influence exceeds their regional importance.

This is only a brief analysis of the factors that can and do significantly influence the determination of several major centers of influence that will be instrumental in the formation of the new social systems. It is indisputable that they will not give up exerting their all-round influence on the social transformations that have already begun, they will even try to define and single out larger spheres of influence.

3. Transformations, challenges, crises and strategic management

Usually, societal transformations are associated with crisis phenomena – political, economic and social. Sometimes they cover smaller territories or societies, but global crises are usually large-scale, both in terms of territory and in their nature, and are a challenge for many countries, existing alliances of different nature – political, economic, military or others. In any crisis, the most affected are people, i.e. the individual, regardless of which of the above-mentioned structures he belongs to and what his duties are.

Linus Carl Pauling, an American chemist born in German, winner of the Nobel Prize in Chemistry and Nobel Peace Prize winner, said: "Nations keep agreements, keep their treaties so long as they continue to do them good". Unfortunately, however, when crises emerge, especially global ones, keeping certain contractual relations is not always doing good. Crises are characterized as risks with a high degree of uncertainty, disruption of the interaction between the factors of each system and high dynamics. Violation of the values of all social groups is also an important part of the development of the crisis. The development of any crisis does not begin from the moment of the violation of the respective balances, but from the moment when the society prepares for it in its organizational structure. The principles that are followed in crisis management are related to speed, risk assessment, analysis, planning and impact.

The implementation of all strategies and the achievement of all goals must definitely pursue the preservation of maximum values for the good existence of the people. The assessment of actions and possible perspectives is objectified by certain criteria and indicators. The fairness and accuracy of each assessment may be different, as well as different in accuracy and correctness for different groups of people, even for a particular individual.

This questions or at least creates discomfort in the formation and implementation of each step of the strategy, regardless of whether it is implemented on a limited scale without significant fluctuations in the internal or external environment or in a situation of general and active dynamics.

In every case or in any specific situation, the use of objective, measurable and realistic goals in the implementation of strategic management is of paramount importance and a task with a high degree of complexity. This directly corresponds to the planning of certain actions and activities in order to be able to meet the strategic goals to the maximum extent.

Crisis circumstances require societies to quickly rethink and develop adequate strategies and respectively to formulate strategic goals and plan processes. In many cases preliminary analysis and assessment are practically impossible /especially when it comes to natural disasters or crises/ and this requires a different operational order of problem solving, which includes formulating new unconventional goals and then implementing planning not objectified by a concrete and accurate

analysis. All this puts whole systems and societies to the test, and those who are empowered to manage the process – under high pressure from unforeseen circumstances and not always objective judgments. Which, in turn, creates a number of subsequent critical issues in the management process.

All this definitely does not define this process as non-strategic, but puts it in a different environment. The strategic nature is determined at least by the fact that it directly or indirectly concerns a very large group of people, and that it determines the actions of one or more systems.

In the last few years, such global crisis has become the pandemic caused by COVID-19. It has forced societies to make certain decisions of strategic nature to overcome the situation that threatens the lives and health of people around the world. It is more than obvious that the applied strategic approach includes many factors that change in the different periods of the crisis and seems to decompose the crisis itself into smaller elements in nature and scope. This does not change the strategic goal that is protecting human life and health.

Undoubtedly, each country has its own crisis response programmes and plans, but it is important whether those states with power to govern societies are able to quickly and accurately assess the changing environment, to implement these programmes and plans adequately, and last but not least to reformulate their strategic goals and plans and put them at the service of the respective community, taking into account the external environment /mandatory in a number of crisis situations/

The implementation of any crisis management strategy is directly dependent on the capacity of its managers, both administratively and financially. The realities of the last few years have shown that not everyone can cope with this critical governance process in a relatively complex and difficult situation.

Everyone determines their actions for the benefit of their community, but not everyone has the financial and material ability, and last but not least, the intellectual scientific capacity to achieve all this. Imbalances, even without using the specific statistics, are present and show significant differences. Even in global crises, some societies cope faster with the specific crisis circumstances, while others more slowly. For some societies the consequences are quite severe, and for others – relatively acceptable. All of them have faced certain consequences, which must be assessed after the crisis situation in order to take appropriate corrective actions.

It would be difficult to explain the speed of corrective action in different societies. This, in turn, corresponds to the ability to reformulate certain goals, as well as the ability to achieve them effectively.

Linus Carl Pauling said: "If you want to have good ideas you must have many ideas. Most of them will be wrong, and what you have to learn is which ones to throw away". The world-famous chemist drew his conclusions based on the accumulated knowledge, experience and sufficient information, which helped him define the problem that the lack of a sufficiently large set of ideas from which to select those worth implementing leads to significant difficulties. The transfer of ideas, algorithms or the copying of entire processes from one society to another has historically shown that it does not always or at least in most cases does not mean good outcome. Scientifically based approbation of something or a process is too complicated when we talk about strategic management of social processes. Social processes practically include all management systems and their management has its high complexity at almost all stages, as well as a very complicated mechanism of influence. The second example of a high scale crisis that is currently taking place is the situation in Ukraine. By its nature, it is political, but accompanied by economic and social issues. It is regional in scope, but with signs of becoming global.

The conflict between Russia and Ukraine is putting societies in yet another crisis situation due to the manifestation of a territorial, political, economic and military component. In its development, it is acquiring a global character.

This places certain restrictions on societies when reformulating their strategic decisions and implementing effective strategic management. Analyses of this crisis are divergent and at this stage do not allow to develop a unified strategy for resolving it, precisely because political and military crises

are among the most complex in the world. In addition, this crisis is multipolar and besides the two countries directly involved, it effects many other countries, alliances, each with its own strategic goals, inconsistent with the others or without any diplomatic rapprochement so far.

I would like to draw attention to an analysis of the Bulgarian professor Marusya Lyubcheva dated February 25, 2022, published on the Internet portal Pogled.info, which describes a certain chronology of this conflict and tracks the change of certain relations from strategic partnership to military conflict (2023a).

"In the years when Bulgaria joined the European Union, the European Union was developing documents for a strategic partnership with Russia. Until 2009, the Strategic Partnership Report with Russia went through discussions in the European Parliament and was structured on trade, economy, energy, climate change, research, education, culture, security, including the fight against terrorism, non-proliferation of nuclear weapons and conflict resolution in the Middle East.

Discussions covered Russia's accession to the World Trade Organization, which took place several years later. Russia was part of the Black Sea Synergy, the comprehensive report that placed not only the six Black Sea countries but also the wider Black Sea region in an important region for the European Union. Until the moment the European Union made a reorientation towards the Eastern Dimension or Partnership. The Black Sea region was forgotten and until 2018 it remained with only one report after the Synergy, delayed in its implementation. Everyone had high hopes for the Eastern Partnership. The signing of declarations of closer co-operation between the European Union and Ukraine, Belarus, the Republic of Moldova, Georgia, Armenia and Azerbaijan organized their relations. It was also part of the neighborhood policy, defined by J.M. Barroso as "forming a circle of friends" and was implemented for the purpose of mutually beneficial economic and political relations between the European Union and the neighboring countries. The discussion also covered the South Caucasus region. The Eastern Partnership together with the Strategic Partnership between the European Union and the Russian Federation, offered a new approach to East-West relations, based on cooperation and mutual support for building a more secure and sustainable world order. Until it became clear that the idea was not purely European. The limit was in 2013 - Ukraine. When the aspirations of the Eastern Partnership countries for NATO membership began to dominate and displace the principles of the original idea. Many of the iconic politicians in the European Union at the time began to talk about modifying the Eastern Partnership. However, the events in Ukraine took place. Today we call them a "'revolution", but in 2013 they were not named that. Only a few MEPs waved the Ukrainian flag in plenary and set out on a revolution in that country. There were also different opinions. And no one has the right to forget that. Personal archives also speak. Artificial and one-sided support of these events, without trying to solve the arisen problems through diplomacy. One conflict always involves at least two sides. And this conflict involved many countries. So, resolutions to impose sanctions were issued, one after the other, negotiations took place, certain pawn candidates were imposed in the elections in Ukraine, the government was financed without proper control as to what for and how the funds are used, funding of foreign NGOs that pursue policies not typical even for Ukrainians. Surely these backstage schemes will come to light one day, because the documents proving it are still there. Tension that has transformed the strategic partnership into a constantly evolving sanctions regime, in which the European Union has participated more and more. Economic crisis, energy security strategies that went wrong, difficult negotiations on climate change, not very successful foreign policy, complicated negotiations on the migrant crisis, etc.

Despite attempts to come to an agreement, incl. Minsk agreements (which Ukraine has long refused to fulfill), the European Union has not done everything necessary to save itself. Surely, not all countries are democratic, according to officials in the European Union or the United States, but nowhere can democracy be imposed by force or behind the scenes. If it is necessary to force it, the risk of identity destruction or removal of dissidents is particularly high. Many people today are contemplating and looking for the ones to blame.

For years, Europe, including Ukraine, has been guided by various desires, incl. the desire to bring back the attitudes to certain groups of people characteristic for the years of fascism. Who condemned or sanctioned them? Who condemned the so-called Maidan? Did the truth about the so-called Maidan come out? It turns out that we, Europeans, have not only supported the imposition of democracy and freedom. We imposed someone's interests, along with other external forces.

The situation required a lot of strategic vision and assessment, which was the possible outcome. It required leadership devoid of the black and white thinking. There are at least two sides in a conflict, but this conflict involved more than two countries. We are all in this conflict. Now no one has the right to just blame".

The complexity of this situation is determined by the special dynamics, as well as by the fact that societies and countries have different assessments of what is happening. Making quick decisions in this case is necessary, although there is a high risk that they would be ineffective. The strategic goals for overcoming this crisis are inconsistent due to the fact that the societies determine their strategic policy first of all in terms of national interests and then their belonging to certain political unions. The development of the crisis seems to be on parallel axes, and the complexity of the development of the economic and information component changes the attitudes and interests of the respective societies, as well as the consequences of certain strategic decisions.

The restriction of certain freedoms related to access to reliable information is reminiscent of the Cold War. And this is an element of implementing the strategies of all participating countries. This objectively dooms the people from the respective community to the one-sidedness of the received information and the lack of at least partial objectivity for its comparison. Probably such deep military crises create conditions for shifting the democratic conditionality and applying the elements of the tactical military art. Whether they give the appropriate result is difficult to predict when you are part of a crisis situation.

All political leaders who are called to govern societies carefully determine or rather justify good or bad decisions and strategies they prepare for crisis management, with the national security of their societies. In any case, this has the greatest weight in determining the relevant strategic decisions, but they are not always adequate to the respective realities inside and outside the respective societies. Last but not least, the preparedness of the various levels of government is a response to the crisis.

According to Linus Carl Pauling, "Science is the search for truth, the effort to understand the world: it involves the rejection of bias, of dogma, of revelation, but not the rejection of morality."(2023b).

Do scientists play a part in crisis management and what is their role? They definitely do! The role and mission of scientists is not only to support this process, but to be part of the process of developing such strategic decisions in management, which would as much as possible and as quickly as possible meet the expectations of societies. This raises expectations about whether scientists are able to generate good enough ideas to convince societies about their usefulness and to suggest ways to effectively implement them. Due to the knowledge of the processes, the analytics with which scientists work and the ability to analyze databases, as well as the facts about each crisis, scientists can be at the forefront of the crisis management model. Another question is whether management elites rely on scientists or crisis management is done with other tools that do not involve scientists that much. It is a question of relevance, of conformity assessment, of systematicity, of justification and of the application of two principles which are applied in the technological sciences, namely the "principle of reasonable sufficiency" and the "principle of synergy". Their implementation can "alleviate" evolving crisis situations, even the one we quoted above (2023b).

All this is a task of paramount importance and it must be carried out constantly, especially in times of crisis. Today, when societies are divided and set precedents for public judgement of one party or another, give certain qualifications, I believe that international scientific forums are the time and place for such discussion to suggest solutions and proposals. Restricting the participation of both (depending on who organizes the scientific forum) is unacceptable and rather offensive and does not create

opportunities for the best prepared and most informed environment to fulfill its mission as an innovator (2023b).

And because the authors are chemists, we will still use the words of Linus Carl Pauling, who said: "I recognize that many physicists are smarter than I am - most of them theoretical physicists. A lot of smart people have gone into theoretical physics, therefore the field is extremely competitive. I console myself with the thought that although they may be smarter and may be deeper thinkers than I am, I have broader interests than they have".

Objectively good strategic decision-making requires, above all, good preparation of the people whose responsibility is to make them, and especially of the teams that provide essential scientific and intellectual resources for making the same.

4. The role of socially dominant leaders in the emergence of crises

The fear of happening realities turns out not to be exaggerated not only in our realities but also in our accompanying being. The confusion of conflicting and ambiguous messages that put us in a state of disarray as people who have clear and coherent logical thinking increasingly feeds our fears. Although we are used to the half-baked and even sometimes lyrical political messages that are thrown as messages on the political market in Bulgaria and Europe, lately we feel more and more a strong concern from the more balanced and more diplomatic political leaders. Their personal and political prudence has put us in the extremely unattractive position of waiting a long time for something to happen, and this against the background of their becoming public knowledge of their wanderings in search of certain solutions for which they have proved to be quite unprepared.

Personal and collective living in yet another political system has exhausted its significance both for those who consume it and for those who observe it from the outside. The inability to self-preservation and to react to the changing world is an unequivocal answer that she is looking for her new and completely different transformation. These periods of transformation are usually accompanied by severe and painful transitional states, which are accompanied by many and varied conflicts. No matter how simplistic all this sounds, it has a definite and strong logical, and not only, basis - we should not underestimate our historical memory in this direction, which would prove these statements of ours with a high degree of relativity.

The immediate question would be - how and what happens to the political reality? The next one is not at all useless - but what happens to ourselves? And if the answer to the second question is relatively easier, then the answer to the first is of a much more complex nature, both in substance and process nature. Eventually, we will have to go through periods of active transformations of our entire social system in one way or another, which will also include a change in political models of existence. If by a social system, we understand the whole set of relations, it would be practically more grounded and more realistic.

The failures and ups and downs of existing political realities are many and have their essential differences. Comparing and explaining them is important, as it can bring some benefits in our movement forward, as well as explaining the new processes taking place. These processes will bring elements that we know well and even read and explain well, but also elements that will surprise us and will be new with their high sensitivity.

The defective political reality will try to preserve some of its elements, which it will successfully carry over into future periods. This is of course quite uncertain, even unlikely, because these elements exist in one relationship with all others, and even if some of them survive in one form or another, they will have a different relationship with others that are now created.

If we are in the position that the defects in these political realities have already passed the possibility of being repaired or tamed in the sense of the accumulated grievances of the people, then their destruction

will occur at an avalanche speed. The consequences of the defective political reality will be felt with different strengths and to different degrees. This is quite reasonable because they will be at different distances from the source of these processes. These influences will have a set of fluctuations that will be misunderstood by those involved because they are new and unpredictable in nature and consequences.

Giving organic examples of these processes in specific concreteness as signals of what is happening can be found even now. We have built up a certain sensitive tolerance to different processes because we do not know them, and we do not have enough time to explore them.

All of this comes against a background of numerous emerging signals from different places. Their power is increased by the ability of those who create them and those who transmit them. Certainly, those with the best array of active elements are the best and fastest at creating and transmitting these signals. Their creators are in a process of struggle not for survival, but for dominance. This process will form groups that will try to create new dependencies that will define the new social reality. Determining the zones of influence will also give rise to the social importance of those who are contenders for certain leadership in this environment. More important will be how these new socially dominant leaders will determine or create the system of social relations that will determine the creation of new social systems. Political realities or systems will be the consequence of these new social relations.

Turbulences in these formed new social systems will last from a historical point of view for a very short time and from the point of view of the participants in them - for a very long time.

These processes have a high complexity and are almost unpredictable as a final result. Even if we have information and sufficient data about their progress, the power of influence of certain elements cannot be accurately and faithfully defined and measured, which will generate frequent and unpredictable changes.

That the social system is changing under the pressure of the multitude of social defects is almost visible to all, and is felt in certain and varying degrees. Much more interesting is how we will manage to pass through this long and sufficiently unpredictably difficult period, which we can unequivocally define as a process. It is unlikely that we will be able to have the kind of preparedness that would put us in a sufficiently favorable position so that everything happens in a certain acceptability for all participants. Anxiety grows with the constant multi-directionality of signals and with the succession of emerging social defects in the system.

We know that a system - whatever it may be - must have a certain efficiency, which is also associated with a particular financial significance. Whether those trying to be the leading elements in the creation of the new social system have the knowledge and willingness to accept the dependencies that have existed so far is difficult to predict. It is obvious that this system of social efficiency also creates problems in its existence. The problems that can be defined are behavioral. As unacceptable as all this may sound, all too often the behavioral patterns of a particular individual have so altered a particular social system that it has been preserved long enough without interest in any effective relationships. It is possible that certain behavioral elements again sensitively influence the already started process and bring it to a certain stage in which the new realities will have a different meaning.

The easiest conclusion would be to wait and see what happens in the end. But whether and how we will have this opportunity and whether as direct participants we will be able to evaluate this process? It is best to make some effort to ensure some preparedness for all of this. Even if we appreciate and realize that the signals that we will create and transmit will be relatively small in strength, perhaps we should consider that it would be much greater if there is an essential content that is a response to these ongoing processes.

Historians with a dose of authoritative academic conviction argue that history always moves forward. There is a certain timidity in their current messages, combined with an unintended sense that history may be repeating itself in one form or another. If you answer at least part of the questions asked, or at least think deeply and unprejudiced about them, it can protect us from those repetitions that we would

not like to happen (Terziev, 2022a; 2022b; Terziev & Lyubcheva, 2022c; Terziev, 2022d; 2022e; Terziev & Solovev, 2022f; Terziev, 2022g).

From a historical point of view, there are enough examples in which transformations and changes in social systems were mostly influenced by new social leaders. This has drastically changed the social systems themselves and created qualitatively new and different conditions for their existence and development. Another issue is their sustainability over time. A characteristic example is the social system of socialism. Despite the knowledge of its theoretical foundations, its leaders in the Union of Soviet Socialist Republics exerted a major influence. Such are Vladimir Ilyich Lenin, Chairman of the Council of People's Commissars of the Union of Soviet Socialist Republics, Joseph Vissarionovich Stalin - General Secretary of the Central Committee of the Russian Communist Party (Bolsheviks), Chairman of the Council of Ministers of the Union of Socialist Republics (from March 15, 1946), Nikita Sergeevich Khrushchev - First Secretary of the Central Committee of the Communist Party of the Soviet Union, Leonid Ilyich Brezhnev - General Secretary of the Central Committee of the Communist Party of the Soviet Union, etc.

Socialism is a political philosophy and movement encompassing a wide range of economic and social systems (Busky, 2000) which are characterised by social ownership of the means of production (Busky, 2000), as opposed to private ownership (Horvat, 2000; Arnold, 1994; Hastings et al., 2000). As a term, it describes the economic, political, and social theories and movements associated with the implementation of such systems (The Free Dictionary, 2023c). Social ownership can be public, community, collective, cooperative (Sherman & Zimbalist, 1988; Rosser & Rosser, 2003; Badie et al., 2011), or employee (Horvat, 2000; O'Hara, 2003). While no single definition encapsulates the many types of socialism (Lamb & Docherty, 2006), social ownership is the one common element (Arnold, 1994; Hastings et al., 2000). Socialism is traditionally placed on the left-wing of the political spectrum (Left, 2023d). Different types of socialism vary based on the role of markets and planning in resource allocation, on the structure of management in organizations, and from below or from above approaches, with some socialists favouring a party, state, or technocratic-driven approach. Socialists disagree on whether government, particularly existing government, is the correct vehicle for change (Nove, 2008; Docherty et al., 2006).

Socialist systems are divided into non-market and market forms (Kolb, 2007). Non-market socialism substitutes factor markets and often money with integrated economic planning and engineering or technical criteria based on calculation performed in-kind, thereby producing a different economic mechanism that functions according to different economic laws and dynamics than those of capitalism (Bockman, 2011). A non-market socialist system seeks to eliminate the perceived inefficiencies, irrationalities, unpredictability, and crises that socialists traditionally associate with capital accumulation and the profit system in capitalism (Nove, 1991). Market socialism retains the use of monetary prices, factor markets and in some cases the profit motive, with respect to the operation of socially owned enterprises and the allocation of capital goods between them. Profits generated by these firms would be controlled directly by the workforce of each firm or accrue to society at large in the form of a social dividend (Marangos, 2004; O'Hara, 2003; Pierson, 1995).

Socialist parties and ideas remain a political force with varying degrees of power and influence on all continents, heading national governments in many countries around the world. Socialist politics have been both internationalist and nationalist; organised through political parties and opposed to party politics; at times overlapping with trade unions and at other times independent and critical of them, and present in both industrialised and developing nations (Newman, 2005).

Social democracy originated within the socialist movement (Ely, 1883), supporting economic and social interventions to promote social justice (Merkel et al., 2008; Heywood, 2012). While retaining socialism as a long-term goal (Roemer, 1994), since the post-war period social democracy came to embrace a mixed economy based on Keynesianism within a predominantly developed capitalist market economy and liberal democratic polity that expands state intervention to include income redistribution, regulation,

and a welfare state (Badie et al., 2011). Economic democracy proposes a sort of market socialism, with more democratic control of companies, currencies, investments, and natural resources (Smith, 2005).

The socialist political movement includes a set of political philosophies that originated in the revolutionary movements of the mid-to-late 18th century and out of concern for the social problems that socialists associated with capitalism (Lamb & Docherty, 2006). By the late 19th century, after the work of Karl Marx and his collaborator Friedrich Engels, socialism had come to signify anti-capitalism and advocacy for a post-capitalist system based on some form of social ownership of the means of production (Gasper, 2005; Giddens, 1998). By the early 1920s, communism and social democracy had become the two dominant political tendencies within the international socialist movement (Newman, 2005), with socialism itself becoming the most influential secular movement of the 20th century (Kurian, ed., 2011). Many socialists also adopted the causes of other social movements, such as feminism, environmentalism, and progressivism (Sheldon, 2001).

While the emergence of the Soviet Union as the world's first nominally socialist state led to socialism's widespread association with the Soviet economic model, several scholars posit that in practice, the model functioned as a form of state capitalism (Chomsky, 1986; Howard & King, 2001; Fitzgibbons, 2002) Several academics, political commentators, and scholars have noted that some Western European countries have been governed by socialist parties or have mixed economies that are sometimes called "democratic socialist" (Barrett, ed.,1978; Sanandaji, 2021). Following the end of the Cold War and the revolutions of 1989, many of these countries have moved away from socialism as a neoliberal consensus replaced the social democratic consensus in the advanced capitalist world (Sanandaji, 2021), while many former socialist politicians and political parties embraced "Third Way" politics, remaining committed to equality and welfare, while abandoning public ownership and class-based politics (Socialism, 2023e). Socialism experienced a resurgence in popularity in the 2010s, most prominently in the form of democratic socialism (Judis, 2019; Cassidy, 2019). A vivid example of a new social leader who, through his personal views, changes and even helps to cease the existence of a social system. This is Mikhail Sergeevich Gorbachev - General Secretary of the Central Committee of the Communist Party of the Soviet Union and President of the Union of Soviet Socialist Republics. In implementing his domestic policy, Mikhail Gorbachev tried to implement economic reforms that would contribute to a change in the standard of living. This is the so-called "perestroika" policy. His reforms were ineffective and failed to achieve substantial direct results and change the existing system of planned and command economy. It would be important to study the ongoing modern processes that require rapid and sudden changes in social systems. Whereas in the recent past, there were certain indications of the changes taking place that could be examined and analyzed, now the changes that are occurring are sudden and rapid. The emergence of new social leaders creates conditions through their behavior, ideas, interests, and even a set of irrational views to transform the existing social systems. The influence of the new social leaders can be presented as sensitive and in many cases decisive for the transformations taking place. It is necessary to identify a new criterion apparatus that objectively and quickly enough gives us true and accurate information. The reliability of this venture is rather difficult to determine.

Social processes in a period of severe crisis situations are accompanied by a high speed of their progress. Their detailed and systematic description and subsequent analysis are almost impossible. The search for specific research approaches is mandatory in these situations. The study of the behavioral patterns of dominant social leaders is of particular importance. Here any researcher would face two sets of problems. The first is related to obtaining sufficiently accurate and true information, which is handled by statistical methods of analysis, as well as sociological methods. This will create a particular difficulty in using both of them. The accessibility of this type of information and data is difficult to collect, but even if they succeed somewhere, it will be filtered in a special way by the relevant state-engaged security services. The second group of problems will arise when assessing the development of the behavioral model of the respective individual who has acquired the role of a socially significant and dominant leader. Knowledge and his personal characteristics will have undergone various transformations during

the period of his rule, namely, these characteristics will not have been public enough, and the information we will get will be from the mass media or other public meetings.

Overcoming the two groups of difficulties may in certain situations be insurmountable and the use of similar approaches for the implementation of research activity – is impossible.

Regardless of the research situation in which we will find ourselves, it is necessary to look for opportunities to study the influence of socially dominant leaders on social processes.

Similar and analogous examples from a historical point of view can be cited with quite success. Even if we conditionally accept the two world wars as such severe crises, the actions of the leaders who participated in these processes cannot always be explained logically and do not carry their economic, political, and other arguments. Conditionally, these are also social processes that have changed both their direction and their speed as a result of socially dominant leaders. Here we should make one important clarification, namely, that they took place too slowly, according to the current social processes. The factors of the external and internal environment have changed both in their essential characteristics and their quantitative dimensions. Some of the researchers would pay particular attention to the study of environmental factors that undoubtedly have and will continue to have an impact on ongoing social processes. Another question is to what extent they influence the decisions and behavior of the new socially dominant leaders. This can be established too late and only at the end of a certain stage of a certain social process.

The tendency but socially dominant leaders who are empowered to make decisions and have sufficient resources (political, economic, financial, etc.) tend to make decisions of an operational nature in crises, in which decisions exclude consideration of the environment but rather represent motives other than political and economic logic. Usually, when a crisis occurs, the power tools focus on a small group of people who follow and have to bear the burden of decision-making in an extreme situation.

In a cursory analysis of the social processes that are taking place in the world at the moment, one can make a relatively true conclusion that they are predominantly managed by the new socially dominant leaders. The use of the concept "the new socially dominant leaders" has a sacred convention, because the individuals we now define as dominant social leaders may have been leaders of states, corporations, unions, etc. in previous periods, but only now have acquired such importance.

Undoubtedly, ongoing social processes are due to active changes in recent decades in political, economic, military, and financial aspects. The results of all this will be manifested to the greatest extent in the imposition of new social rules in the new social systems. The inevitability of imposing new regulatory functions in the structure of new social systems is almost obvious. Resistance to change is also evident. Evolutionary social processes currently dominate revolutionary social processes. Perhaps we should make a stipulation that these social processes are inevitably associated with local military conflicts, financial cataclysms, or political instability of certain regions, but not with a continental or worldwide presence of social discomfort. The imposition or the possibility of the establishment of a new social system with new rules cannot help but be accompanied by certain negative actions as well as consequences.

Unfortunately, the scientific community will study, analyze, and predict all this too late. The utility of such an undertaking at a later stage of time will have its significance, but it will be far less than if it happened now.

The importance of such action and research in this direction is of particular importance to each human individual as well as to different communities. Even if these studies mark little progress at the present stage, they must seek their place, serving as an element for the preparation of our societies for a new interaction in the new social environment.

The understanding that everything should be left at the current level of preparedness could prove disastrous for some of our societies. Moreover, there is sufficient reason to believe that some of the

leaders of the smaller communities, or those who will not play a dominant role, will prove to be too unprepared, even unsuited to the new social situation.

5. Social transformations, changing societies, and human resource development

At the end of the 20th century, a mantra became established: "We must meet the challenges of the 21st century." This conclusion was invariably included in various analyses, reports, programs, and opinions. It is not certain that everyone who used it was aware of what this meant. And the 21st century arrived, not interested in this wisdom, and brought changes that explained to the "challengers" what this meant. Rapidly changing societies, new models of interactions, contradictions between the global and the regional, the transnational versus the national. Changing societies are characterized by dynamic and complex transformations that affect all aspects of life. The new models that are taking shape are the result of the interaction of a set of multiple factors. Analysis is mandatory, but unfortunately, it is done at different levels, in different areas of interest, by different structures, and never acquires sufficient comprehensiveness to explain all the ongoing processes. There are several main factors, and for each of them, there are many more limited ones, which makes the picture of the ongoing social changes very complex.

Globalization has led to an unprecedented level of interconnections between countries, cultures, and economies. This has created new opportunities, but also increased interdependence and vulnerability. The development of transnational corporations has changed the structure of the global economy, which has led to the concentration of power and resources in the hands of a small number of companies. Globalization has stimulated migration processes, which have led to an increase in diversity in societies, but also to serious problems related to the integration of migrants.

Technological innovations have led to a serious change in the environment, which has transformed communications to completely new models unknown until now. Digitalization has changed the way we communicate, work, and live. This has created new opportunities, but has also increased inequality in access to technology. Automation has caused changes in the labor market, increasing unemployment in some sectors and creating a need for retraining of the workforce. Artificial intelligence has entered not only as a technological element in socio-economic systems, but has also called for a general transformation, but also for the start of a new era in human-machine relations. The development of biotechnology has led to transformations and dilemmas related to genetic engineering and cloning.

No less are the changes in the social sphere, some of which, of course, are also related to the factors we have defined.

Demographic changes are perceived as the most serious because they are related to the development of the human factor. Without a doubt, human capital in its extraordinary diversity will continue to dominate social and economic development throughout the rest of this century through the mechanisms of managing political, social, economic, and technological processes, as well as determining new models of interaction between human and artificial intelligence. The aging of the population in many European countries has led to challenges related to the functioning of pension systems and health systems. Changes in family structure are part of the changes in social norms and expectations that are already a fact. Deep liberal trends have created the prerequisites for lasting changes in the social structure of societies, such as changes in traditional gender relations, new elements of correlation with identity, value orientation, and traditional perception of human relations. Urbanization has caused the concentration of the population in cities, which has created challenges related to infrastructure, the environment, and social services. Regional inequalities and divisions in communities have deepened.

Technological development has created the prerequisites for ecological changes that have caused climate change, threatening biodiversity and human health. Dependence on fossil fuels has increased, leading to an energy crisis and the imposition of new energy models and technologies.

The new patterns of changing societies are complex and dynamic from a political perspective.

Political transformations have a significant impact on human resource development by changing the framework within which organizations operate and manage human and material resources. Political transformations change social relations, which can lead to stability or instability in governance, sometimes to crises that need serious rethinking and management. Political uncertainty changes economic stability, which in turn can affect investments, including those for human resource development. Conversely, political stability often creates a more favorable environment for strategic long-term planning and development.

One of the key aspects of political transformations is related to changes in legislation and regulations. New laws and policies can impose new models for economic development, including human resource development, as well as all elements of labor relations affecting this development. In this way, they directly influence human resource management strategies.

Political transformations are associated, in addition to economic changes, with changes in educational, social and technological systems. That is, they affect all specific policies, imposing approaches that comply with international standards and practices related to digitalization, mobility, adaptation. In the case of political stability, this is associated with modernization and sustainable development, but in other cases it can lead to lagging behind and delayed development of human resources.

What has been said so far clearly defines the relationship between transformations in societies and the development of human resources, as well as the need to consider the adaptation of human resources to them, i.e. to monitor how human resources cope with these challenges in order to ensure sustainable development.

The idea of sustainable development has gone through various manifestations and not all of them have been positive for societies and people. The political transformations that have occurred, have characteristics of certain social technologies. Certain phenomena are observed, such as populism. The rise of populist movements is causing political instability in many countries. Nationalism has led to conflicts and tensions between countries, identifying tensions in entire regions. The lack of effective global governance has led to problems related to climate change, pandemics, and other global crises.

The new models of changing societies are complex and dynamic. To better understand them, it is necessary to analyze the interaction of the entire set of influencing factors and to develop adequate strategies to address the challenges.

The modern world is witnessing unprecedented social and technological changes that have a profound impact on all spheres of public life, on the labor market, and require continuous adaptation of human resources. These transformations are not just trends, but fundamental changes that transform the way we work, live, and interact.

Technological transformations include the introduction of digital technologies, automation, and artificial intelligence. These innovations lead to the emergence of new professions, changes in existing ones, and the need to acquire new digital skills. For example, automation in production processes is already a fact, which requires a workforce with higher qualifications and skills to manage complex machines.

In turn, social transformations encompass changes in the demographic structure, values, and expectations of people. Globalization, increasing intercultural diversity, and the growing demand for flexibility in working hours and location are just some of these processes. Employees are increasingly looking not only for financial security, but also for meaning in their work, a balance between professional and personal life, as well as opportunities for personal and career development.

Social and technological transformations encompass all development processes – from management at the highest levels to those at the lower levels of the service sector, where labor is less skilled. These transformations change the environment, change systems, institutions, and ways of interaction, and have an impact on all participants in the processes and individuals. As a result, human resources are

adjusting to unfamiliar waves of political, organizational, physical, social, cultural, and technological behavior.

In this context, the adaptation of human resources becomes a critical factor for success, because the systems and organizations through which transformation processes are implemented consist of people. This means active engagement, which requires new knowledge, skills, and competencies: knowledge – about the nature of the processes; skills – for effective and high-quality implementation of the processes; competencies – for effective management and inclusion. In this sense, the adaptation of human resources to societal transformations requires continuous learning, development of professional and transferable skills (analytics, critical thinking and emotional intelligence, digital literacy, decision-making, etc.). Part of the adaptation process is the transformation of systems and organizations into a supportive environment that promotes flexibility, innovation, and learning, while taking care of the well-being of participants in the transformations along the entire chain.

What does the adaptation of human resources to social and technological transformations mean? Simply put, it is an adaptation to the changing social and technological environment. In essence, this is a comprehensive cultural and historical process in which the individual is both an object and a subject of the processes - many influences are exerted on him, and he also influences the systems. That is, this is human resource development, which is basically an uninterrupted process. Today it takes place in conditions of an extremely dynamic changing environment. If in the 20th century and even in the first years of the 21st century, the development of human resources was associated with training through courses, under certain programs and with certain lecturers, and this training was sufficient to create skills for a longer period of time, then social and technological transformations today impose requirements for an almost explosive accumulation and use of new knowledge and skills. The presence of computers, tablets, the Internet, online communications, technologies, etc. All this requires a high speed of reaction on the part of individuals, i.e. social and technological proactivity. Today's knowledge is no longer sufficient tomorrow, tomorrow's skills will not be sufficient in a few days, because they will not correspond to the changed labor market, the changed requirements of employers, they will not be sufficient for newly emerging professions, or the new codes and keys of information and communication flows.

Here are some of the social factors of adaptation, what specifically requires adaptation, and what human resources must be ready for - changes in the structure of the workforce; aging of the population; increasing role of women in the labor market; increased mobility of the workforce; changed qualification structure of employment; change in job security, etc.

Human resources must adapt to changes in values and expectations: Employees are increasingly looking for a balance between work and personal life, flexible forms of employment, meaningful work, satisfaction, career, and development opportunities. Changes in social norms, values, and expectations affect motivation, commitment, and satisfaction. Human resource development should focus on creating a positive work environment that meets new social expectations and the formation of new social relationships.

Globalization and cultural diversity also determine some directions of human resource adaptation. These are: managing diverse teams and understanding different cultural norms are becoming increasingly important; the imposition of international corporations and companies; cross-border or longer-distance transitions are becoming the norm of human resource implementation. Globalization increases competition in the labor market and requires companies to invest in the development of their employees in order to remain competitive. Human resource development must focus on the development of global competencies, language skills, and intercultural communication.

Demographic changes are becoming increasingly significant. Population aging, migration, as well as changes in family structure have an impact on the available human capital and require adaptation of human resource development policies. The model of training, qualification, and retraining is changing depending on the dominant age, the presence of migrants, etc.

Even more serious is the pressure from technological transformations - mainly green and digital transformations. Without knowing borders, they have been spreading almost simultaneously since the day of their discovery.

The factors of technological transformations - automation, digitalization, green technologies, and other technological innovations change the demand for skills and competencies. Human resources follow this development and must adapt to the requirements. Human resources development must focus as quickly as possible on providing training and retraining that meet the changes.

The model of training and retraining is changing: the technologization of education is a response to technological transformations. Computer technologies, laptops, tablets, the Internet, and STEM training are gaining key importance in education at all levels for the adaptation of human resources to new requirements.

Learning on the move (different from online learning) will become the new paradigm of lifelong learning. Adaptation becomes a competition for compliance with new realities. This process implies continuous development of the personality in different conditions in which it should exist - favorable and/or unfavorable. The unity of the personality with the social and technological environment implies continuous development of the personality“ (Ilieva, 2025).

Adaptation goes hand in hand with the development of key competencies. The development of key competencies such as analytics, critical thinking, creativity, communication, and teamwork is necessary to cope with changing conditions. New management models are emerging extremely quickly as a response to technological and social transformations. Creating flexible and adaptable organizations is one of the possibilities for such models. Creating flexible and adaptable organizations that can quickly adapt to changes is key to success in a dynamic environment.

The adaptation of human resources to social and technological changes also requires a new paradigm of development - Change Management. This is a key reversal - transformations cause the need for adaptation, and adaptation itself leads to the need for effective change management. In fact, this is the key to development - human resources as the object and subject of transformations and the role of their adaptation in minimizing their negative impact on employees and organizations.

The adaptation of human resources has another side, and this is the preparation of human resources for inclusion in the changes and subsequent adaptation. Each generation enters into realization during a certain period, when the generations before it have already moved on to the adaptation process. All this means that at whatever stage of the changes you enter the realization process, you must be initially prepared, more than any previous generation. This continuous process requires a serious model of educational preparation, which is different for each generation and must correspond to the level of transformations in society. Assessing the conservatism of the educational system, this will obviously be difficult to achieve, and must provide for a sufficient balance between information, new knowledge, and skills that the respective generation must acquire. In support of these models, the efforts of the business, where the prepared personnel are realized, must be added. That is, education is distributed, while adaptation almost always remains with the business. Another essential element in the preparatory and adaptation process is introduced, and this is knowledge management. Only through its inclusion can all educational, cultural and communication channels be envisaged and implemented to ensure both preparation and adaptation.

Human resource development is key to addressing social transformations and changing societies. Investments in training, retraining and development of key competencies are necessary to ensure the competitiveness and well-being of employees and organizations.

Conclusion

Crisis management is too complex in today's dynamic and rapidly changing environment. In the last few years, we have lived in an environment of uncertainty and many ongoing processes that have a significant impact on the environment. The presence of these processes requires serious attention to the decision-making process in severe crises. This turns out to be a particular challenge both for the people who are empowered to make these management decisions and for the experts who study these processes. The certain social importance of the consequences of making the relevant decisions places them with a high priority of importance. All this implies new preparation and qualitatively different expertise. That leads to the creation of new technology for making such decisions. Scientists, researchers, managers, and policymakers must make additional and focused efforts to create such technology and a set of related procedures (Terziev, Georgiev, Ivanov, 2022h; Terziev, 2022i; 2022j; 2023f; Terziev, Georgiev, 2023g; 2023h; Terziev, 2023i; Terziev et al., 2025a).

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Factors Push Workers to Withdraw from Work Despite the High Unemployment Rates among Young People in Jordanian Society

Faktori koji uzrokuju povlačenje radnika sa posla uprkos visokoj stopi nezaposlenosti među mladima u jordanskom društvu

Hussein Omar Alkhozahe[1]

[1]*Al-Balqa Applied University, Princess Alia University College, Department of Applied Sociology, Jordan, huss1960@bau.edu.jo*

Abstract: Objectives*: This study aimed at identifying the Factors that push workers to withdraw from work despite the high unemployment rates among young people in Jordanian society, and the most important procedures and solutions that help workers withdrawing to confront this withdrawal.* ***Methodology:*** *This study used the comprehensive social survey method for all offices specialized in helping job seekers in Jordan which reaches70 office located in all government and districts of the Hashemite Kingdom of Jordan. The sample consisted of (2200) including (1,740) males and (460) females, who were visiting these offices seeking employment.* ***Findings:*** *The leading causes of the withdrawal from the labor market are low wages, followed by a lack of and the health insurance, and the high transportation costs poor managerial treatment, and the unfair employment conditions, long working hours, and finally, family reasons (lack of reconciliation between work and home). The most important procedures to solve the problem of withdraw from work is through raising wages and Providing health insurance for workers and their families, facilitating investment and tax exemption, cooperation between government and private sector and establishment of unemployment insurance fund, and solving it requires rehabilitating and training young people to gain the necessary skills for work, and providing childcare facilities at the work , finding job opportunities within the same governorate, and encouraging them to accept job opportunities even if they are not up to their expectations.* ***Conclusion:*** *Raising the minimum wage, family and community encouragement for young people to accept job opportunities, in addition to canceling the requirement for an experience certificate when announcing a job opportunity, and providing transportation to the workplace, or paying a transportation allowance, and providing health insurance for workers and their family.*
Keywords: *Unemployed, withdraw from work, job opportunities.*

Apstrakt: Ciljevi: *Ova studija je imala za cilj da identifikuje faktore koji podstiču radnike da se povlače sa posla uprkos visokoj stopi nezaposlenosti među mladima u jordanskom društvu, kao i najvažnije procedure i rešenja koja pomažu radnicima koji se povlače da se suoče sa ovim povlačenjem.* ***Metodologija:*** *Ova studija je koristila sveobuhvatnu metodu socijalnog istraživanja za sve kancelarije specijalizovane za pomoć tražiocima posla u Jordanu, koja obuhvata 70 kancelarija koje se nalaze u svim vladinim okruzima i okruzima Hašemitske Kraljevine Jordan. Uzorak se sastojao od (2200) ljudi, uključujući (1740) muškaraca i (460) žena, koji su posećivali ove kancelarije tražeći posao.* ***Nalazi:*** *Vodeći uzroci povlačenja sa tržišta rada su niske plate, zatim nedostatak zdravstvenog osiguranja, visoki troškovi prevoza, loš tretman menadžmenta, nepravedni uslovi zaposlenja, dugo radno vreme i, na kraju, porodični razlozi (nedostatak usklađivanja posla i doma). Najvažniji postupci za rešavanje problema povlačenja sa posla su povećanje plata i obezbeđivanje zdravstvenog osiguranja za radnike i njihove porodice, olakšavanje investicija i oslobađanje od poreza, saradnja između vlade i privatnog sektora i osnivanje fonda za osiguranje za slučaj nezaposlenosti, a rešavanje ovog problema zahteva rehabilitaciju i obuku mladih ljudi kako bi stekli potrebne veštine za rad, obezbeđivanje ustanova za brigu o deci na radnom mestu, pronalaženje*

mogućnosti za posao u istoj guberniji i podsticanje mladih da prihvate mogućnosti za posao čak i ako one ne ispunjavaju njihova očekivanja. ***Zaključak:*** *Povećanje minimalne zarade, podsticanje mladih od strane porodice i zajednice da prihvate mogućnosti za posao, pored ukidanja zahteva za potvrdom o radnom iskustvu prilikom objavljivanja mogućnosti za posao, i obezbeđivanje prevoza do radnog mesta ili isplata naknade za prevoz, i obezbeđivanje zdravstvenog osiguranja za radnike i njihove porodice.*
Ključne reči*: Nezaposleni, povlačenje sa posla, mogućnosti za zapošljavanje.*

Introduction

Work is an essential part of the lives of individuals in society; it is a means of self-realization and perceiving the meaning of life, it contributes to the development of the individual's personality, the enhancement of their skills. and the achievement of their financial, social, and psychological stability. It is also a fundamental driver for the progress and prosperity of society, contributing to social development, strengthening cohesion among its members, and helping to confront problems such as poverty, unemployment, non-marriage, the desire for emigration, and the commission of crimes. It also works to strengthen social ties, community interaction, and social participation.

Many individuals hesitate to resign from their jobs in the companies or institutions they work for, regardless of the surrounding circumstances, such as low wages, lack of health or social insurance, unavailability of transportation to the workplace, exhaustion, fatigue, or unsuitable job nature that does not match their qualifications. Despite all these difficult circumstances, some workers cannot tolerate these repelling work conditions and choose to resign and withdraw from their jobs.

Youth currently entering the labor work face a difficult task in finding decent and permanent job opportunities. Unemployment rates are constantly rising amidst an increase in temporary, informal, and other forms of unstable work. Globally, two out of every five young men or women are either unemployed or working but living in poverty (International Labor Organization, 2017).

1. An overview of Jordan

The specific nature of the Jordanian society that adheres to religion, which combines a morals, customs and traditions that encourages every individual to work, self-reliance, social solidarity, and helping family and relatives; It requires searching for work, and not remaining unemployed or dependent on others (Alkhozahe, 2020).

The population of Jordan had reached (11) million (893) thousand; (6,097) million of them are males, and (5,828) million are females until the 19/09/2025. There are also (12) administrative governorates in Jordan, and (42%) of the total population is concentrated in the capital, Amman, and the rest are distributed among the other remaining governorates. There are (11) governorates. (Department of Statistics, 2025).

2. Unemployment in Jordan

The continuous rise in unemployment rates is one of the problems that pose a risk to Jordanian society. The general unemployment rate was (12.5%) in (2010), rose to (18.6%) in (2018), and then to (21.3%) in (2025), based on data from the Department of Statistics related to the results of the Employment and Unemployment Surveys for the years (Department of Statistics, 2010, 2018, 2025).

Regarding youth, the unemployment rate in the age group (15-19) is (61.5%) while the rate is (45.7%) among youth in the age group (20-24). The unemployment rate during the current year 2025 reached (21.3%), with males at 18.6% compared to 31.2% for females. The percentage of unemployed individuals varied according to educational level and gender, with the percentage of unemployed males holding a Bachelor's degree or higher being 27.8%, compared to 76.6% for females, and the percentage for both

males and females being 44.1%.This is according to the data from the Second Round of the Employment and Unemployment Survey (2025).

Therefore, the research addresses the issue of withdrawal in Jordan, especially among the economically and age-active group, which is the youth. Based on the data from the Department of Statistics related to the results of the Employment and Unemployment Survey, First Round (2025), the general unemployment rate reached (21.3%). This high rate, in light of the lack of job opportunities and the prevailing economic situation in Jordan, necessitates conducting a study that focuses to investigate the causes of withdrawal from the labor work despite the high unemployment rates among youth in Jordanian society from their point of view, in light of the low job opportunities, and to identify the reasons of withdrawal from the work and the procedures that help confront withdrawal from the workers withdrawing.

The cooperation between the government and the private sector to establish an unemployment insurance fund. Also, unemployment rates among young people are rising constantly, and solving it requires rehabilitating and training young people to gain the necessary skills for work, and encouraging them to accept job opportunities even if they are not up to their expectations this is the best wat to solve the unemployment Problem in Jordan (Alkhozahe, 2024).

2.1. Study problem

The labor work in Jordan suffers from the problem of youth withdrawing from and leaving the job opportunities they managed to secure. Government statistics indicate that (46%) of those who obtained a job opportunity in 2023 left their employment (Department of Statistics, 2023). This high rate of job withdrawal, despite the lack of job opportunities and the prevailing economic situation in Jordan. This is the problem of this study.

Study Question: Accordingly, the study problem can be formulated with the following question:

1. What are the causes of withdrawal from work, despite the high unemployment rates among youth in Jordanian society, from their perspective, in light of low job opportunities?

2. What are the measures and solutions that help to confront withdraw from work from the point of view of withdraw from work?

2.2. Study terms and operational definitions

2.2.1. Withdrawal from work (job withdrawal)

The concept of "intention to quit" or "leaving work" was introduced by (Porter & Steers, 1973), which we defined as "the step related to considering withdrawal from work due to dissatisfaction with the job and making the decision to resign and leave work".

Job withdrawal (leaving work) is considered one of the important behaviors that must be of concern to the institution or workplace due to its effect on work performance. Withdrawal from work is a set of behaviors and practices performed by the individual that express separation from the organization and an unwillingness to work there (Redmond, 2010), and it is the worker's ability to leave the job (Long et al, 2012).

This study defines Withdrawal from Work operationally as the individuals' dissatisfaction with the job to the extent that it leads them to decide not to remain in it.

2.2.2. Job opportunity (employment opportunity)

This study uses the operational definition of a job opportunity to refer to those who suffer from unemployment or those who are uncomfortable in their current job, and who had the opportunity to apply for a job or position. After their experience, abilities, and qualifications are evaluated, and they are selected for the job because the applicant has the requirements that suit the job or task, and the

worker is able to perform this job, thereby capitalizing on the job opportunity available to them (Andini, 2010) .

2.2.3. Unemployment

Linguistically, unemployment means: something becoming idle, lost, or vain. A hired worker becoming idle means they become unemployed (Ibn Manzur, 1988).

Defining the concept of unemployment is a complex matter; there is no general and comprehensive definition for it, and it is considered one of the concepts that has taken on great importance in research and analysis in contemporary societies. The Department of Statistics in Jordan defined unemployment as all individuals of working age who did not work at all during the reference period in any kind of work, and who were available and actively looking for work during that period by one of the methods, such as: reading newspapers, registering at employment offices, asking friends and relatives, or other methods (Al).

The International Labor Organization (ILO) considered the unemployed person to be every individual who is able and willing to work, is seeking work, and accepts it at the prevailing wage level but without success (International Labor Organization, 2017).

On the other hand, unemployment arises in economies where a labor market imbalance occurs, which is represented by an increase in the supply of labor over the demand for it. Unemployment is therefore defined as the difference between the volume of labor supplied and the volume of labor utilized, and the prevailing wage levels in the labor market, during a specific period (Al-Jaloudi, 1992).

2.2.4. Unemployment in Jordan

The leading causes of the unemployment problem in Jordan are the large number of graduates from institutes and universities, insufficient salaries or wages, exploiting unemployment to control work and impose conditions on workers, nepotism and nepotism, then requiring an experience certificate, high transportation costs, and the lack of health insurance.(Alkhozahe , 2025)

2.2.5. Theoretical framework

The researcher employed Role Theory to guide this study, as it is linked to the customs and traditions of Jordanian society, where work is considered a vital and important part of human life. Those who do not work or are unemployed suffer from pain and regret and are viewed negatively by society. One of the most prominent scholars of Role Theory is Robert Park, from the Chicago School, who believes that an individual is connected to groups and society through the roles they occupy, and that the formation, growth, and expression of the self are linked to the role and its status in the social structure. Ralph Linton defined status as the set of rights and duties associated with a positional status in the social structure, and defined role as representing the dynamic aspect of the status. The social reality is a network of interconnected statuses through which the individual performs roles (Othman, 2007).

3. Methodological procedures for the study

3.1. Study methodology

The study used the descriptive analytical survey method consistent with the objectives of the study, which is based on describing data, characteristics, and components of the study population, analyzing them, interpreting them, shedding light on them, testing the initial and causal hypotheses, and coming up with generalizations that help in finding some solutions to the social problems under research, and analyzing them as they are. In fact, he describes it accurately (Dodin, 2010).

3.2. Study population and sample

3.2.1. Study Population

This study used the comprehensive social survey method for all offices specialized in helping job seekers in Jordan which reaches 70 office located in all government and districts of the Hashemite Kingdom of Jordan. The sample consisted of (2200) including (1,740) males and (460) females, who were visiting these offices seeking employment.

3.2.2. Study sample

The study adopted a comprehensive social survey method for all offices specialized in helping job seekers in Jordan which reaches 70 office located in all government and districts of the Hashemite Kingdom of Jordan. The sample consisted of (2200) including (1,740) males and (460) females, who were visiting these offices seeking employment during the implementation period of this study, which began on March 1 and continued until the end of April(2025).

3.3. Study instrument

To achieve the objectives of the study; A questionnaire was developed to collect data consisting of (36) items distributed over three areas: The first area includes (5) paragraphs examining the economic, social, and demographic characteristics of the study community. The second area addresses (14) paragraphs that address the causes of withdraw from work in Jordan from the point of view of withdrawing from work. The third area, which includes (17), deals with the procedures and solutions that It helps to confront withdraw from work, from the point of view workers withdrawing from work.

3.3.1. Validity and reliability of the instrument

To confirm the validity of the study instrument; The questionnaire was presented in its initial form to seven expert judges and faculty members specialized in sociology, work values, social service, women's studies, economics, public administration, and business administration. To verify the veracity of its paragraphs, and based on the arbitrators' observations, which were taken into account, whether by addition, modification, deletion, or wording of some paragraphs, until the study tool appeared in its final form, the researcher considered the arbitrators' opinions and amendments an acceptable indicator of the veracity of the tool's content. The study and the suitability of its items, which were distributed to the sample.

3.3.2. Instrument stability

After confirming the validity of the instrument's content; Its reliability was examined by using the test and retest method. The study tool was applied to an exploratory sample of young people who frequent youth centers, consisting of (35) young men and women from outside the study sample. The test was re-applied two weeks after the first application, and the internal consistency of all items of the questionnaire was calculated, and the Cronbach alpha value was extracted (Cronbach Alpha), which is the degree of internal consistency between the questionnaire items. The overall reliability coefficient reached (0.89), which indicates that the study tool (the questionnaire) can be applied, relied upon, and the results it will produce can be trusted, achieve the purposes and objectives of the study, and answer its questions.

Table 1. Reliability coefficients of the tool (Cronbach's alpha) for each field of study and for the tool as a whole

No.	Study area	Paragraph No.	Internal consistency reliability coefficients (Cronbach alpha)
1.	Causes of withdraw from work	14	0,85
2.	Ways to confront the problem of withdraw from work	17	0,89
3.	The instrument as a whole	31	0,88

From Table 1 that the general reliability coefficient of the questionnaire reached (0.88), which is a high reliability coefficient. It is clear that the reliability coefficients (Cronbach alpha) range between (0.85-0.89) for the study areas, and they are high. This indicates that the questionnaire has a high degree of reliability and can be relied upon in the field application of the study. Reliability coefficients are acceptable and appropriate if they are more than (70%) according to (Santos, 1999). Accordingly, the reliability coefficients in this study are appropriate and lead to achieving the objectives of the study.

Presentation, analysis and discussion of the study results:

Results related to the first question: What are the social, demographic and economic characteristics of the study sample?

Table 2. Distribution of study sample members according to social and demographic characteristics

Sex	**Number**	**Percentage**
Male	1704	79
Female	460	21
Total	**2200**	**100**
Age	**Number**	**Percentage**
15-19	440	20
20-25	770	35
25-29	660	30
30-40	330	15
Total	**2200**	**100.0**
Marital Status	**Number**	**Percentage**
Single	1584	72
Married	528	24
Widow	22	1
Divorced	66	3
Total	**2200**	**100.0**
Qualification	**Number**	**Percentage**
Less than secondary	110	5%
Secondary level	330	15%
Diploma	352	16%
Bachelor	990	45%
Master	268	13%
Ph.D.	132	6%
Total	**2200**	**100.0%**

Table 2 shows that the number of males reached (1704) individuals, constituting (79%) of the study sample, while the number of females reached (460), representing (21%). The higher percentage withdraw from work of males than females is explained by the high with among females. Because the areas in which they live are in the governorates far from the capital and job opportunities are low, and finally, family reasons (lack of reconciliation between work and home).

From the data of the same Table 2 we can find that the percentage of young people in the age group (20-24) constitutes the first place, as their percentage is (35%), followed by the age group (25-29), which constitutes a percentage of (30%), while ages (15-19 years) constituted approximately (20%) of the sample. These age groups are characterized by activity, vitality, production, and love of work, and they suffer from withdraw from work rates, because of the low wages.

From Table 2 we can consider that the majority of the withdraw from work respondents are single, as their number reached (1584) individuals, representing (72%). This is explained by the high rates of unemployment among the youth, and the high average age at marriage for males and females in Jordan, where it reaches (32 years for males and 28 years for females), according to data on population and demographic indicators of the population in Jordan. (Department of Statistics, 2025)

The same Table 2 shows that the majority of the withdraw from work respondents hold academic degrees. It reached (45%) among bachelor's degree holders, followed by intermediate diploma holders (16%), then master's holders (13%), and doctorate holders (6%), and the lowest percentages were among high school graduates and below. The explanation for this is that holders of practical degrees are looking for job opportunities that are appropriate and compatible with their academic degrees, while those in high school and below accepts any job, and with any wage for this work.

Table 3. Families' income

Monthly income of the family in which the withdraw from work lives	Number	Percentage
Less than 300	770	35.0
300 – 399	616	28.0
400 – 499	440	20.0
500 – 599	220	10.0
600 – 699	110	5.0
Above 700	44	2.0
Total	**2200**	**100.0%**

Table 3 reveals that most of the withdraw from work respondents live in families whose income is (300-399 JOD); Their number reached (770)individuals, and they constituted a percentage of (35.0%) of the study sample, while those who live in families with an income of (above 700 JOD) were the lowest in the study sample, and their number reached (44) individuals, who constituted a percentage of (2.0%) of the study sample. While those living in families with an income of (600-699 dinars) constituted (5.0%) of the study sample.

Results of the second question: What are the causes of withdrawal from work, despite the high unemployment rates among youth in Jordanian society, from their perspective, in light of low job opportunities?

To answer the question arithmetic means, standard deviations, frequencies, and percentages were calculated as shown in Table 4.

Table 4. Arithmetic means, standard deviations, frequencies, and percentages of the causes of withdraw from work from the perspective of the withdraw from work

Worker's withdrawal cause	Arithmetic mean	SD	Strongly agree	Agree	Neutral	Strongly disagree	Strongly disagree	Numbing	Ranking
Insufficient salaries or wages	4.85	.48	1949 88.6%	195 8.9%	35 1.6%	15 7%	7 3%	1	**High**
No health insurance	4.80	.52	1848 84.0%	288 13.1%	44 2.0%	15 7%	7 3%	2	**High**
High transportation costs and lack of transportation to work	4.80	.55	1857 84,4%	261 11.9	45 %2.0	20 9%	9 4%	3	**High**
Unfair employment contract terms	4.79	.57	1859 84.5%	261 11.9	46 2.1%	20 9%	11 5%	4	**High**
Management mistreatment (lack of adequate appreciation in terms of work or treatment)	4.79	.58	1857 84,4%	261 11.9%	46 2.1%	24 1.1%	11 5%	5	**High**

Length of working hours.	4.74	.65	1764 80.2%	332 15.1%	46 2.1%	35 1.6%	25 1.1%	6	**High**
Search for better opportunities	4.72	.58	1738 %79.0	382 %17.4	55 %2.5	17 8%	7 3%	7	**High**
Unhealthy work environment (relations with colleagues)	3.63	.78	1645 74.8%	352 16.0%	134 5.9%	130 52.4%	20 9%	8	**Medium**
Inequality and unfairness at work in terms of salary and bonuses	3.61	1.43	898 40.8%	391 17.8%	407 18.5%	217 9.9%	299 13.6%	9	**Medium**
Inequality and unfairness in work in terms of positions	3.60	1.56	943 42.9%	462 21.0%	211 9.6%	136 6.2%	444 20.2%	10	**Medium**
No general safety clothing	3.06	1.54	534 24.7%	447 20.3%	407 18.5%	200 9.1%	601 27.3%	11	**Medium**
No nursery at work	2.93	1.54	504 22.9%	400 18.2%	382 17.4%	273 12.4%	640 29.1%	12	**Medium**
Injustice and equality at work in terms of positions	2.80	1.53	473 21.5%	288 13.1%	444 20.2%	306 13.9%	688 31.3%	13	**Medium**
Family reasons (lack of reconciliation between work and home)	2.41	1.46	334 15.2%	198 9.0%	387 17.6%	407 18.5%	876 39.8%	14	**Medium**
Total	**3.44**	**74.**	**-**	**-**	**-**	**-**	**-**	**-**	**Medium**

As indicated in table 4 that the causes of withdraw from work came to a medium degree, with a mean (3.44) and a standard deviation (.74), where the reason (Insufficient salaries or wages) was the highest of those reasons, with a high degree, and with an average Arithmetic (4.85), and standard deviation (48.) It was answered by a very large percentage of (88.6%) of the sample members, while the reason (family reasons for not reconciling work and home) was less specific and to a medium degree, with an arithmetic mean of (2.41) and standard deviation of (.74) was answered by (9.0%) with a degree of agreement among the sample members.

Findings related to the second question: What are the measures and solutions that help to confront withdraw from work from the point of view of withdraw from work?

To answer the question arithmetic means, standard deviations, frequencies, and ratios were calculated for the measures and solutions that help confront from the point of view of unemployed youth, as shown in Table 5.

Table 5. Arithmetic means, standard deviations, frequencies, and ratios for the most important procedures and solutions that help workers withdrawing to confront this withdrawal

Measures and solutions that help confront workers withdrawal	**Arithmetic Mean**	**SD**	**Strongly agree**	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**	**Numbing**	**Rank**
Raising the minimum wage	4.85	.48	1949 88.6%	176 8.9%	35 1.6%	15 %,7	7 %,3	1	**High**

Training and qualifying youth in job search skills	4.83	.52	1848 84.0%	288 13.1%	44 2.0%	15 7%	7 3%	2	**High**
Family and community encouragement for young people to accept job opportunities	4.81	.55	1848 84.4%	261 11.9%	44 %2.0	20 9%	9 4%	3	**High**
Providing health insurance for workers and their families	4.79	.57	1859 84.5%	255 **11.9%**	46 2.1%	20 9%	11 5%	4	**High**
Providing transportation for employees to reach the workplace	4.79	.58	1857 84.4%	262 11.9%	46 2.1%	25 1.1%	11 5%	5	**High**
Establish fair and non-discriminatory employment contracts	4.75	.57	1764 80.2%	356 16.2%	46 2.1%	26 1,2%	7 **3%**	6	**High**
Providing support for establishing small projects	4.74	.56	1738 79.0%	383 17.4%	55 2.5%	17 8%	7 **3%**	7	**High**
Providing job opportunities within the same governorate	4.74	.59	1745 79.3%	374 17.0%	57 2.6%	9 4%	15 7%	8	**High**
Continuous government monitoring of companies and institutions	4.72	.68	1764 80.2%	33 15.1%	46 2.1%	35 1.6%	24 1.1%	9	**High**
Creating job opportunities suitable for people with disabilities	4.71	.61	1713 77.9%	370 16.8%	90 4.1%	19 **9%**	7 **3%**	10	**High**
discrimination in wages between males and females	4.70	.68	1722 78.3%	354 16.1%	70 3.2%	35 1.6%	17 8%	11	**High**
Study vocational specialties	4.65	.66	1610 73.2%	453 20.6%	105 4.8%	24 1.1%	11 5%	12	**High**
Creating job opportunities for Jordanians outside Jordan	4.64	.73	1657 75.3%	363 16.5%	121 5.5%	44 2.0%	14 7%	13	**High**
Replacing Jordanian workers with expatriate workers	4.61	.78	1645 74.8%	352 16.0%	130 5.9%	53 2,4%	19 9%	14	**High**

Removing the experience requirement	4.60	.77	1613 73.3%	371 %16.9	143 %6.5	61 2.8%	11 5%	15	**High**
Finding nurseries in the workplace for worker women	4.57	.73	1518 69.0%	488 22.2%	152 6.9%	29 1.3%	14 7%	16	**High**
Eliminate saturated university majors	4.56	.84	1603 72.9%	326 14.8%	187 8.5%	61 2.8%	24 1.1%	17	**High**
Total	**4.71**	**.44**	**-**	**-**	**-**	**-**	**-**	**-**	**High**

As indicated in Table 5 that all the solution methods to confront the withdraw from work problem proposed by withdraw from work came at a high degree, with an arithmetic mean (4.71) and a standard deviation (.44), and the method of (Increase workers' wages) was the highest and most important of those solutions to the withdraw problem, with a degree High, with an arithmetic mean of (4.85) and a standard deviation of (.48), and it was represented by (88.6%) to a very large extent among the sample members, while the solution (abolishing saturated university majors) was the least of the methods and solutions, with a high degree, and with an arithmetic mean of (4.56). A standard deviation of (.84), and a very large percentage of (72.9%) of the sample responded to it.

Conclusion

Recommendations: In light of the findings and discussion in this study; the following recommendations have been made:

- raising the minimum wage,
- training and qualifying young people in job search skills,
- providing health insurance for workers and their families,
- family and community encouragement for young people to accept job opportunities,
- canceling the requirement for an experience certificate when announcing a job opportunity,
- providing transportation to the workplace, or paying a transportation allowance,
- finding stablishing a nursery at work for working women.

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Understanding the Media Effects as a Precondition for Contemporary Education Development

Razumevanje efekata medija kao preduslov za razvoj savremenog obrazovanja

Dragana Stojanović[1]

[1]*Institute for Philosophy and Social Theory, Belgrade, Serbia, dragana.stojanovic@ifdt.bg.ac.rs*

Abstract: *As an integral part of living material culture, education is both shaped by and inseparably linked to the media environment and the technological conditions within which it develops. Put differently, media and technology function not only as tools but also as constitutive elements of education. This paper examines the complex interplay between education, media, and technology through the theoretical lens of media effects proposed by Régis Debray. The paper argues that a clear understanding of media effects is essential for contemporary education development. Finally, the study offers recommendations for further reflection and practice, with particular emphasis on the constructive engagement with educational mediaspheric environment.*
Keywords: *Education, media, media effects, technology.*

Apstrakt: *Bivajući delom materijalne kulture, ali bivajući i ključni factor doprinosa istoj, obrazovanje je neminovno oblikovano i isprepletano sa medijskim okruženjem i tehnološkim uslovima zahvaljujući kojima se razvija. Drugim rečima, mediji i tehnologija u isto vreme predstavljaju alate, ali i sastavne elemente obrazovanja. Ovaj rad ima za cilj da istraži kompleksnost dijaloga između obrazovanja, medija i tehnologije, analizirajući ih putem teorijskog koncepta efekata medija koji je definisao Režis Debre. Prateći ovu ideju, rad postavlja tezu da je razumevanje efekata medija neophodni predislov za razvoj savremenog obrazovanja. Na kraju, istraživanje nudi preporuke za dalja promišljanja i obrazovnu praksu, naglašavajući konstruktivno razumevanje fenomena medijasfere za postizanje najboljih razultata u obrazovanju.*
Ključne reči: *Obrazovanje, mediji, efekti medija, tehnologija.*

Introduction

Education emerges from a complex interplay of diverse elements and actors – first and foremost (though not in a hierarchical order) the teacher or educator, the students, the subject matter with its methodological tools, and the sociotechnological environment. According to Weiss (2006: 5), these constitute the minimum elements necessary for any educational process. This places the sociotechnological environment on the same plane of importance as its human counterparts. In this sense, education is not merely the act of humans using technology within a given society. Rather, it unfolds as a dynamic, multidirectional process involving human, technological, and theoretical-conceptual elements in an active, multilayered dialogue. Technology here is not only a tool or mechanism, but also the relation achieved between bodies of knowledge, learners, and mediated materials. Thus, both the act and the outcome of learning arise from the transformation of the entire assemblage of learning elements and actors. Teaching, learning, and the (re)formation of knowledge occur not solely within individual actors but within relational spaces – the bio-eco-technological connective tissue that binds educators, students, and their environments more closely together (Downes, 2008). From this perspective, and in light of education's dynamic, interrelational nature, the educational process may be understood as a communication field. Accordingly, it can be interpreted as

a communicational process, which opens the way for media and communication theories to become valuable tools for both understanding and advancing educational research and practice.[1]

1. Education and media/technology: building a productive framework for constructive educational development

1.1. Media and communication theories as a platform for understanding educational processes

Bringing media and communication theories into dialogue with educational studies is a much-needed step toward building a productive framework for constructive educational development. Learning environments always manifest as social spaces, since learning itself unfolds in social and collaborative contexts. Moreover, all participants in the educational process enter it from different and often multiple points of entry, bringing with them their own levels of knowledge, literacy, technological experience, expectations, and communication styles (Weiss, 2006). In this way, they frequently import or "copy/paste" their communicational habits into the learning space, while also opening themselves to transformation that will, inevitably, or at least ideally, emerge from the educational process. Education is, therefore, always a space of vulnerability, and understanding this, along with its relationship to the field of communication, becomes crucial for mindful and productive educational guidance. Only a comprehensive grasp of the educational process in its interconnection with media and technology can unlock the full potential of interest, involvement, imagination, and interactivity, which are all essential for successful educational outcomes (Burbules, 2006). Furthermore, the presence of technology within education foregrounds the need to understand technology not merely as a set of tools, but also as a certain attitude, whether individual or generational, toward the world in which educational subjects live. This kind of technological awareness should be cultivated in both educators and students, ideally leading to an appropriate level of media literacy, which serves as a precondition for any successful teaching and learning achievement (Kellner, 2006; Kalogeras, 2014).

According to Kellner (2006), a media literate person is "skillful in analyzing media codes and conventions, able to criticize stereotypes, values, and ideologies, and competent to interpret the multiple meanings and messages generated by media texts" (Kellner, 2006: 249-250). Since both educational materials and the educational process are always mediated (through particular spaces and specific technologies), media literacy becomes a key precondition for cultivating successful teaching and learning environments. Such environments must acknowledge, utilize, and advance the constant changes occurring daily across the realms of knowledge, society, and technology. A medium modifies and extends the power and capacity of any message conveyed in communication (Tække & Paulsen, 2022). In education, this translates into the enhanced power and capacity of the educational message itself. Moreover, if the medium is the message (McLuhan, 1964; Kalogeras, 2014) and if it actively shapes and strengthens the communicational ecosystem (Pfeffer, 2012), then a deep understanding of media and their effects can assist both educators and learners. Such understanding enables them to choose

[1]Media theories and communication theories are often treated as distinct domains, yet they are also deeply intertwined. This interconnection is thematized most prominently in the work of Régis Debray, who introduced the term mediology to describe a theoretical approach that encompasses this relationship. According to Debray (2000), mediology is neither a new field in itself nor a science in the strict sense of the word. It is not a sociology of media systems, nor does it rely on any single branch of the humanities as the primary interpreter of media environments and their effects. Rather, mediology arises from an analytic act that brings together the mechanical and conceptual dimensions of space, time, and technology with thought-based fields such as knowledge, ideology, politics, religion, and art/creativity—understood in terms of their relational consequences and accomplishments. Mediology thus inhabits the zone between technology and culture, tracing the transformations that unfold in their interplay and the ways these transformations inevitably shape and reshape one another. From this perspective, the present paper analyzes the educational process through a mediological lens, understanding the development of education as a direct outcome of precisely this dynamic interaction.

their preferred medium for learning, or to adapt and reshape the medium itself, with the aim of creating a more functional learning environment. In this way, education can more effectively nurture the development of connective knowledge (Downes, 2008) while also responding to the diverse needs of contemporary education within its specific social, economic, and material contexts (Hug, 2008; Tække & Paulsen, 2022).

1.2. Mediasphere as a teaching/learning bio-techno-eco-environment

Understanding the interrelation between technology and culture (here: between technology and education[23]) becomes clearer when viewed through the theoretical concept of the mediasphere, developed by Régis Debray (Debre, 2000). According to Debray, the mediasphere is a bio-infotechnological communicational macroenvironment that regulates and shapes social beliefs, conceptions of time, and the modes through which communities communicate and integrate. Mediaspheres change with the emergence of new technologies that intervene in these aspects; yet they do not entirely disappear. Instead, each new mediasphere layers over the previous ones, retaining their tools and legacies. To put it simply: the printing press did not erase handwriting, nor did the internet eliminate television. The same layering occurs in education, where older mediational and communicational tools continue to be used, though the dominant modes and manners of communication inevitably shift. This is particularly significant for education, since a lack of awareness in this field can cost educators their synchronicity with the contemporary modes of communication and thought that students already inhabit. Conversely, if students themselves fail to grasp the complexity of the mediasphere they live in, they may find the educational process unengaging, boring, or even irrelevant. These challenges will be examined more closely further in the text.

What is also essential, when employing the theory of mediaspheres for educational advancement, is to understand how each mediasphere reshapes the dimensions of educational space, time, and experience. For example, traditional education, shaped in the industrial era, was oriented toward the preparation – even the "production" – of students who were trained in standardized sets of knowledge and skills (Russell, 2006; Jan, Tan & Chen, 2015). Teaching and learning methods were designed to serve this aim and were typically carried out in a linear, hierarchical structure between educator and student. In this structure, the educator maintained the dominant position of "holding" the knowledge, while the student's role was to receive, internalize, and inherit it (Russell, 2006). This teaching-learning dynamic was enabled and reinforced by the then-dominant mediasphere – the graphosphere (and later the videosphere) – which allowed primarily for one-directional communication: from author or publishing house to readers, or from television screens to viewers. This model of receiving information from a central source translated directly into the classroom, shaping the preferred and often unquestioned norms of teaching and learning. In other words, it is not only political and economic systems that determine the dominant forms of education; technological systems, in interaction with the societies that employ them, also regulate the material conditions and beliefs about what education should be and how it should be practiced. Today, however, we find ourselves living within a new mediasphere – the hypersphere – marked by the rise of networked communication and, most recently, by the rapid emergence of artificial intelligence, which is on the verge of being integrated into educational systems. This shift brings with it a renewed sense of urgency around the question of media literacy in education. The hypersphere introduces network-based communication, synchronous access to billions of pieces of information, new modalities of presence and participation, and the restructuring of social relations through novel models of centralization and decentralization. Together, these developments generate new possibilities for knowledge production, mediation, and dissemination (including in education), as well as new models of convergence-based learning. The concept of the "material classroom" is thus being gradually (if not rapidly) redefined, as educational methods multiply. Yet this raises the question:

[2]As education itself is a culture, presents as a culture, uses cultural means and knowledge, and extends into different fields of culture in a society it takes place (Tække & Paulsen, 2022; Galés & Gallon, 2020).

is such a transformation an opportunity, a challenge, or even a problem for educational practice? Importantly, the physical classroom and the physical body are not disappearing, nor are they becoming obsolete within the hyperspheric reality. They remain integral to the educational process and crucial for the applicability of knowledge acquired. In this sense, Web 2.0 did not "replace" older media, but this in no way diminishes its significance. On the contrary, it increasingly becomes the daily standard for perceiving and engaging with reality, inevitably shaping educational practices.

If Web 2.0 reality – standing as Media 2.0 with all its transformations – demands Education 2.0 (Buckingham, 2015), then the pressing question becomes: how should educators and learners negotiate their communication practices in this transitional moment? The next chapter will pose further questions, highlight key challenges, and outline possible answers, or at least pathways for deeper reflection. It will do so with the aim of raising awareness of media effects in education as a foundation for the quality-driven transformation of contemporary educational practice.

2. Understanding media effects in education: a critical theory for transformative practice

The media effects analysis used in this paper is based on the concepts and terminology presented by Régis Debray in his book *Introduction à la Médiologie* (Debray, 2000). Similar ideas had already been introduced, discussed, and developed in some of Debray's earlier works. The media effects I chose to apply to educational theory and practice for this paper are specifically derived from the Serbian translation of *Introduction à la Médiologie* (*Uvod u mediologiju*, Debre, 2000); therefore, the names of the effects may not correspond directly to their original French terminology. Moreover, some effects are discussed by Debray under a specific name and category (e.g., the jogging effect or the stagecoach effect, which in this paper appears as the "readiness effect"), while others are explored through broader theoretical frameworks or through theorizing cultural and contextual phenomena related to the introduction of new media technologies. Consequently, the number and type of media effects presented here reflect my own interpretation and selection, based on their applicability to contemporary education. In other words, Debray's rich theorization of the interrelation between technology, media, and culture allows for various classifications of media effects. However, the classification chosen here is specifically aimed at addressing challenges commonly encountered in contemporary education,[4] and it includes the discovery effect, the frenzy effect, the readiness effect, the jogging effect, and the End effect.

2.1. The discovery effect

The discovery effect becomes visible when it is unmistakably clear that a new technology has established itself and begun to modify the present mediasphere, introducing a new one ahead. Put differently, the discovery effect is specifically the proof that a new technology, together with its corresponding mediasphere, has taken hold. It is often recognized in a sudden urge to romanticize or glorify past times and eras (as if they were better, more "human-centered," or safer than the present), or to introduce nostalgia into interpretations of the past. What is actually occurring is that the new technology inevitably integrates into contemporary society and practices, while romanticization or nostalgia serves as a narrational base – or even a cover – for the anxiety associated with being unprepared for the new mediasphere. Simultaneously, the discovery effect operates across two mediaspheres: the old one, which is actively reformed and transformed, and the new one, which is still emerging and may appear "optional" (Debre 2000; Buckingham, 2015).

In the context of education, the discovery effect often manifests as technophobia within the educational process, frequently exhibited by educators who were heavily immersed in the previous mediasphere,

[4]I was also using observation as a method of field work while teaching students of bachelor, master, and doctoral studies in Faculty of Media and Communications, Singidunum University. During the previous ten years, I was working first as an Assistant Professor (2014-2019), and then as an Associate Professor (2019-2025).

in which they likely learned both how to learn and how to teach. Educators influenced by the discovery effect may view technology in a technodystopic or technodeterministic way and act as "protectionists" (Kellner, 2006). In reality, both technoeuphoria and technophilia, as well as technodystopia and technophobia, if approached without critical perspective, can significantly slow the constructive adaptation to the new aspects offered by the emerging mediasphere (Kellner, 2006; Schofield, 2006; Buckingham, 2015). The discovery effect can also create a mismatch between the values and expectations of educators and those of students. Students, often more immersed in the new mediasphere, may perceive traditional teaching methods as outdated or irrelevant (Schofield, 2006). Without awareness of this media effect and open communication between educators and students, the effectiveness and quality of the teaching-learning process can suffer. For instance, contemporary students are often characterized as less inclined to read long texts, having shorter attention spans, lower capacity for memorizing facts, and a propensity for continuous multitasking and networking (Kalogeras, 2014). These traits, however, need not be viewed as disadvantages; rather, educators can interpret them as indicators of a misalignment between their own expectations and the students' engagement with the new mediasphere, reflecting the discovery effect within educational dynamics. Therefore, the problem should not be reduced to a mere "lack" of concentration in students, because technology "…doesn't alter what human attention is or how it works in any very basic way, but by changing the conditions under which we can give it, and to whom, it alters how it gets distributed and how important it can be for us" (Goldhaber, 1998). It is the quality, not the quantity, of attention that shifts with the use of new technology and participation in the new mediasphere – both for students and educators (Tække & Paulsen, 2022). Ultimately, learning is always a collaborative experience (Kalogeras, 2014), and the discovery effect, if recognized and understood in time, can be crucial for establishing a high-quality collaborative atmosphere between educators and learners, as well as for fostering a productive learning environment overall.

2.2. The frenzy effect

The frenzy effect emerges as the other side of the same coin on which the discovery effect appeared, manifesting in the initial human reaction to new technology that changes the world and the practices we previously knew. The frenzy effect can be just as radical as the discovery effect, and in fact, it may be even more pronounced. Its main characteristic lies in strong, enthusiastic, even techno-utopian thinking about the new mediasphere, or in the general belief that the new technology will "make everything better" (Kellner, 2006).

If these ideas arise in either educators or students, and are not properly recognized, understood, and discussed within the educational environment, the new tools and technologies, despite their potential, may not be fully utilized. In such cases, the euphoric approach can inhibit critical and creative thinking that could extend the potential of the new mediasphere in education to its fullest extent (Schofield, 2006). Additionally, students and educators may experience this frenzy stage separately, each holding their own expectations or hopes regarding the influence of new technology on the educational process. For example, students may expect a rapid integration of new technologies into their learning, while educators may assume that students are inherently media-literate simply because they use these technologies extensively in daily life (Buckingham, 2015). If such expectations and assumptions are not discussed collaboratively, the achievement of the educational process's full potential can be slowed. Fortunately, as with the discovery effect, the frenzy effect occurs early in the formation of a new mediasphere and soon gives way to other effects, such as the readiness effect or the jogging effect. Importantly, technology does not exert a uniform effect on the educational process as a whole, nor does it act as an external "entity" influencing education from above. Rather, a constructive perspective recognizes technology as both a co-creator of the educational process and a tool within it (Tække & Paulsen, 2022). The key question, then, is not what technology imparts to education or how it changes it, but how we, as humans, use it, integrate it into our educational practices and environments, and grow through this bio-techno-eco coexistence.

2.3. The readiness effect

The readiness effect is certainly one of the most intriguing media effects, especially when applied to historically developed practices, such as education. It is reflected in a generation's inability to fully conceive technology in its maximum potential – that is, to use technology in ways that could enable entirely new forms of invention, innovation, and social enhancement. For example, Régis Debray provides the case of the locomotive, explaining that the first trains were designed primarily to pull a long row of carriages rather than fully exploiting the locomotive's capacity to pull larger and stronger wagons, because people had not yet conceived of such possibilities (Debre, 2000: 231–232). Similarly, the first printed books unnecessarily mimicked handwritten manuscripts, early photography imitated classical painting even when the technology could have supported a departure from these forms, and early television studios were modeled after radio ones (Debre, 2000: 231–232). In the hypersphere, where this effect is felt more intensely than ever (though it applies to previous mediaspheres as well), humans engage in communities of practice composed not only of people but also of technology, which coexists and co-acts in the process of social and individual transformation (Maxwell, 2006; Tække & Paulsen, 2022). As John W. Maxwell notes, "To recognize this is to adopt a theory of human action that is inclusive of its technological and artifactual extensions; one not limited to the mind/body reductivism of a Cartesian worldview" (Maxwell, 2006: 289).

In the context of education, the readiness effect directly follows from the frenzy effect, illustrating that all media effects are mutually intertwined and interrelated. For example, the failure to use the Internet to develop entirely new forms of education (such as those grounded in network-based platforms for designing learning and assessment tasks or facilitating communication) may result from both frenzy and readiness effects. Within the frenzy effect, the rush to adopt the Internet as a quick solution, assumed to enhance educational quality, can instead lead to its use merely as a database supplement to existing teaching and learning methods (Schofield, 2006; Downes, 2008). From the perspective of the readiness effect, this phenomenon reflects a "slowdown" in the evolution of the mediasphere, or a "cut-and-paste" approach to literacy, occurring when educators and learners alike are unable to envision new ways of using technology beyond simply augmenting existing models of mediation and communication.

Examples of successful development in the educational process following the readiness effect include not only the use but also the creation of new types of space and time within the learning environment. This could involve students accessing materials or even participating in educational sessions regardless of specific temporal or spatial constraints, opening the classroom to the outside world and vice versa, and challenging the "clear-cut" distinction between classroom and everyday reality (Tække & Paulsen, 2022). Additionally, new teaching practices emerging from the hypersphere might involve engaging students' multiplexing skills and integrating them into the educational process.[5] Additionally, new media should be integrated into the educational process in ways that support internal communication and classroom activities (Tække & Paulsen, 2022). Moreover, the readiness effect can facilitate the creation of a connective learning environment, fostering the development of productive connective knowledge. As Stephen Downes defines it, connective knowledge is "knowledge that can be described as distributed, because it is spread across more than one entity. A property of one entity must lead to or become a property of another entity in order for them to be considered connected; the knowledge that results from such connections is connective knowledge" (Downes, 2008: 77). When applied or envisioned as an outcome of teaching and learning, this concept fundamentally transforms the paradigm of educational processes, methods, and outcomes. This is a transformation that cannot occur overnight. Ultimately, to know [how to do] something is to develop a neural and mental structure corresponding to our surroundings (Downes, 2008) – and this, certainly, takes time.

[5]According to Tække & Paulsen, multiplexing is „focusing our attention on the same intentional object using more than one medium" (Tække & Paulsen 2022: 61).

2.4. The jogging effect

The jogging effect is most clearly observed as the effect of surprise—for instance, when a negative prognosis about the emergence of a new mediasphere proves to be entirely unfounded. The effect was named by Régis Debray, arising from his observation of modern, motorized humans (Debre, 2000: 238). Despite initial concerns that excessive car use would compromise physical mobility and health, people began exercising more to naturally counteract the effects of prolonged sitting. Moreover, a whole social and consumer culture around exercise and gyms has developed.

The jogging effect typically highlights the irrational fear of technology or the new mediasphere, though it manifests differently from, for example, the discovery effect. Understanding this effect can help address similar anxieties in education. For instance, fears surrounding online education as a source of alienation, or concerns about a diminishing authority of the educator in networked, decentralized learning environments, may be unfounded. When the jogging effect is recognized and thoughtfully addressed, appropriately designed didactic forms can enhance the connection between educators and learners and between learners themselves, while learning tasks can simultaneously amplify connective knowledge and foster human-to-human interaction in the learning environment (Ainley & Armatas, 2006). Additionally, strategies such as cultivating "playing attention" through designing or using serious games in education (De Castell & Jenson, 2006:1012) or engaging hyperattention for learning processes (Hayles, 2008) can encourage the jogging effect, reduce the often exhibited fears of "weakened attention of the young generation" and facilitate a smoother transition into the new educational mediasphere.

2.5. The end effect

The End effect is relatively straightforward, relating to effects that manifest early in the emergence of a new mediasphere. It is often visible in technodystopian theories of "The End of…", frequently concerning the body, space, small languages, or reading. This phenomenon reflects a fear that the relevance of these categories might be lost forever, along with the social, economic, political, and semiotic frameworks we have known throughout history and modernity.

However, as the jogging effect demonstrates, such fears are largely irrational. While technology does propel society in entirely new directions and the hypersphere challenges the centrality of the physical body and space, both bodies and their experiences of time and space continue to exist in daily life (including educational environments), and remain legitimate and influential. In education, the physical body, time, and space continue to matter; although both educators and learners have to adapt to extended offline/online realities, their physical bodies remain equally important as their use of technology in the learning process. Moreover, the physical bodies are crucial in this process, and their material experience deeply influences the educational process. Regarding the frequently expressed fear of one-language dominance,[6] online spaces and intensive digital communication can actually enhance the environments in which small languages exist and evolve, which actually represents a manifestation of the jogging effect. Similarly, reading has flourished in new ways through online communication, driven by the interests and engagement of both students and educators in the digital environment. In conclusion, across all these media effects, "ends" are rarely final; rather, they serve as invitations for constructive transformation – a principle that holds true to education as well.

Conclusion

In conclusion, it is important to emphasize that understanding media effects is a crucial precondition for the development of contemporary education. As demonstrated in this paper, the educational process is inseparable from both its human and technological actors, who co-create the educational environment and transform the process through their interaction. Furthermore, because teaching and learning can be

[6]Today, the most prominently used language on the Internet is English.

understood largely as processes of communication and mediation, communication and media theories constitute essential frameworks for educational studies. Recognizing and understanding each media effect as it occurs can help educators and students avoid unnecessary worries, doubts, and communicational failures, as well as alleviate fears about the transformation of education in the hypersphere. Ultimately, the hypersphere is simply another mediasphere; it is not the first one, and certainly not the last one. As Debray's media effects illustrate, the constructive development of contemporary and future education must involve researching, understanding, and applying media theories, learning from the challenges of previous mediasphere transformations, and striving to find solutions that enable contemporary educators and students to navigate the changes ahead with confidence, curiosity, and inspiration.

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Contribution to Sustainable Economic and Social Development Through the Implementation of Renewable Energy Systems

Doprinos održivom ekonomskom i društvenom razvoju kroz implementaciju sistema obnovljivih izvora energije

Srđan Žikić[1]

[1]*University Business Academy in Novi sad, Faculty of Social Sciences, Belgrade, Serbia, srdjan.zikic@fdn.edu.rs*

Abstract: *The development of renewable energy sources (RES) represents a key instrument for economic and social transformation, particularly in transition countries such as Serbia. Investments in RES stimulate employment growth, create new jobs in production, construction, and maintenance of energy facilities, and promote complementary sectors such as agriculture, tourism, and services. At the same time, the RES sector contributes to rational energy use, increased energy efficiency, and reduced dependence on imported fossil fuels, strengthening economic stability and competitiveness. The analysis shows that integrating RES into Serbia's energy mix enables regional diversification, rural development, and improvement of living standards in local communities. Despite existing challenges, such as low current utilization of renewables and the dominance of coal, strategic energy transition policies and infrastructure investments ensure long-term economic and social benefits. The RES sector has the potential to become a driving force for sustainable development, economic growth, and social inclusion in Serbia.*

Keywords: *Renewable energy sources, energy transition, economic development, rural development, employment, energy efficiency.*

Apstrakt: *Razvoj obnovljivih izvora energije (OIE) predstavlja ključni instrument ekonomske i društvene transformacije, posebno u zemljama u tranziciji kao što je Srbija. Ulaganja u OIE podstiču povećanje zaposlenosti, stvaranje novih radnih mesta u proizvodnji, izgradnji i održavanju energetskih objekata, kao i razvoj komplementarnih sektora kao što su poljoprivreda, turizam i usluge. Istovremeno, sektor OIE doprinosi racionalnoj upotrebi energije, povećanju energetske efikasnosti i smanjenju zavisnosti od uvoza fosilnih goriva, što jača ekonomsku stabilnost i konkurentnost. Analiza pokazuje da integracija OIE u energetski miks Srbije omogućava regionalnu diverzifikaciju, razvoj ruralnih područja i unapređenje standarda života lokalnih zajednica. Uprkos postojećim izazovima, kao što su nisko iskorišćenje obnovljivih izvora i dominacija uglja, strateške politike energetske tranzicije i investicije u infrastrukturu obezbeđuju dugoročne ekonomske i socijalne koristi. Sektor OIE ima potencijal da postane motor održivog razvoja, ekonomskog rasta i socijalne inkluzije u Srbiji.*

Ključne reči: *Obnovljivi izvori energije, energetska tranzicija, ekonomski razvoj, ruralni razvoj, zapošljavanje, energetska efikasnost.*

Introduction

The energy transition toward renewable energy sources (RES) represents one of the key challenges and opportunities for contemporary economies and societies. The paradigm shift from fossil fuels to sustainable, low-carbon energy sources has become a global policy priority aimed at mitigating climate change, strengthening energy security, and fostering economic development (Sahlian et al., 2021). The introduction of renewables is not merely a technical or environmental issue but carries profound economic and social implications — from enhancing energy independence and reducing reliance on

fuel imports, to creating new industries and jobs, improving quality of life, and decreasing social inequalities (Stevanović & Stevanović, 2022).

Global trends show that investment in renewable energy yields multiple benefits. According to the International Labour Organization (ILO, 2023), the number of jobs in the renewable energy sector has surpassed 12 million worldwide, while it is estimated that increasing the share of RES could contribute up to 1.3 trillion USD to the global GDP by 2030 (UNFCCC, 2022). Such outcomes clearly indicate that the shift toward renewable sources has the potential to generate sustainable economic growth and enhance social welfare, particularly in developing countries (Xie et al., 2023).

In the context of the Western Balkans, and particularly Serbia, the energy transition presents a specific challenge due to the heavy reliance on lignite and imported fossil fuels. However, research indicates that transforming the energy system toward RES can significantly contribute to sustainable growth, emission reduction, and the strengthening of energy security (Jovanović et al., 2024; OECD, 2023). Therefore, the aim of this paper is to analyze how the implementation of renewable energy systems contributes to sustainable economic and social development — both globally and through specific examples from the region and Serbia. The paper first discusses the concept and development trends of RES, followed by the economic and social aspects of their implementation, key challenges and obstacles, and finally, conclusions with recommendations for further development.

1. Research methodology

The starting point of the research is based on the significance of renewable energy sources in the context of energy security, climate change, and sustainable development. The main objective of the study is to determine the extent to which renewable energy sources contribute to improving the economic and social dimensions of sustainability. The research is grounded in the general hypothesis that the long-term application of renewable energy sources significantly contributes to the realization of the concept of sustainable development, as it stimulates economic growth and enhances social well-being while reducing negative environmental impacts.

Based on this main hypothesis, several auxiliary hypotheses were formulated, encompassing the economic and social aspects of renewable energy application. It is assumed that their use has a positive effect on economic development by increasing energy efficiency, reducing energy production costs, and encouraging investment in new technologies and job creation. From a social perspective, the use of renewable energy is expected to contribute to improving the quality of life, reducing regional disparities, and raising awareness of the importance of sustainable development.

To test the proposed hypotheses, a combined scientific research approach was applied, including analytical and synthetic methods, as well as a comparative analysis of different models of renewable energy implementation. These methods made it possible to examine theoretical assumptions and verify them through comparison with empirical indicators, thereby confirming the relevance of the research hypotheses.

2. Renewable energy sources – definition and trends

Renewable energy sources (RES) are energy resources that are naturally replenished and used to produce electrical, thermal, and mechanical energy. Their key advantage lies in their inexhaustibility, as they are renewed in accordance with natural cycles (Zhang et al., 2021). According to the United Nations definition, renewable energy includes sources that are naturally replenished without depleting resources or increasing harmful gas emissions (UNFCCC, 2023). RES are divided into traditional sources (biomass, biogas, hydropower) and new sources (small hydropower plants, geothermal, solar, wind, and ocean energy) (Zhao & Wang, 2022).

Global trends indicate a continuous increase in the use of RES, driven by declining technology costs, climate goals, and growing demand for cleaner energy (Sanchez et al., 2023). The share of RES in global primary energy consumption exceeds 13%, including solar, wind, biomass, and hydropower (Our World in Data, 2025). Their utilization contributes to reducing carbon dioxide emissions and building more resilient energy systems (Sahlian et al., 2021). According to the UNFCCC (2023), global CO_2 emissions must be reduced by 45% by 2030 to limit global warming to 1.5°C, confirming the central role of RES in the energy transition.

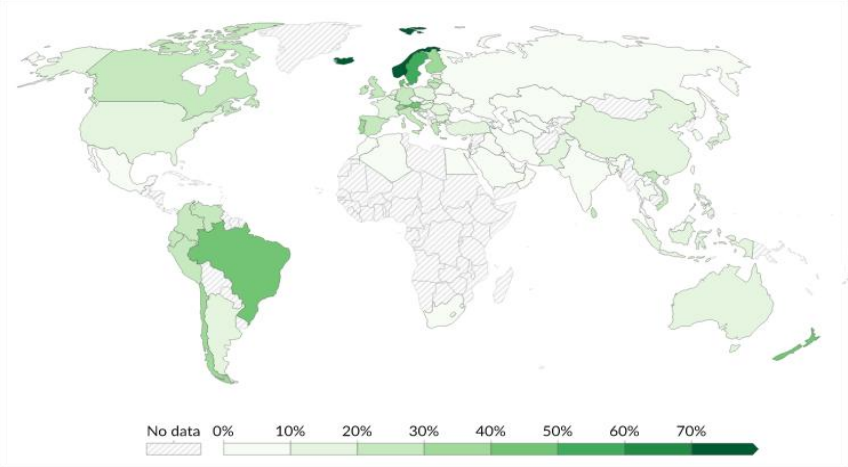


Figure 1. Share of renewables in global primary energy, 1965–2023.
Source: Our World in Data (2025)

Thanks to technological innovation, the cost of producing energy from RES has drastically decreased over the past decades, enabling their wider application (Wang & Liu, 2024). Investments in RES are often significantly lower than in conventional sources, with faster returns due to reduced operational costs and new business models (Rao et al., 2023). The European Union, for example, plans for at least 40% of its energy to come from RES by 2030 (European Commission, 2022).

The use of renewable energy sources also brings substantial social and economic benefits. RES contribute to the creation of new jobs in energy production, installation, and infrastructure maintenance sectors. The global renewable energy job market reached 12.7 million in 2022 and is expected to grow by 5–10% by 2030 (ILO, 2023). Beyond their economic contribution, RES improve quality of life by reducing pollution and enhancing access to energy in rural areas (Jovanović et al., 2024). Rapid progress in RES development has resulted from falling technology costs and international cooperation. The price of solar panels has dropped by more than 80% since 2010, contributing to their widespread adoption (Stevanović & Stevanović, 2022). The share of RES in global primary energy consumption is around 13% (BP Statistical Review of World Energy, 2023), confirming their growing significance.

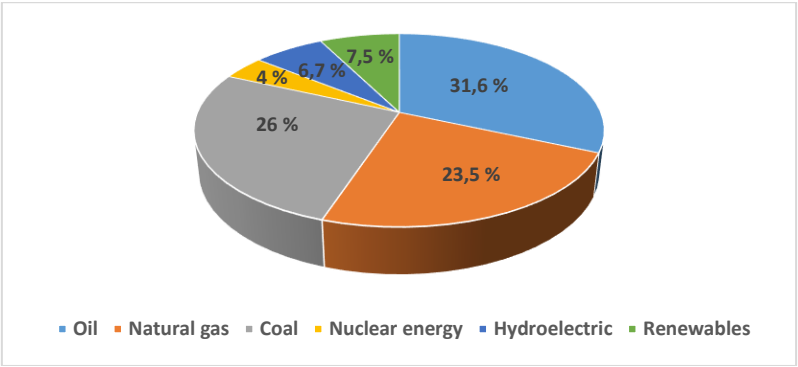


Figure 2. Structure of global primary energy consumption by source
Source: BP Statistical Review of World Energy (2023).

In a regional context, RES play a key role in enhancing energy security, especially in developing countries. In Serbia and the Western Balkans, the energy transition is particularly significant due to high dependence on coal. The implementation of RES can contribute to reducing energy dependency, improving efficiency, and lowering greenhouse gas emissions (Jovanović et al., 2024). Major challenges include a lack of financial resources and the integration of new technologies into existing systems. Strategies based on decentralized models—such as solar farms and microgrids—represent a sustainable path of development.

According to the OECD (2023), future implementation of RES depends on technological development, political commitment, and international cooperation. The European Union, through its climate policies, leads in setting ambitious targets for increasing the share of RES. In this context, renewable energy sources are not only a tool for mitigating environmental impacts but also a driver of economic growth and innovation.

In conclusion, RES represent a fundamental pillar of the global energy transition and sustainable development. Their broader implementation can enhance energy independence, reduce emissions, create new jobs, and improve quality of life. In Serbia's case, the transition toward RES represents a strategic opportunity for modernizing the energy system and strengthening economic resilience in line with global trends (Jovanović et al., 2024).

3. Economic aspects and benefits of using renewable energy sources

The economic aspects of renewable energy sources (RES) are based on the utilization of local resources, which increases employment, channels funds into other sectors, and improves energy efficiency (IEA, 2023; World Bank, 2022). Investments in RES can stimulate national economic growth, reduce dependence on fossil fuels, and create new opportunities for innovation and technological development (Liu, Wang, & Zhang, 2021). The widespread adoption of these sources strengthens economic stability, develops local communities, and improves the population's quality of life.

The development of RES also acts as a tool for economic diversification. Beyond the direct effects—creating jobs in the production, construction, and maintenance of energy facilities—positive effects emerge in complementary sectors such as tourism, agriculture, and construction (Sarkar & Rahman, 2020). Solar and wind projects generate employment in equipment manufacturing, finance, and maintenance, creating broader economic networking. According to the European Commission (2023), the RES sector in the EU employs over 1.5 million people, with an expected growth of more than 40% by 2030. Globally, the number of jobs in RES reached 13.7 million in 2022, an increase of one million compared to 2021 (ILO/IRENA, 2023).

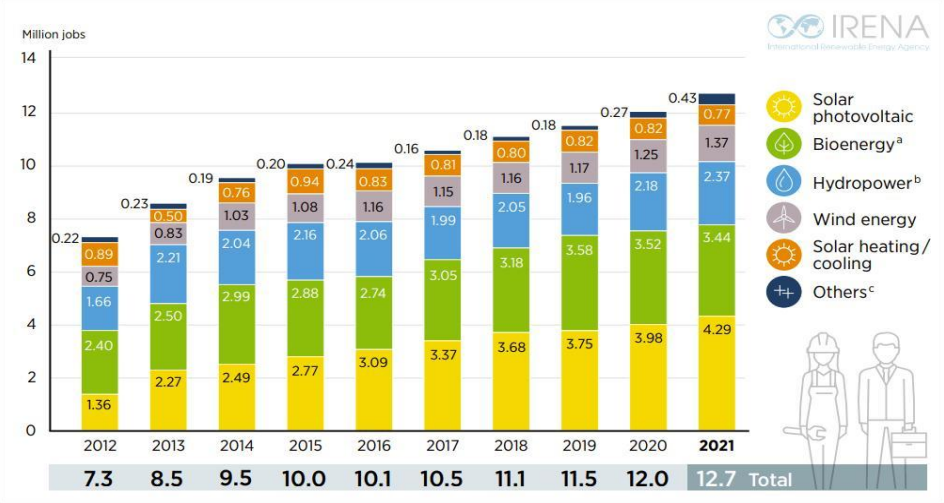


Figure 3. Growth of employment in the renewable energy sector globally
Source: IRENA/ILO, 2023)

Experiences from the USA confirm similar effects. The study Renewing Arizona's Economy (Arizona PIRG, 2022) showed that increased solar energy use in Arizona leads to GDP growth, higher employment, and increased net incomes for workers. Similar conclusions are highlighted by BloombergNEF (2023), emphasizing the multidimensional impact of RES on the economy.

A key economic advantage of RES is the increase in energy efficiency—minimizing losses in energy production and consumption reduces costs and enhances competitiveness (Lotfi, Farhat, & Chihi, 2019). Investments in local resources simultaneously reduce the need for energy imports and strengthen energy independence (Boroumand & Shafiee, 2018). This is particularly important for developing countries, where RES can significantly impact the stability of rural communities (Turyareeba, 2018; Houston, Gillis, & Choi, 2020).

The integration of solar and biomass systems in agriculture leads to energy cost savings, reduced CO_2 emissions, and increased employment (Marino, Ferrante, & Romano, 2021). Such models make rural communities more economically sustainable, reduce regional inequalities, and promote local development. The combination of renewable energy and energy efficiency measures allows for rational resource use, investment promotion, and job creation, thereby strengthening the economy's resilience to global energy and climate challenges (Zhou, Li, & Chen, 2022; REN21, 2024).

In the national context of Serbia, the development of an energy sector based on RES can become a driver of regional growth—through employment in the construction and maintenance of facilities, as well as the development of complementary activities in agriculture, tourism, and eco-industries. Increasing energy efficiency contributes to the competitiveness of the domestic economy and reduces dependence on imported energy. Utilizing domestic resources—solar, wind, and biomass—provides a direct economic effect through infrastructure investments (Zezelj et al., 2020).

In the Autonomous Province of Vojvodina, there is significant untapped biomass potential, indicating opportunities for investment in rural areas and linking agriculture with energy production (Zezelj et al., 2020). This synergy can reduce regional inequalities, improve living standards, and retain population in less developed areas. According to the Ministry of Mining and Energy (2025), the "green jobs" sector in Serbia is in its initial phase, but there is potential to create approximately 6,100 jobs by 2030, mainly in the solar industry. This development also contributes to better energy efficiency and lower costs for end-users. However, Serbia faces challenges—low utilization of RES and a dominance of coal (about 70% of electricity production), which complicates the transition (Smajilhodžic & Bouissou, 2023). Nevertheless, state strategies foresee an increase in the RES share and investments in infrastructure, making sector development economically justified.

Southern Serbia has significant potential for solar, wind, and biomass energy. Their deployment can increase the region's energy independence and stimulate the local economy (Petrović, Ilić, & Marković, 2021). Investments in solar and wind farms create several hundred jobs during construction and maintenance (Stanković, 2022), with multiplier effects in other sectors. The use of agricultural and forestry biomass further increases farm income and reduces heating costs. The region faces challenges such as insufficient infrastructure and complex administrative procedures (Jovanović & Ristić, 2023), but the national strategy anticipates increasing the share of RES in the energy mix over the next decade. This could significantly improve the economic situation, reduce energy dependence, and expand employment.

In conclusion, in the context of Serbia, RES represent a foundation for economic diversification, rural development, new employment, and greater energy efficiency. Properly targeted investments and energy policies can position this sector as one of the key drivers of economic growth and regional balance in the coming decade.

4. Social aspects and benefits of using renewable energy sources

The development of energy production from renewable energy sources (RES) has a significant impact on overall social development, improving living standards, and promoting more balanced regional development. According to Carabajal et al. (2024), the introduction of solar mini-grids in rural areas led to a fourfold increase in household income and greater participation of women in economic activities, demonstrating that RES can have profound social implications—from better health and energy security to more stable local economies. In Europe, data from the European Environment Agency (EEA, 2023) show employment growth of over 65% in environmental protection and renewable technology sectors over the past decade, confirming that RES represent both a social and economic development tool. Similarly, in Serbia, the development of this sector could enable employment and economic growth, particularly in rural and less-developed areas.

The REN21 report Economic and Social Value Creation (2024) highlights that employment in the RES sector increased by approximately 15% between 2019 and 2022, while employment in fossil fuels declined by 4%. The report emphasizes the need for a "human-centered" approach to the energy transition, which includes the active involvement of workers, communities, and regional development mechanisms. Incorporating RES into local energy production and supply systems can directly impact living standards in less-developed areas, stimulating technical production, service activities, and small and medium-sized enterprises. This confirms that RES are a powerful tool for regional development and social inclusion.

In the context of Serbia, the development of RES can bring multiple benefits: employment in the renewable energy sector, strengthening local production, improving infrastructure, and stimulating regional economies. This contributes to more balanced development and reduces disparities between urban and rural areas. Transitioning from fossil fuels to RES has the potential to improve energy security, as well as socio-economic development and living standards (Zezelj et al., 2020). Therefore, the energy transition is not only a technological process but also a means for broader economic and social change. According to the Integrated National Energy and Climate Plan of the Republic of Serbia until 2030, with a vision to 2050 (Ministry of Mining and Energy of the Republic of Serbia, 2024), Serbia plans to increase the share of RES in final energy consumption to at least 33% by 2030. This is a prerequisite for energy independence, economic competitiveness, and the reduction of greenhouse gas emissions. New investments in the RES sector can particularly stimulate the local economy in rural areas rich in biomass, solar, and wind potential.

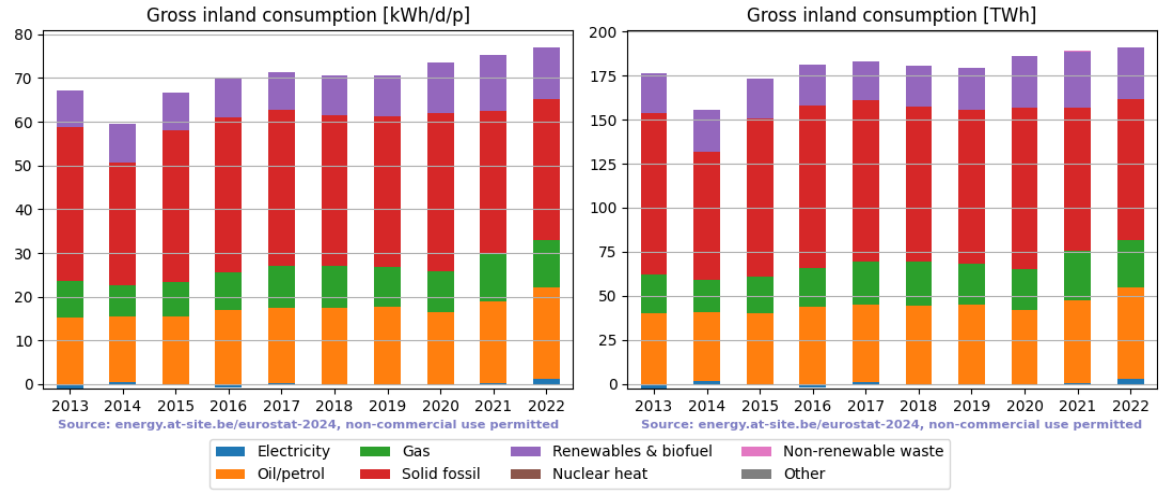


Figure 3. Share of renewable energy sources in Serbia's final energy consumption (data and target for 2030)
Source: Ministry of Mining and Energy of the Republic of Serbia, 2024

Žikić et al. (2022) found that the population in rural regions of Serbia increasingly recognizes the importance of RES for local development. Although awareness is uneven, consciousness of economic benefits—such as new jobs and improved infrastructure—is growing. The authors emphasize that public education is a prerequisite for more active participation in the energy transition.

Zezelj et al. (2020) highlight that the development of solar and wind energy infrastructure in Vojvodina enabled direct employment in the energy sector and increased demand for local products and services, supporting decentralized economic growth. Reljić, Mihić, and Cvijović (2024) note that Serbia is achieving moderate but steady progress in RES utilization compared to Central and Eastern European countries, but stronger institutional capacities and financial incentives are necessary for full integration into national policy.

Social effects are particularly significant: the development of RES in rural areas reduces demographic decline and encourages young people to remain. Žikić et al. (2022) emphasize that access to clean energy and new employment opportunities strengthens the sustainability of local communities. Such projects are increasingly recognized as key to balanced regional development.

To enable a more effective transition, it is necessary to improve the regulatory framework and public-private sector cooperation. The Integrated National Energy and Climate Plan (2024) foresees the introduction of green bonds and subsidies for households installing solar panels, which will accelerate sector development.

In summary, existing studies show that the development of energy production from renewable sources positively affects employment, living standards, and the creation of added value in communities. To maximize these effects, policies are needed that promote local investment, workforce and infrastructure development, and active community participation. In this way, RES become not only a technological but also a social transformation. With its natural potential, Serbia has the opportunity to become a regional example of a successful energy transition based on economic efficiency and social responsibility in the coming years.

Conclusion

The development of renewable energy sources (RES) represents a significant instrument for both economic and social transformation, at global and national levels. The analysis shows that investments in renewable energy directly contribute to increased employment, the creation of new jobs in the production, construction, and maintenance of energy facilities, as well as the development of complementary sectors such as agriculture, tourism, and services. At the same time, this sector promotes the rational use of energy, enhances energy efficiency, and reduces dependence on imported fossil fuels, resulting in strengthened economic stability and competitiveness.

At the national level, as illustrated in the context of Serbia, integrating RES into the energy mix enables regional diversification and the development of rural areas, stimulates local economies, and mitigates demographic decline. The strategic use of solar, wind, and biomass energy can lead to significant economic networking, increased investment potential, and improved living standards in local communities.

Although challenges exist, such as the currently low utilization of renewable energy and the dominance of coal in electricity production, state strategies and energy transition policies provide a framework for faster sector development. A combination of infrastructure investments, support for local initiatives, and public awareness efforts allows renewable energy sources to become a driver of economic growth and social progress.

In summary, renewable energy in Serbia has the potential to become a key factor in sustainable development, contributing simultaneously to economic stability, regional balance, and improved quality of life for citizens. Properly directed efforts and strategic support can ensure that the energy

transition is not only technological but also a socio-economic transformation with long-term positive effects.

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Application of Artificial Intelligence in Strategic Management and Marketing: Opportunities and Challenges

Primena veštačke inteligencije u strateškom menadžmentu i marketingu: prilike i izazovi

Pavle Brzaković[1], Miloš Mastilović[2], Tijana Đukić[3]

[1]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, pavle.brzakovic@mef.edu.rs*
[2]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, office@clickmedia.rs*
[3]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, tijana.djukic@mef.edu.rs*

***Abstract**: The application of Artificial Intelligence (AI) is revolutionizing decision-making in strategic management and marketing. This paper examines the main opportunities that AI offers to managers and marketers, including enhanced decision-making, predictive analytics, automation of processes, and personalized customer interactions. Additionally, the paper discusses ethical, security, and societal challenges brought by AI adoption. Case studies of companies such as Amazon, Netflix, and Tesla illustrate practical applications. The paper concludes with recommendations for the responsible and strategic integration of AI in management and marketing.*
***Keywords**: Artificial Intelligence, strategic management, marketing, automation, ethics, data privacy.*

***Apstrakt**: Primena veštačke inteligencije (VI) revolucioniše donošenje odluka u strateškom menadžmentu i marketingu. Ovaj rad analizira glavne prilike koje VI pruža menadžerima i marketarima, uključujući unapređeno donošenje odluka, prediktivnu analitiku, automatizaciju procesa i personalizovanu interakciju sa klijentima. Takođe, razmatraju se etički, bezbednosni i društveni izazovi koje donosi primena VI. Primeri kompanija poput Amazona, Netfliksa i Tesle ilustruju praktičnu primenu. Rad se završava preporukama za odgovornu i stratešku integraciju.*
***Ključne reči**: Veštačka inteligencija, strategijski menadžment, marketing, automatizacija, etika, privatnost podataka.*

Introduction

Artificial intelligence has rapidly become a pivotal technological force reshaping organizational practice in the twenty-first century. Within strategic management and marketing, AI extends analytical reach and shortens decision cycles by converting voluminous and heterogeneous data into precise, operationally useful insights. This capability enables firms to tailor communications and offerings at scale, to anticipate market shifts more effectively, and to align tactical actions with long-term strategic objectives.

At the same time, embedding AI into strategic processes generates a set of substantive challenges: it raises ethical questions about automated decision-making, creates exposed vectors for privacy breaches, and can foster excessive dependence on algorithmic outputs at the expense of human judgment. Thus, managers and marketing professionals must pair technological adoption with robust governance, clear accountability mechanisms, and organizational practices that preserve critical oversight while unlocking AI's strategic potential.

1. Opportunities and impact of Artificial Intelligence

The implementation of artificial intelligence into business operations is transforming strategy development and regular management activities, with recent research indicating that the integration of digital marketing substantially enhances organizational efficiency when bolstered by AI-driven decision-making frameworks (Nikolić et al.,2024). AI-based technologies enable organizations to extract structured patterns and insights from vast sets of historical and real-time data, building predictive models capable of recognizing market shifts, anticipating demand and indicating operational risks with greater confidence than traditional, intuitive approaches. This shift from a subjective to a data-based thinking model changes the fundamental logic of strategic planning. The introduction of machine learning and artificial intelligence methods enables the creation of significantly more personalized marketing campaigns, and also improves customer support through chatbots and automated responses (Mastilovic et al., 2024). Integrating these technologies into digital marketing strategies brings a range of operational and tactical benefits — from better segmentation and timely messaging to scalable automation of interactions — but also opens up new challenges related to design, ethics and performance evaluation. These results correspond with current research emphasizing the increasing importance and influence of artificial intelligence in marketing (Petrušić, et al., 2024). Therefore, it is necessary for researchers and practitioners to carefully approach implementation, assess risks, and develop methodologies for measuring effects and managing adverse consequences (Kaponis et al., 2022).

From the perspective of decision-making science, the application of such models significantly shortens the time gap between the appearance of signals and managerial reaction: managers no longer have to wait for retrospective financial reports to intervene, but can implement targeted, proactive solutions based on predictive insights. Comparable approaches have been proposed for financial reporting platforms, where AI-based ranking supports faster and more informed decision-making (Mladenović, et al., 2023). In practice, this means fine-tuning inventory management, logistics and pricing policies, reducing uncertainty in supply chains and improving service levels. Automated demand forecasting systems and dynamic inventory management have already led to reduced shortages, inventory optimization and tangible cost savings.

The latest generation of AI tools—especially generative models such as ChatGPT—has substantially expanded organizations' ability to exploit both internal datasets and externally available information to refine practices and secure competitive advantage (Agrawal et al., 2018; Bassano et al., 2018). These systems facilitate rapid synthesis of unstructured data, automated generation of content and insights, and more effective discovery of latent patterns, all of which can be embedded into operational workflows to speed innovation, improve decision quality and personalize customer interactions. To convert this technical capacity into sustained strategic value, firms must also attend to data governance, deployment practices and organizational change management so that model outputs are reliable, actionable and aligned with business objectives.

Artificial intelligence subsumes a set of technical capabilities such as automatic speech recognition, computer vision for image analysis, machine-learning models and semantic search engines that enable systems to interpret, classify and retrieve multimodal information. These methods allow algorithms to discriminate between different sounds and visual patterns, extract meaningful features from raw audio and imagery, and link that content to relevant semantic concepts for downstream tasks. As a result, AI systems can perform functions ranging from transcribing and understanding spoken language to identifying objects or scenes in images, with the underlying machine-learning models continuously improving as they are exposed to more data (Panwar et al., 2021). However, the strategic value of AI lies not only in better projection of future changes but also in its ability to be fully integrated into managerial workflows. When the results of predictive models are placed through operational dashboards and follow clear decision-making rules, managers move from reactive problem solving to a mode of continuous, planned strategy correction. In this way, AI becomes both an information

amplifier and an execution tool—improving the timeliness and quality of strategic decisions and enabling the constant alignment of short-term actions with the organization's long-term goals.

The integration of artificial intelligence into organizational flows enables the automation of routine and repetitive activities that previously required human intervention. In management and marketing functions, this includes automated customer services, systematized data entry and processing, activity planning and implementation of segmented, personalized electronic campaigns. Automating these processes reduces operational costs, while freeing up employees' time for analytical, strategic and creative tasks that create greater added value for the organization. As a practical example, digital services companies use machine learning algorithms to automate content recommenders and personalize communications, which contributes to greater user engagement and better subscriber retention.

1.1. Personalized interaction with customers

AI enables communication and offers to be tailored to individual user preferences and behavior on a scale that is inaccessible to human operations. Analyzing data on preferences, purchase history and behavioral patterns enables the generation of targeted recommendations, dynamic offers and personalized customer experiences. Such hyper-personalization enhances message relevancy, elevates satisfaction levels, and fortifies consumer loyalty, resulting in improved retention rates and augmented customer relationship value. AI-driven personalization and content strategies significantly benefit small and medium-sized firms by augmenting their competitiveness in local marketplaces and transforming digital marketing methodologies (Mladenović et al., 2024). As an illustration, services that automatically compile music or content lists according to individual usage patterns demonstrate how continuous learning from user behavior leads to a better experience and differentiation in the market. Precision marketing is based on the systematic collection and analysis of consumer data—including personal information, search history, and content browsing patterns to derive preferences and perform precise segmentation of user groups. Based on these insights, modern computer technologies and algorithms are used to target and deliver highly personalized advertising messages that are more relevant to individual users. At the same time, such an approach enables the establishment of an effective system for two-way communication with customers, thereby improving the quality of customer service and deepening consumer engagement (O'Connor, 2019).

1.2. Strategic competitive advantage

When AI is integrated into an organization's strategic processes, it becomes the basis for creating sustainable competitive advantages. Algorithmic methods drive innovation in product development, enable more sophisticated analysis of user feedback, and support predictive maintenance and adaptive marketing approaches. Faster and more informed adaptation to changes in the market improves the company's positioning and facilitates the transformation of business models. In practical terms, companies that apply AI to analyze feedback, monitor device health, and dynamically adapt communications consolidate the image of a technology leader and create additional barriers to competition. Example: Tesla exemplifies the strategic application of AI beyond its autonomous driving technologies. By utilizing AI in customer feedback analysis, predictive maintenance, and adaptive marketing strategies, Tesla has reinforced its brand image as a cutting-edge technological leader and continues to set new standards in the automotive and energy industries.

2. Challenges and risks of Artificial Intelligence application

The application of artificial intelligence brings significant advantages, but also a number of serious challenges that organizations must clearly recognize and systematically solve in order for the implementation to be responsible and sustainable. Equivalent conclusions are obtained in research on AI applications in financial management, where obstacles and opportunities arise concurrently (Knežević & Milojević, 2024). The following sections break down the main risks and practical

implications that require attention when designing and managing AI solutions. Thanks to the application of artificial intelligence techniques and machine learning methods, we were able to efficiently process large data sets and formulate optimal, practically applicable action scenarios. These algorithmic approaches allowed us to systematically express alternative options, quantify their outcomes and select the one that provides the best ratio between feasibility and expected benefits (Maxwell et al., 2011).

2.1. Ethical issues

AI systems can embed and reproduce biases present in the data they are trained on, leading to unequal treatment of certain social groups. This resonates with broader discussions on intellectual property protection and regulatory implications of AI adoption in contemporary business contexts (Milošević, et al., 2023). In addition, the complexity of many models creates a "black box" problem it's hard to explain how a particular conclusion was reached, making accountability difficult and reducing user trust. Therefore, it is necessary to develop mechanisms for regular testing of models for bias, clear procedures for explaining decisions and channeling complaints, as well as ethical guidelines that follow the life cycle of the model. Nevertheless, the deployment of AI technologies necessitates rigorous attention to ethical principles, privacy safeguards and comprehensive data-security practices. Organizations should embed privacy-by-design and accountability mechanisms into system development, ensure lawful and transparent data handling, and implement technical and organizational measures to protect against unauthorized access and misuse. These safeguards are essential to preserve user trust and to mitigate the social and legal risks associated with AI applications (Dumitriu & Popescu, 2020).

2.2. Data privacy and security

Scaled collection and processing of personal and business data introduces serious privacy and security risks. Organizations must establish robust data protection approaches access policies, encryption, access controls, and incident response plans because failures to protect information lead to legal consequences and reputational damage. Also, data minimization and anonymity should be considered as standard practices when designing AI systems.

2.3. Impact on workforce and training policy

Automation of repetitive tasks can reduce the need for certain jobs, especially in administration and customer support, which requires strategic planning of human resources. When transitioning to AI-supported processes, organizations should plan retraining and additional training programs, redefine roles, and create opportunities for jobs that require creativity, critical thinking, and emotional intelligence.

2.4. Over reliance on technology

Overreliance on algorithmic outputs without critical human review can impair an organization's ability to recognize errors, ethical dilemmas, or changes in the model's operating context. Maintaining an adequate level of human oversight, verification procedures, and decision escalation mechanisms is critical to maintaining decision-making quality and organizational resilience.

3. Case studies of ai implementation

3.1. Amazon

Amazon has grown into one of the most influential global companies primarily due to its online commerce platform, but its growth strategy clearly goes beyond e-commerce. The company is systematically entering additional sectors — from food retail and streaming services to electric vehicle research to diversify revenue streams and expand its service ecosystem.

One of the key mechanisms of growth acceleration is the acquisition policy: by purchasing target companies, Amazon quickly gains access to new markets, technologies and content, thereby simultaneously enriching its offer and consolidating its position in already existing segments. These acquisitions are not limited to tactical elimination of competitors, but are often part of a broader integration strategy — Amazon incorporates the acquired competencies into its developed e-commerce framework and thus exponentially increases the value it provides to a large user base.

It is this ability to combine the organic development of the platform with acquisitions that allows the company to quickly scale new business directions, while maintaining an advantage in access to users, data and logistics capacities. As a result, Amazon is no longer just an online shopping service, but a complex corporate ecosystem whose further expansion stems from the synergy between technological infrastructure and strategic acquisitions (Wang, 2022).

Amazon is an example of an organization that has integrated artificial intelligence into nearly all of its core business functions, demonstrating how the comprehensive application of AI can transform both the operational and strategic aspects of business. The company recognized that AI serves not only to achieve operational efficiency, but also to improve the customer experience and scalable personalization of the offer.

First of all, personalization is one of the central applications of AI technologies at Amazon. Recommendation algorithms process vast amounts of data including users' search behavior, purchase history and time spent on individual products to generate precise and individualized suggestions. Such personalization increases the likelihood of purchase, raises the conversion rate and improves the overall user experience on the platform.

Second, a significant contribution of AI comes from the optimization of logistics and supply chain. By using robotics and predictive models to forecast demand, Amazon has redefined warehouse operations and delivery networks. Algorithms determine inventory needs, optimize product positioning within warehouse spaces, and plan delivery routes to minimize delivery time and costs. As a result, the company is able to offer same-day or next-day delivery in many regions, setting high standards in logistics.

Also, the development of voice assistants, presented through Alexa technology, enabled users to interact with services in natural language, making the purchase process simpler and more accessible. In addition, voice assistant interactions generate data on user behavior in real time, which further informs marketing and manufacturing decisions.

Overall, the strategic applications of AI at Amazon produce a mutually reinforcing cycle: better personalized offers increase customer satisfaction, optimized logistics improve service and efficiency, while collected data enables continuous improvement of the offer. With this, the company strengthened its market position and demonstrated how the integration of AI can become a key source of competitive advantage in the digital economy.

3.2. Netflix

The integration of artificial intelligence has significantly contributed to the transformation of the business model of one of the world's leading entertainment platforms. Through the application of advanced algorithms, the company is able to individualize the user experience, optimize content recommendations and direct decisions in the production process, thus creating a synergy between technical capabilities and strategic goals. One of the key strategies of the platform is an increasing reliance on its own original content, with a special focus on original documentary series, with an effort to secure the exclusive global right to distribute such titles. This achieves greater control over the catalog and the possibility of differentiating the offer, which contributes to retaining subscribers and strengthening the brand's position on international markets. Especially in the segment of documentary content, having exclusive rights enables the creation of unique value that is not easily replicated by competitors. (Iordache, et al., 2022)

The central element of that system is a recommendation mechanism. Analytical models process large amounts of data about user behavior — viewing history, ratings, searches and time spent within different genres — and based on patterns predict the content most likely to hold an individual subscriber's attention. This personalization leads to a significant increase in engagement and a decrease in user turnover, as users are constantly offered relevant content tailored to their preferences.

In addition to the recommendations themselves, data analysis becomes an instrument in the creation and selection of the original program. Systematic analysis of audience preferences and market trends enables the identification of formats and topics with a higher potential for success, reducing the risks of investing in new productions. In this way, the data serves not only to optimize distribution, but also to inform creative decisions, which is illustrated through cases of series that are supported based on insights from viewer behavior. One of Netflix's key strategies is reflected in its international expansion, realized through a coordinated set of tactical and operational measures. Those activities are planned and sequenced and aimed at expanding the presence of the service and the adaptability of the offer in different geographical environments, which enables faster realization of market reach and greater accessibility of content globally. (Lobato, et al., 2020)

Technological optimization of streaming represents another dimension of application: adaptive systems evaluate the available network bandwidth and automatically adjust the transmission quality to minimize playback interruptions and maintain a satisfactory user experience. Such mechanisms enable a consistent level of service and, under certain conditions, reduce user complaints related to performance.

In conclusion, the comprehensive use of AI has grown into a competitive advantage: personalization increases content relevance and user retention, an analytical approach improves content selection and planning, and technology solutions for material delivery guarantee the quality of the experience. As a result, the platform has evolved into an organization that simultaneously manages data and creative processes, shaping new standards in digital content consumption.

3.3. Tesla

Tesla, under the leadership of Elon Musk, has systematically implemented artificial intelligence across multiple business domains, resulting in disruptive changes in the automotive sector, energy and related technologies. Tesla offers a specific value proposition compared to conventional car manufacturers thanks to its direct sales model, which removes middlemen and simplifies the buying process. By doing so, the company makes transactions more accessible and efficient for customers, reducing logistics and marketing distribution costs and enabling faster and more consistent control over the shopping experience (Liu, 2022). The application of AI in the company is not limited to autonomous driving; it also includes areas such as marketing, customer support and product innovation, turning technology into a strategic element of business.

In the field of autonomous systems, Tesla is developing one of the most complex networks based on real-world driving data. The company's vehicles continuously collect massive amounts of sensor data, which is used to train and iteratively improve neural models. This feedback loop allows for the gradual improvement of algorithms and approaching higher levels of autonomy, with the possession of an extensive data set from real traffic situations being a key competitive advantage over approaches that rely predominantly on simulations.

In addition to self-driving systems, AI is also used at Tesla for predictive maintenance: analytical models monitor telemetry signals and sensor parameters in real time to detect patterns that precede failures. Such a proactive model reduces service costs, raises the level of safety and contributes to greater user satisfaction through fewer unexpected downtimes and faster interventions.

Finally, AI is also integrated into the company's marketing and communication processes. Instead of traditional broad campaigns, the company bases its marketing and production decisions on the analysis of customer feedback, sentiment and changes in the market, which allows for rapid adjustment of the

offer and preservation of a strong brand with lower advertising costs. Overall, the strategic application of AI across business functions enables Tesla to combine technological superiority with operational efficiency and customer focus, thereby achieving a sustainable competitive advantage. Tesla should focus its market activities towards the mass segments of middle and upper income, with special attention being paid to the regions of North America, Europe and Asia. Those geographies capture the bulk of current demand and represent the most promising market for near-term adoption due to relatively high levels of purchasing power and infrastructure maturity. Targeting these segments requires a synchronized strategy that combines product affordability, customized financial models, and service development that support customer experiences in diverse regulatory and cultural environments. This focus enables more efficient utilization of operating capacities and acceleration of the growth of electric vehicle acceptance in key market areas (Hardman et al., 2016).

4. Integration of AI into strategic planning processes

Integrated strategic planning is a critical function of an organization that is responsible for the establishment of long-term objectives, the allocation of resources, and the development of initiatives to maintain or enhance its competitive advantage. Recent research has confirmed that digital transformation and AI trends are also reshaping processes in the public sector, necessitating new governance and strategic planning models. The significance of AI integration is not limited to private companies (Orlandić, et al., 2024). In today's environment characterized by volatility, uncertainty, complexity and ambiguity (VUCA), the application of artificial intelligence in the process of strategic planning is becoming increasingly important for achieving sustainable business success. Building on a balanced assessment and in light of rapid developments in artificial intelligence, this study seeks to delineate the defining features of strategic planning that are effective in VUCA environments — those marked by volatility, uncertainty, complexity and ambiguity. The objective is to identify planning practices, decision-making routines and organizational capabilities that enable firms to sense emerging signals, evaluate alternative futures and adapt actions quickly and coherently. Emphasis is placed on mechanisms that combine predictive analytics with scenario testing, institutionalized learning cycles, and governance arrangements that preserve managerial judgment while exploiting AI-driven insights. Ultimately, the aim is to specify how strategy processes must evolve so organizations can sustain competitive advantage under the dynamic conditions that characterize contemporary global markets.

According to Baran and Wozny (2020), five key trends will influence the intensity of the VUCA environment in the coming years:

1. Rapid technological progress and continuous innovation, which accelerate changes in business models and competitive capabilities;
2. Economic and financial instability, including market fluctuations, trade imbalances and liquidity pressures;
3. Environmental and social challenges, such as climate change and social inequalities, which redefine stakeholder expectations and regulatory priorities;
4. Geopolitical tensions, regulatory changes and security issues, which create disruptions in supply chains and the legal framework of business;
5. Workforce dynamics—changes in employment structure, worker expectations, and demands for new skills—that affect the availability of competencies and the ability of organizations to adapt.

These factors act simultaneously and often reinforce each other, thus fostering the complexity and unpredictability of the business environment, so strategic planning must be designed to recognize and respond to each of these dimensions.

AI contributes to planning primarily through improved ability to predict future trends through predictive analytics. While traditional approaches often relied on historical data and subjective judgments, leading to reactive and sometimes inaccurate decisions, data-driven models enable the

analysis of real-time market signals, customer behavior and macroeconomic trends. Based on these insights, organizations can anticipate change instead of just reacting to it, giving them a significant strategic advantage.

AI-powered scenario modeling tools further improve the quality of planning: they enable the simulation of various hypothetical development paths from economic downturns to technological breakthroughs or regulatory changes and quantify their potential effects on business operations. Methodological parallels can be observed in academic staff selection, where multi-criteria decision-making (MCDM) approaches demonstrate the strategic value of AI-supported evaluation frameworks (Popović, et al., 2024).

Thus, strategic documents become more flexible and resistant to unexpected shocks because they are created on the basis of tested assumptions and alternative outcomes.

Another advantage is the early detection of market opportunities: continuous data mining and trend analysis often reveal early, poorly expressed consumer needs, niches or growing geographic segments, which allows organizations to design proactive strategies in time and gain a first-mover advantage in the market. In addition, AI-powered decision support systems also enable rapid strategic corrections — when external conditions change, the system can immediately process the new input and suggest specific adjustments.

Finally, the introduction of AI into strategic planning also fosters an evidence-based culture: decision-making is increasingly based on empirical insights and current analysis instead of mere intuition or outdated data. Such a shift increases accountability, clarity of strategic goals, and the organization's capacity for learning and adaptation. In short, the application of artificial intelligence in strategic planning not only improves forecast accuracy and scenario readiness, but also empowers organizations to act more agile and predictive in unpredictable conditions.

5. Ethical frameworks for AI usage in marketing

The integration of artificial intelligence into marketing practices necessitates the establishment of ethical frameworks that are both applicable and precisely defined. The capacity of AI systems to analyze, predict, and influence consumer behavior entails obligations that organizations must actively assume and oversee. Recent bibliometric analyses have verified that ethical and security considerations are among the most extensively researched domains in AI research (Ilić et al., 2024).

Marketing and advertising increasingly raise ethical and social dilemmas particularly around data security, privacy, algorithmic transparency, and bias that reflects broader social inequalities. A key question is whether existing ethical frameworks, regulations and corporate practices can keep up with the rapid development of data-driven techniques. The solution requires an integrated approach: technical solutions for privacy protection and explainability, organizational policies and oversight, and regulatory compliance to align data use with accountability and consumer trust (Voeneky et al., 2022).

First, the issue of user privacy is a central ethical challenge. Models that support personalization often work on the basis of extensive profiles of individuals, which involves the collection, storage and processing of large amounts of personal data. Without clear data protection procedures and compliance with legal frameworks, there is a real risk of privacy violations, legal consequences and loss of public trust. Therefore, it is necessary to establish strict standards for data collection, the principle of least necessary processing and mechanisms to ensure consent and transparency towards users.

Second, the transparency of algorithmic decisions should become a normative design element of AI systems in marketing. Many complex models function as "black boxes", which makes it difficult to understand the criteria on the basis of which certain recommendations or target group selections were made. In a marketing context, such non-transparency can result in unfair outcomes — e.g. by unexplained exclusion of groups of users or hidden selection of messages. Ethics applied to AI

recommends the introduction of mechanisms for explainability and documentation of decisions, to enable users and regulators to monitor and evaluate the performance of the system.

Third, there is a moral obligation to prevent manipulative practices that exploit consumer vulnerabilities. Deep personalization techniques, if used without restraint, can instrumentalize the emotional or cognitive weaknesses of individuals for short-term profit. An ethical approach to AI-based marketing requires defining the boundaries of application rules that place user welfare and respect for autonomy ahead of aggressive tactics aimed at impulse consumption.

Fourth, accountability for biases built into models must not be neglected. If the training data is contaminated with historical biases, the algorithms may inadvertently reproduce and reinforce injustices in segmentation or targeting. Regular ethical audits, anti-bias testing, and corrective actions must be an integral part of the model's lifecycle to ensure fairness and inclusiveness in communications and offerings.

In practice, organizations should develop internal policies that include key elements of the ethical use of AI in marketing:

1. Consistent standards for data privacy and security;
2. Measures for transparent explanation of algorithmic decisions;
3. Rules that prevent manipulative marketing practices;
4. Regular bias assessments and independent ethical reviews.

Organizations are increasingly adopting a set of proven practices aimed at reducing the negative effects of ethical issues related to the application of artificial intelligence, with the aim of preserving consumer trust and protecting brand reputation. Such measures include the establishment of clear and accessible privacy policies that specify the scope and purpose of data processing, transparent communication of how data is used to end users, and active technical and organizational interventions to detect and correct bias within the model. Involving consumers in the processes concerning their data through informed consent mechanisms, the ability to manage their own data and feedback channels is also key to ensure accountability and social acceptability of AI-solutions. Implementation of these practices requires continuous auditing, internal education, and transparent monitoring and response procedures (Gunning et al., 2019).

The General Data Protection Regulation (GDPR) sets out strict principles for the processing of personal data transparency, informed consent and the "right to be forgotten" and introduces the obligation of "privacy by design and by default." For AI systems, this means that privacy protection must be integrated from the beginning of development: minimization of data collection, technical and organizational access control, and mechanisms that allow users to exercise their rights. In other words, GDPR compliance should be an integral part of the lifecycle of an AI solution, not an afterthought (Voigt et al., 2020).

Finally, an ethical approach to AI-marketing is not only a liability in terms of compliance and risk avoidance building consumer trust through the responsible application of technology is also a strategic advantage. Brands that consistently demonstrate that they respect privacy, explain decisions and protect users from manipulation create a more stable relationship with customers, strengthen reputation and reduce exposure to regulatory and reputational risks.

Conclusion

Artificial intelligence offers transformative potential for strategic management and marketing by supplying richer, faster and more granular insights that enhance decision quality, streamline operations, deepen customer engagement and stimulate innovation. When harnessed appropriately, AI can shift organizations from reactive to anticipatory postures, enabling more precise forecasting, scenario testing and real-time adaptation of strategic choices.

At the same time, the deployment of AI creates material risks that require a deliberate managerial response: ethical dilemmas, privacy vulnerabilities, workforce displacement pressures and the danger of excessive dependence on automated outputs. Left unaddressed, these risks can undermine legitimacy, introduce systemic bias into decision processes and weaken organizational resilience.

Responsible adoption therefore demands a balanced program of governance: transparent algorithmic practices, robust data-protection and security measures, and sustained investment in people through reskilling and role redesign so that human judgment remains central where it matters most. Equally important are institutional mechanisms for continuous monitoring, explanation and corrective intervention, which preserve accountability and enable organizations to learn from model-driven actions.

Ultimately, the long-term advantage will accrue to entities that pair technological capability with ethical stewardship and managerial oversight. Organizations that embed AI within a framework of clear principles, operational controls and human-centered governance will be better positioned to convert analytical power into sustainable competitive value in an increasingly digital economy.

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CONFERENCE PAPERS

Challenges of Talent Retention in the Healthcare Sector: Unveiling its Realities and Implications on the Sustainability of Healthcare Institutions in Africa

Izazovi zadržavanja talenata u zdravstvenom sektoru: Otkrivanje stvarnosti i implikacija na održivost zdravstvenih ustanova u Africi

Abiodun Peter Abogunrin[1], Yusuf Olamitunji Yisa[2]

[1]*University of Ilorin, Faculty of Management Sciences, Department of Industrial Relations and Personnel Management, Ilorin, Nigeria, abogunrin.ap@unilorin.edu.ng*
[2]*University of Ilorin, Faculty of Management Sciences, Department of Industrial Relations and Personnel Management, Ilorin, Nigeria, 17/66rp125@students.unilotin.edu.ng*

Abstract: *The retention of skilled healthcare professionals is a pressing challenge across Africa, affecting the performance and long-term sustainability of care institutions. This study investigates the multifaceted challenges of talent retention within African healthcare sector, using Nigeria as a representative case. Employing a quantitative research design, data was collected from a population of 3,921 employees across three major healthcare institutions in Nigeria: the National Orthopaedic Hospital, Lagos University Teaching Hospital, and One Health Medical Centre. A stratified sampling technique yielded 350 valid responses via a structured questionnaire. Descriptive and inferential statistical analyses reveal persistent retention issues, particularly in areas of employee compensation, career development opportunities, and work-life balance. Regression analysis indicates that approximately 63% of the variance in healthcare sustainability can be attributed to the effectiveness of talent retention strategies. These findings underscore the urgency of implementing robust retention frameworks, not only in Nigeria but across African health systems facing similar structural constraints.*
Keywords: *Talent, employee retention, organizational sustainability, African health systems and care sector.*

Apstrakt: *Zadržavanje kvalifikovanih zdravstvenih radnika predstavlja ozbiljan izazov širom Afrike, utičući na efikasnost i dugoročnu održivost zdravstvenih ustanova. Ova studija istražuje višeslojne izazove u vezi sa zadržavanjem talenata u afričkom zdravstvenom sektoru, koristeći Nigeriju kao reprezentativan slučaj. Kvantitativnim istraživačkim pristupom, podaci su prikupljeni od populacije od 3.921 zaposlenog u tri značajne zdravstvene ustanove u Nigeriji: Nacionalna ortopedska bolnica, Univerzitetska bolnica u Lagosu i One Health Medical Centar. Stratifikovanim uzorkovanjem dobijeno je 350 validnih odgovora putem strukturisanog upitnika. Deskriptivna i inferencijalna statistička analiza ukazuje na postojane probleme u zadržavanju kadrova, naročito u oblastima kompenzacije zaposlenih, mogućnosti za razvoj karijere i ravnoteže između posla i privatnog života. Regresiona analiza pokazuje da se približno 63% varijacije u održivosti zdravstvenih ustanova može objasniti efikasnošću strategija zadržavanja kadrova. Ovi nalazi ističu hitnost primene čvrstih okvira za zadržavanje kadrova, ne samo u Nigeriji već i širom afričkih zdravstvenih sistema koji se suočavaju sa sličnim strukturnim izazovima.*
Ključne reči: *Talenat, zadržavanje zaposlenih, održivost organizacije, afrički zdravstveni sistemi, zdravstveni sektor.*

Introduction

One of the aspirations of businesses in this twenty-first century is to attract a high level of talented workforce, while retaining over a long period of time (Sorn et al., 2023). However, the prevailing scarcity of talents, as well as the decreasing pool for skilled professionals have made retention a challenging yet critical human resources function today. Following a recent Wall Street Journal article in 2024, nearly 42% of successful business owners reported difficulty in filling key positions due to talent shortages. Meanwhile, employees on other hand often cite low career opportunity and poor labor concerns as key reasons for departures (WSJ, 2024). In the quest for survival, corporate managers are hereby challenged to increasingly implement effective strategies for attracting and retaining capable talents over a long period of time.

Talent retention can be viewed as a strategic HR approach aimed at sustaining the commitment of skilled and valuable workers over an extended period. It involves the managerial process of providing a conducive work environment that caters to individual professional growth while meeting employees' needs and expectations. As Yisa et al. (2024) noted, adopting an effective retention strategy is no longer a choice rather a critical necessity. With about 72 million workers (comprising 47% of global workforce) considers to leave their jobs annually and an increasing number of roles becoming hard-to-fill (Okoroafor et al., 2023: Smith, 2024), firms across the globe are facing mounting pressure to create compelling strategies for employees to stay, most especially in critical sectors like the healthcare.

Lacurci (2025) identified the healthcare as a crucial pillar safeguarding lives and wellbeing of the people. Despite its crucial significance, reports have overtime shown that the sector globally has continued to face an escalating challenge of attrition with skilled individual's switches to either another country or different career entirely. Although, Sabitova et al. (2019) affirmed that healthcare is a strenuous and highly demanding professions, which in spite of its esteemed status, workers often voiced dissatisfaction due to the overwhelming work demands and limited personal and family time. However, the exodus of poor talent retention has created a vicious cycle in Nigeria, where more and more health workers are seeking more departures. Barely within one year, not less than 57,000 highly skilled and trained Nigerian doctors have sought authorization in developing countries like Germany, France, USA and particularly UK, a talent loss implication that Orhungul et al. (2023) identified as a threat not only to care institutions, but entire national care sustainability at large.

More concerning is the evidence that this labor challenge is not allied to only one country, but affecting in nearly all nations of the world today. In many developing societies, particularly in Africa, the effectiveness of talent retention has overtime deteriorated owing to issues like economic instability, inadequate remuneration, poor working conditions, and a lack of resources to support healthcare professionals (Yisa et al., 2024). Consequential to this, the World Health Organization (WHO) lamented that the sub-Saharan Africa accounts for about 25% of the global disease burden, yet has only 3% of the world's healthcare workforce, underscoring the severity of the retention crisis in the region. This talent deficit not only compromises the quality of healthcare services but also threatens the broader health outcomes of populations dependent on these overburdened systems.

Dzinamarira and Musuka (2021) cautioned that the challenge is not only in underdeveloped or developing economies but also in developed societies like the UK, among others, hence making retention a recent issue of global concern in the healthcare sector. In lieu of these, talent retention has therefore become as a critical issue in the global business across industries in the world. Ultimately, organizations within the healthcare sector must prioritize the development of innovative and comprehensive talent retention strategies, focused on improving working conditions, offering competitive compensation, and fostering work culture. Towards this, the present research is undertaken to examine the realities behind talent retention in Africa, and its impacts on healthcare sustainability in Nigeria as a case study. It is in the interest of these that this present study seeks to provide answers to the underlying research questions that follows;

a. How effective are the strategies for integrating talents into African healthcare workers?

b. To what extent does these strategies aid in retaining capable talents in Africa?

c. What are the challenges affecting talent retention practices in African care sector?

1. Literature review

Retention has long been conceptualized as an organizational effort to keep workers for a long period of time. However, Krishnamoorthy and Aisha (2022) defined talent retention as the strategic process of maintaining and preventing highly skilled and competent workers from quitting employment in an organization. Victoria et al. (2024), from a management perspective, argued that talent retention is an integral process of enhancing an organization's most skilled workers through policies and practices that encourage their desire to remain over a long time frame. On this note, Vui-Yee and Paggy (2020) discussed that the emphasis of talent retention is largely on two main factors: keeping special workers and ensuring their stay over a long time frame. Although Tang (2023) argued that retention is far beyond merely keeping workers, as it encompasses series of interconnected process designed to ensure that talented workers are not only integrated into the organization effectively but also motivated to stay over a long period of time (Yisa et al., 2024).

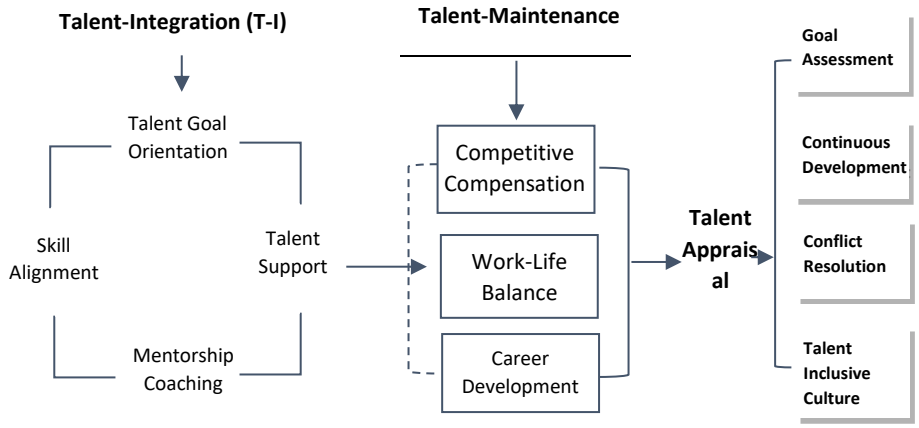


Figure 1. Processes involved in talent retention
Source: Adapted from Yisa et al. (2024), Singh (2019) and Oyekale (2017)

The retention of talents involves three critical stages which include talent infusion, maintenance and evaluation which individually encompassed a range of practices that align worker's capabilities and gifts with the goals and objectives of an organization while fostering a supportive environment. Evidenced from Twineamatsiko et al. (2023) and Opio et al. (2022), each phase of talent retention addresses critical aspects of employee engagement, from aligning goals and skills to providing growth opportunities and fostering an inclusive culture. Unlike other industries, healthcare depends heavily on human capital due to the specialized nature of its services, making the retention of skilled workers essential for maintaining service quality and patient outcomes (Agba et al., 2020).

Evidence in extant literatures have shown that competition and scarcity of skilled professionals renders attracting and retaining capable and gifted employees a strenuous task for every nation (Wassem et al., 2019). Sadly, Nigeria faces an acute challenge in this regard, due to various factors such as persistent brain drain, poor organizational culture among other factors limiting the success of talent retention in the country. In Nigeria today, brain drain remains a significant concern, with many talented professionals seeking better prospects abroad due to economic instability, lack of adequate infrastructure, and limited professional development programs (Agba et al., 2020). The emigration of skilled workers has intensified the talent gap, making it increasingly difficult for organizations to sustain a stable and competent workforce. Data from the NBS, (2020) revealed that up to 21.7million of over 80millions in the Nigeria labor market are unemployed and inexperienced. Even those with employment, over 22 million of them are relatively underemployed.

Meanwhile, over the years, these rates keep increasing with no substantial attempt to alleviate its damage (Zanak et al., 2024). Thus, Nigeria labor market became crowded with incapable and low-skilled individuals (Jeyaseeli, 2022). This alone threatens the easy exploration and development of talented by corporate organizations talk less of retaining them. Retention and sustainability has, in recent years, become one of the most widely studied and examined concepts in the fields of management and labor economics. As organizations increasingly recognize the crucial role that talent plays in sustaining competitive advantage, scholars and experts across the globe have explored its impact and challenges (Xu and Liu, 2020; Agba et al., 2020). Despite a broad consensus on the significance of talent retention, there remains considerable debate on the mechanisms by which organizations can successfully retain top talent and the impact of evolving market conditions on retention strategies.

From Singh (2019) observation, talent retention is particularly crucial in fields like telecommunications, health and IT where highly skilled professionals are needed to manage the complexities of modern technology and education systems. Sharing similar view, Tang (2023) conducted an operational performance analysis in Hong Kong and found nearly 47% of small and medium enterprises (SMEs) success relies on the ability of firms to retain their most capable workforce. However, the majority of studies on talent retention, specifically in Nigerian predominantly focused on either examining retention as a consequence or its rationale in other sectors like education (Laolu, 2019), banking (Okoroafor et al., 2023) and tourism (Dechawatanapaisal, 2018). Little is evident about its significance in the health sector. Also, while private sector received substantial attention, the public healthcare sector which is a crucial pillar of the country has been neglected. In order to fill this gap, the present research seeks to examine the relative impact of talent retention on the corporate sustainability of healthcare institutions in both the private and public sector.

2. Methodology

In order to achieve the aim of this research, a quantitative method was utilized which centered on the philosophical position of resource based view (RBV) by Wernerfelt (1984) and Barney (1991). The population for the study comprised of the entire three thousand, nine hundred and twenty-one (3,921) staff operating in the three most prominent healthcare services providers in Nigeria. Although the scope of the research is geographically limited to Nigeria, the findings are intended to offer broader insights into talent retention challenges across African healthcare systems, particularly in similarly structured economies. The focused institutions include 2,300 staff members at Lagos University Teaching Hospital (LUTH), 1,257 staff members at the National Orthopaedic Hospital, Igbobi, and 366 staff at One Health Medical, a world-class private healthcare provider with a presence in Sub-Saharan Africa, including Nigeria and Egypt. Krejcie and Morgan formula was used to ascertain the sample size at 350 with the formula as follows;

$$s = \frac{X^2 \mathrm{NP}(1-\mathrm{P})}{\mathrm{e}^2(\mathrm{N}-1)+\mathrm{X}^2\mathrm{P}(1-\mathrm{P})} \quad (1)$$

$$\mathrm{s} = \frac{3.841 \text{ x } 3{,}921 \text{ x } 0.5\ (1-0.5)}{0.05^2(3{,}921\ -1)+3.841 \text{ x } 0.5\ (1-0.5)} \quad (2)$$

$$\mathrm{s} = \frac{3{,}765.14025}{10.76025} \quad (3)$$

$$\mathrm{s}\ = \frac{3{,}765.14025}{10.76025} = 349.9119 \quad (4)$$

This suggests that selecting 350 respondents from entire population of staff members in the Nigerian care sector is considered sufficient and representative of the total population in the study area (Creswell & Clark, 2017). Considering the multi-case studies nature of this research, a proportionate stratified sampling technique was utilized presented in table 1 as follows.

Table 1. Distribution of sample size for respondents across selected departments/units

Departments/Units	Percentage of Population	Lagos University Teaching	Igbobi National Orthopaedic	One Health Medical
Surgical Specialties	18.5%	43	18	4
Emergency and Care	15.2%	21	26	6
Medical Specialties	15.5%	36	14	4
Diagnostic and Lab	13.4%	28	15	3
Dental Services	2.9%	8	0	2
Oncology and Care	3.1%	6	3	2
Non-Clinical Units	31.4%	63	35	11
(%) of Population	**100**	**58.66**	**32.01**	**9.33**
Total Sample Size	**350**	**205**	**112**	**33**

Source: Authors Compilation (2025)

In this study, sample size was determined using a proportionate stratified sampling technique, which ensures that the distribution of the questionnaires across departments reflects the size of each retrospective to their population. The sampled respondents include various categories of health professionals such as resident doctors, pharmacists, nurses, physiotherapists, and medical laboratory scientists. Data was collected through the primary source using a well-structured questionnaire with 20 items on a five (5) points Likert scale. Data in the study were compiled and analysed through the Microsoft excel and statistical packages for social sciences (SPSS) presented in the demographic analysis, realities of talent retention challenges as well as the hypothesis testing its impact on corporate performance of the healthcare sector.

3. Presentation of results and discussions of findings

A total of 297 questionnaires was utilized for this study indicating (84%) response rate. The analysis of data is sectioned into two phases which includes the descriptive analysis of the research questions presented as follows;

Research Question 1: *How effective are the strategies for integrating talents into the Nigerian health workers?*

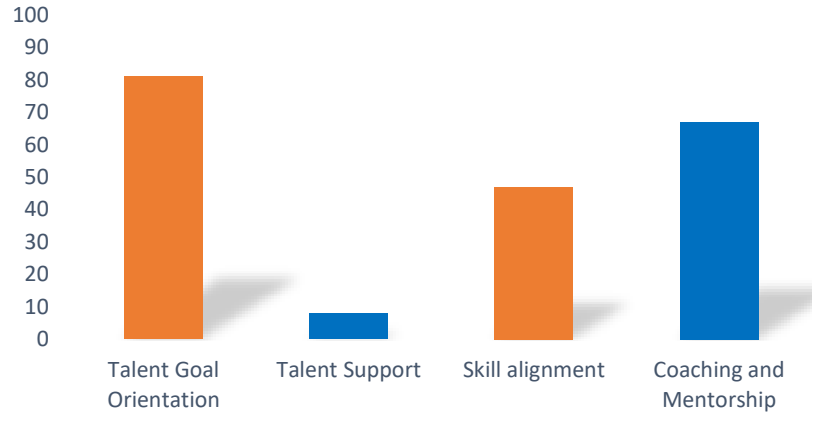


Figure 2. Effectiveness of talent integration in the Nigeria healthcare workers
Source: Survey result, 2025

Results from Figure 2 revealed the extent and effectiveness of talent integration process into the care workers in the Nigerian health sector. The findings indicate that while talent orientation and skill alignment remain critical global challenges (Croke & Ogbuoji, 2023), a majority of Nigerian healthcare workers acknowledge the efficacy of talent orientation ($\mu = 0.81$) and the implementation of skill alignment ($\mu = 0.47$) in the sector. Additionally, the presence of structured career pathways and

onboarding processes (μ = 0.67) suggests that Nigerian healthcare professionals are adequately trained and well-developed in terms of skills and expertise, enabling them to perform effectively in their roles.

However, the low talent support outcome (μ = 0.08) underscores a significant weakness in the system. Despite the strong orientation and coaching mechanisms in place, many Nigerian healthcare workers lack essential institutional support, resources, and amenities necessary for effective service delivery. This finding aligns with existing research by Oyero (2023), which highlights that a wide range of healthcare providers across West Africa suffer from poor institutional backing, inadequate infrastructure, and a lack of essential facilities. According to Nigeria Medical Association NMA (2021), this issue has statistically significant implications, directly affecting employee morale and, consequently, their retention in the sector most especially in Nigeria. Similarly, Okech et al. (2021) emphasized that many private and public healthcare institutions in Nigeria fail to provide adequate resources to enhance employee well-being, contributing to high turnover rates among professionals seeking better working conditions elsewhere.

For instance, in Nigeria, Osaretin and Eddy (2012) documented how the brain drain of medical professionals has led to an overburdened healthcare workforce, longer patient wait times, and declining quality of care. Likewise, in the northern rural area in the country, Oladigbolu et al. (2018) findings unveiled the extent of persistent understaffing in hospitals due to poor working conditions has resulted in increased patient mortality rates and reduced healthcare efficiency. In spite of the challenge however, the findings from this study affirm that talent integration remains a relatively effective process in Nigerian healthcare practices. However, talent support remains the weakest link in the retention strategy, posing a serious threat to workforce sustainability in the sector.

Research Question 2*: To what extent does these strategies aid in retaining capable talents in Nigeria?*

Table 2. Extent of talent retention in Nigeria

	SD	D	U	A	SA	M	Std. Dev
Our compensation packages fails to adequately influence our will to remain as care workers	4 1.3%	10 3.4%	16 5.4%	62 20.9%	205 69.0%	4.53	.850
Given the current state of Nigerian health sector, I will honestly prefer a different industry or profession.	7 2.4%	8 2.7%	4 1.3%	138 46.5%	140 47.1%	4.33	.834
In Nigeria, many of us earn less than $200, making it difficult to sustain a comfortable living in Nigeria.	133 44.8%	104 35.0%	8 2.7%	28 9.4%	24 8.1%	2.01	1.25
I perceive that the government does not prioritize the welfare of the healthcare workers	4 1.3%	8 2.7%	4 1.3%	40 13.5%	241 81.1%	4.69	.752
Allowances and benefits provided to workers are often weak and fail to meet our basic needs.	168 56.6%	52 17.5%	9 3.0%	48 16.2%	20 6.7%	1.99	1.36

Source: Survey result, 2025

The results revealed talent retention as a largely ineffective practice in Nigeria's healthcare sector, particularly in the areas of competitive compensation, work-life balance, and career development. From the findings, a significant majority (69%) of healthcare workers believe that their salaries do not adequately reflect the risks and responsibilities of their roles. While a few respondents affirmed that their allowances are sufficient to meet their basic needs, a large percentage of healthcare workers expressed dissatisfaction, reinforcing Nwogbe and Haliso (2020) argument that inadequate financial incentives are a major factor contributing to poor retention rates in Nigeria. Consequently, about 47% of the sampled workers expressed a strong desire to leave the healthcare sector entirely in search of better-paying opportunities elsewhere. This finding aligns with Adebayo and Akinyemi (2022) research on the push factors driving Nigerian healthcare workers abroad.

Similarly, Croke and Osondu (2023) findings highlighted a significant correlation between low remuneration and growing brain drain in Nigeria healthcare sector. The reality of this according to the Nigerian Medical Association (NMA, 2023), is evident in the migration of over 1,200 locally trained and

skilled medical practitioners to the UK, Canada, and Saudi Arabia, where compensation structures are more attractive. Beyond compensation concerns, the findings uncover the heavy workloads and insufficient staffing in Nigerian hospitals as major work-life balance challenges. Although, less prominent in the public sector, Asakitikpi (2019) survey on private care workers revealed an excessive working hours with low flexibility, negatively affecting job satisfaction and employee well-being. The absence of structured leave policies coupled with the increasing workforce depletion evidence maintaining talents a heralding challenge in the Nigeria care sector.

In furtherance, the result also showed that 81% of the sampled workers feel there are limited opportunities for skill enhancement, specialization, or advanced training in Nigeria, further worsening retention issues. In a similar vein, Ogaboh et al. (2020) reveal that career development is a major shortfall in Nigeria's healthcare sector, where the lack of structured career progression pathways discourages long-term commitment. The implications of these talent maintenance challenges on Nigeria's healthcare sustainability are profound. Yisa et al. (2024) report that the inability to retain skilled professionals due to low compensation, high workloads, and limited career growth opportunities creates a cycle of inefficiency. As more professionals exit the sector, hospitals struggle with understaffing, leading to increased pressure on the remaining workforce, ultimately affecting service delivery and patient outcomes (Okech et al., 2021).

***Research Question 3**: What challenges hinder the effective evaluation of talent in Nigeria's healthcare sector?*

Table 3. Challenges of talent retention in Nigeria

	SD	D	U	A	SA	M	Std. Dev
In the care sector, there are limited concerns for individual assessments for growth and specialization.	36 12.1%	144 48.5%	8 2.7%	73 24.6%	36 12.1%	2.7	1.28
There is a long working hours in our workplace which has remain unreview till date affecting our social lives.	-	-	-	229 77.1%	68 22.9%	4.50	.527
I feel less supported or regarded in my pursuit for skill enhancement.	4 1.3%	8 2.7%	4 1.3%	40 13.5%	241 81.1%	4.3	.822
Healthcare workers in Nigeria find it challenging to balance professional with personal life demands.	4 1.3%	8 2.7%	4 1.3%	40 13.5%	241 81.1%	4.78	.527
The demanding nature of care jobs often enhances burnout and poor mental health among workers.	4 1.3%	4 1.3%	8 2.7%	76 25.6%	205 69%	4.57	.755

Source: Survey result, 2025

The result from the descriptive analysis emphasizes the key issues related to talent assessments and the well-being of healthcare workers in Nigeria. Focusing on the impact of work-life balance, the finding revealed that the overwhelming majority (82.5%) of respondents agree that healthcare workers struggle to balance their professional responsibilities with personal life demands. This struggle has been overly ignored which Oyero (2023) identified as influencing factors contributing to stress, job dissatisfaction, and mental health challenges, which are further exacerbated by long working hours, as shown by 77.1% of respondents. Particularly, the lack of individual assessments for growth and specialization (36%) points to missed opportunities for career development, which could contribute to burnout. In similar opinion, Yisa et al. (2024) reiterated that care workers who feel unsupported in their pursuit of skill enhancement (81.1% reporting feeling less supported) often experience frustration and reduced motivation, further affecting retention and job performance.

Moreover, the demanding nature of care jobs, along with the long hours and inadequate support for skill enhancement becomes key areas to address through talent assessments in the findings. These assessments as Uzomba et al. (2021) noted should not only evaluate performance but also take into account personal well-being, career development, and work-life balance. Implementing individualized development plans and offering flexible working arrangements could potentially reduce burnout and improve retention, leading to better long-term sustainability of healthcare institutions in Nigeria. This insight suggests a need for more comprehensive talent assessments that address both professional

growth and personal well-being, ensuring that healthcare workers are adequately supported to thrive in their roles.

Research Hypothesis: *Talent retention have a significant influence on healthcare sustainability in Nigeria?*

Table 4. Multiple regression statistics

Multiple R	0.822009
R Square	0.675699
Adjusted R Square	0.671257
Standard Error	15.84945
Observations	297

ANOVA

	df	SS	MS	F	Significance F
Regression	4	152833.0088	38208.2522	152.0998	0.0000
Residual	292	73351.9070	251.2052		
Total	296	226184.9158			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	17.451	2.012	8.673	0.000	13.491	21.411
Adequate Compensation	0.015	0.002	6.063	0.000	0.010	0.019
Career Development	0.029	0.003	8.323	0.000	0.022	0.036
Work Life Balance	0.000	0.000	-7.562	0.000	-0.001	0.000

Source: Survey result, 2025

From the multiple regression model above, the result shows that talent retention factors have a significant relationship with corporate sustainability in the healthcare sector. Specifically, the Multiple R coefficient (0.822) reveals a strong level of relationship between talent retention strategies and corporate sustainability. The Regression statistics ($R^2 = 0.6757$) indicate that approximately 67.6% of the variability in the dependent variable (corporate sustainability) can be explained by the independent variables (adequate compensation, career development, employee recognition, and work-life balance). Meanwhile, the remaining 32.4% is explained by other variables not highlighted in the study. The coefficient result therefore formulated the following regression formula, which is expressed as follows:

$$CS = 17.451 + 0.015AC + 0.029CD - 0.000WLB$$

The coefficients indicate the impact of each factor on corporate sustainability in the healthcare sector. Adequate compensation shows a positive effect (0.015), suggesting that as compensation improves, corporate sustainability also increases. Similarly, career development has the strongest positive effect (0.029), implying that providing growth opportunities significantly enhances sustainability. Conversely, work-life balance has a negative effect (-0.000), indicating that practices related to work-life balance may not contribute positively to corporate sustainability in Nigerian healthcare context.

Decision Rule: In lieu of above results, the null hypothesis (H_0) is hereby rejected since the P-values (0.000) are less than the significance level of 0.05. Therefore, the alternative hypothesis is accepted, indicating a significant relationship between talent retention strategies and corporate sustainability in the healthcare sector. This highlights the importance of management adopting effective compensation, career development, and employee recognition strategies to strengthen sustainable organizational performance.

Conclusion

This research explored the challenges of talent retention in Nigeria's healthcare sector alongside its relative impacts on the sustainability of healthcare firms in the country. Findings from the study revealed a significant concern that while talent integration and appraisal practices are effective within the sector, critical retention practices such as adequate compensation, career development, and work-life balance are severely lacking. The results imply that although healthcare workers are well-trained and skilled in Nigeria, the necessary frameworks to retain them and foster corporate growth are insufficient. Furthermore, the regression highlighted a compelling connection between talent retention and corporate sustainability, emphasizing that neglecting the maintenance of skilled employees threatens the very foundation of Nigeria's healthcare system. By implication, if these retention challenges remain left addressed, the sustainability of healthcare in Nigeria is at serious risk, potentially undermining the quality of care and the overall effectiveness of the sector.

Practical recommendations

In lieu of the research findings, immediate action is crucial to ensure a sustainable and efficient healthcare system in Nigeria some of which include;

a. Administrators and managers in the Nigerian healthcare sector should engage strategies that prioritize the welfare of skilled professionals through incorporating their professional growth into organizational objectives.

b. Also, the government are advised to review the compensation framework of healthcare sector considering competitive pay and performance-based incentives for highly skilled workers.

c. The Human Resources managers should as well implement recognition programs to reward outstanding contributions of skilled workers in the sector.

d. Care workers should as well engage in continuous professional development through specialized training and certifications which will aid their contributions in the sector.

e. Policymakers and healthcare administrators should enforce policies that support work-life balance for healthcare workers. This should include flexible working hours, mental health support programs, and workload management strategies.

These measures will not only improve operational efficiency, but also reduce burnout, and enhance overall patient care outcomes in the Nigerian healthcare sector.

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Artificial Intelligence Used in the Economy of the European Union

Primena veštačke inteligencije u ekonomiji Evropske unije

Mihaela-Simona Galea[1], Giaina-Violeta Dragotă[2]

[1]"Tibiscus" University of Timisoara, Timișoara, România, mihagalea21@gmail.com
[2]"Tibiscus" University of Timisoara, Timișoara, România, gianina_dragota@yahoo.com

Abstract: *Artificial Intelligence (AI) is one of the most transformative technologies of the 21st century, with the potential to fundamentally change the way we live, work, and interact. The rapid development in the field of artificial intelligence opens significant opportunities for innovation, productivity, and economic growth, but also raises complex challenges related to ethics, security, and fundamental rights. AI solutions could be implemented in the production process, from research and development to production and distribution. AI can transform various sectors and functions, thus helping to develop the economy and productivity, automatically leading to GDP growth.*
Keywords: *Artificial Intelligence, economy, productivity, European Union.*

Apstrakt: *Veštačka inteligencija (VI) jedna je od tehnologija 21. veka koja ima najveću transformativnu moć, sa potencijalom da fundamentalno izmeni način života i komuniciranja. Ubrzani razvoj u oblasti veštačke inteligencije stvara značajne mogućnosti za kreiranje inovacija, porast produktivnosti i ekonomski razvoj, ali takođe sobom nosi i izazove u pogledu etike, sigurnosti i osnovnih prava. VI rešenja mogu biti implementirana u proizvodnom procesu, od istraživanja i razvoja do proizvodnje i distribucije. Ona može transformisati različite sektore i funkcije, pružajući pomoć razvoju ekonomije i produktivosti što automatski vodi ka povećanju BDP-a.*
Ključne reči; *Veštačka inteligencija, ekonomija, produktivnost, Evropska unija.*

Introduction

This paper addresses the role of artificial intelligence in the economy. We begin by defining artificial intelligence, then present the European Union's approach through the regulation aimed at harmonizing rules regarding artificial intelligence (the AI Regulation). Finally, we present some statistics from Eurostat related to AI in the economy.

Artificial Intelligence (AI) refers to a wide range of technologies through which machines can perceive, interpret, learn, and act by imitating human cognitive abilities.

A market economy makes efficient use of resources to meet consumer needs in a competitive environment, based on the optimal allocation of financial, material, and human resources, which justifies the role of artificial intelligence in the market economy.

Artificial intelligence plays an increasingly important role in our lives and economy, and it already has an impact on our world in many different ways.

AI is seen by many as a driver of productivity and economic growth. It can increase the efficiency with which tasks are performed and significantly improve decision-making by analyzing large amounts of data. It can also generate the creation of new products, services, markets, and industries, thus stimulating consumer demand and generating new revenue streams.

However, AI also has drawbacks, such as its potentially disruptive effect on the economy and society by possibly leading to the creation of "super-firms"—centers of wealth and knowledge—that could have

detrimental effects on the broader economy. Another disadvantage is the potential to exacerbate inequality, widening the gap between developed and developing countries, and increasing the demand for workers with specific skills, while others may be laid off. This trend could have far-reaching consequences for the labor market.

While these concerns remain valid, there is no consensus on whether, and to what extent, the associated risks will materialize.

1. The European Union and AI

The European Union (EU) has the potential to improve its position in global competition and steer AI onto a beneficial path for both the economy and citizens. To achieve this, the EU must first develop a common strategy that leverages its strengths and enables the pooling of member states' resources in the most efficient way.

In October 2020, the European Council discussed the topic of digital transition. In April 2021, the Commission presented a regulation proposal aimed at harmonizing rules on artificial intelligence (the AI Regulation) and a coordinated plan that includes a set of joint actions for the Commission and member states. This regulatory package aims to improve trust in artificial intelligence and stimulate the development and updating of AI technology. On December 9, 2023, after marathon discussions that lasted three days, negotiators from the Council and the European Parliament reached a provisional agreement on the AI Regulation.

The legislative act was formally adopted by the Council on May 21, 2024, and came into force on August 1, 2024.

The AI Regulation aims to ensure that AI systems are developed and used responsibly. The rules impose obligations on providers and implementers of AI technologies and regulate the authorization of AI systems on the EU single market.

As the first law in the world regulating AI, the EU's rules could set a global standard for AI regulation, similar to how the General Data Protection Regulation (GDPR) set a precedent for data privacy, promoting ethical, safe, and trustworthy AI globally.

The AI Regulation addresses the risks associated with certain AI applications by classifying them into four risk levels and establishing different rules accordingly.

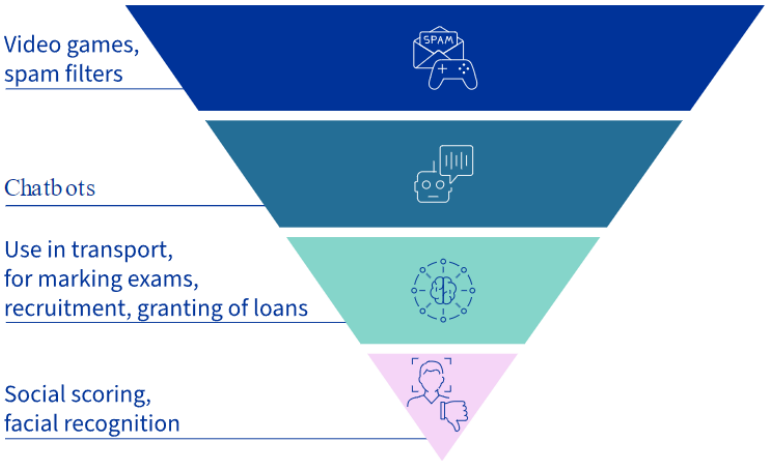


Figure 1. AI risk
Source: European Council

The European Commission has launched an innovation package in the field of artificial intelligence to support startups and SMEs in AI. The AI Pact encourages and assists organizations in planning ahead for the implementation of the AI Act measures. The AI Act came into force on August 1, 2024. Some provisions of the AI Act are already fully applicable, while requirements for high-risk AI systems and other provisions will only become applicable at the end of a transition period (i.e., the time between the Act's entry into force and its full application).

The development of the AI Pact is structured around two pillars:

- **Pillar I** acts as a gateway to involve the AI Pact network (those organizations that have expressed interest in the Pact), encouraging the exchange of best practices and providing practical information on implementing the AI Act;
- **Pillar II** encourages AI system providers and implementers to prepare in advance and take measures to comply with the requirements and obligations set forth in the legislation.

2. The role of AI in enterprises

Three key aspects of AI's role in businesses are outlined below:

- **Data Analysis and Decision Making**: AI enables companies to analyze large volumes of data in real-time, offering valuable insights for strategic decision-making. Machine learning algorithms can identify patterns and trends that may not be apparent through traditional analysis methods.
- **Optimization of Operational Processes:** Companies use AI to optimize supply chains, improve inventory management, and increase logistics efficiency. By integrating AI algorithms, businesses can predict demand fluctuations, optimize delivery routes, and reduce stock losses, which not only reduces costs but also enhances customer satisfaction.
- **Personalization of Customer Experience:** Another crucial role of AI in businesses is personalizing customer interactions. Online platforms and mobile apps use AI to analyze user behavior and provide personalized recommendations. This increases customer loyalty and improves conversion rates.

Most studies emphasize that AI will have a significant economic impact. Research by consulting firm Accenture, covering 12 developed economies that together generate over 0.5% of global economic output, estimates that by 2035, AI could double annual global economic growth rates. AI will drive this growth in three key ways:

- **Labor Productivity:** A strong increase in labor productivity (by up to 40%) due to innovative technologies that allow for more efficient management of labor-related time.
- **Workforce Transformation:** A new virtual workforce—"intelligent automation"—capable of solving problems and learning independently.
- **Diffusion of Innovation:** AI will impact various sectors and create new revenue streams.

This process of diffusion, defined by Everett M. Rogers as "the process through which an innovation is communicated through certain channels over time among the members of a social system," consists of four essential elements: the innovation, communication channels, time, and the social system.

3. Companies using artificial intelligence technologies

In 2023, 8% of companies in the EU with 10 or more employees and self-employed individuals used at least one of the following AI technologies:

- text mining (written language analysis technologies),

- speech recognition (technologies that convert spoken language into machine-readable formats),
- natural language generation (technologies that generate written or spoken language),
- image recognition and processing (technologies for identifying objects or people based on images),
- machine learning (e.g., deep learning) for data analysis,
- robotic process automation based on AI software (technologies that automate workflows or assist in decision-making),
- technologies that allow machines to move physically, observe the environment, and make autonomous decisions.

Compared to 2021, the use of AI technologies increased slightly by 0.4%.

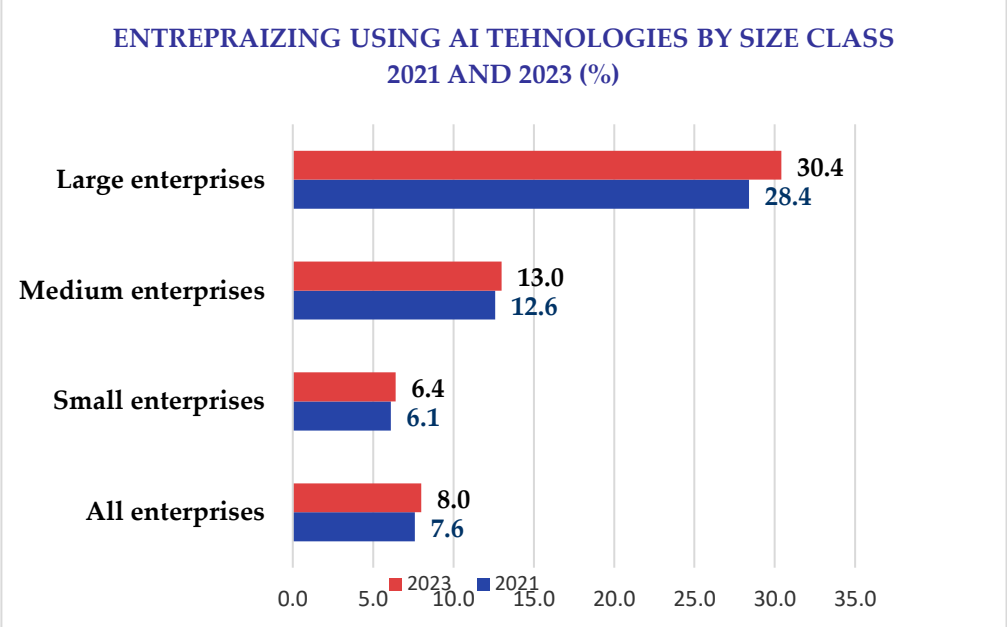


Figure 2. The size of enterprises using AI 2021-2023
Source: Own projection based on Eurostat data

In Figure 2, large enterprises used AI more than small and medium-sized enterprises. In 2023, 6.4% of small enterprises used AI, while 13% of medium-sized enterprises and 30.4% of large enterprises adopted AI. This difference can be explained, for example, by the complexity of implementing AI technologies in a company (i.e., enterprises with greater economies of scale can benefit more from AI).The adoption of AI technologies varies significantly based on the size of enterprises in the European Union. In 2023, large enterprises utilized AI more frequently compared to small and medium-sized enterprises (SMEs). The data shows the following trends:

- **Small enterprises (with fewer than 50 employees)**: In 2023, 6.4% of small enterprises used AI technologies, a slight increase compared to previous years.
- **Medium-sized enterprises (50-249 employees)**: Around 13% of medium-sized enterprises adopted AI in 2023, showing moderate growth over time.
- **Large enterprises (250 or more employees)**: A significant 30.4% of large enterprises integrated AI into their operations by 2023, reflecting their ability to leverage economies of scale and invest in advanced technologies.

This disparity in AI adoption can be attributed to several factors, including the complexity of implementing AI solutions, the financial and technical resources available, and the broader potential for large enterprises to benefit from AI-driven efficiencies.

In Figure 3, the distribution of artificial intelligence (AI) adoption across European Union countries in 2023 is highlighted, revealing significant differences in usage rates among member states. Romania ranks at the bottom, with only **1.5%** of enterprises utilizing AI technologies, a figure that underscores the country's slower pace in embracing AI compared to other EU nations. This may be attributed to factors such as limited technological infrastructure, lower investment in innovation, and challenges in digital transformation among Romanian businesses.

On the other hand, **Denmark** leads the EU with a remarkable **15.2%** of companies incorporating AI into their operations. Denmark's leadership in AI adoption can be linked to its strong focus on digital innovation, robust technological infrastructure, and a favorable regulatory environment that encourages the use of advanced technologies.

Following closely behind Denmark are **Finland** with **15.1%** and **Luxembourg** with **14.4%**. Both countries have also demonstrated a high degree of digital readiness, investing heavily in research and development, fostering innovation ecosystems, and supporting the integration of AI in both public and private sectors. These nations benefit from proactive government policies, widespread digital literacy, and a strong culture of innovation that helps them stay at the forefront of AI adoption in Europe.

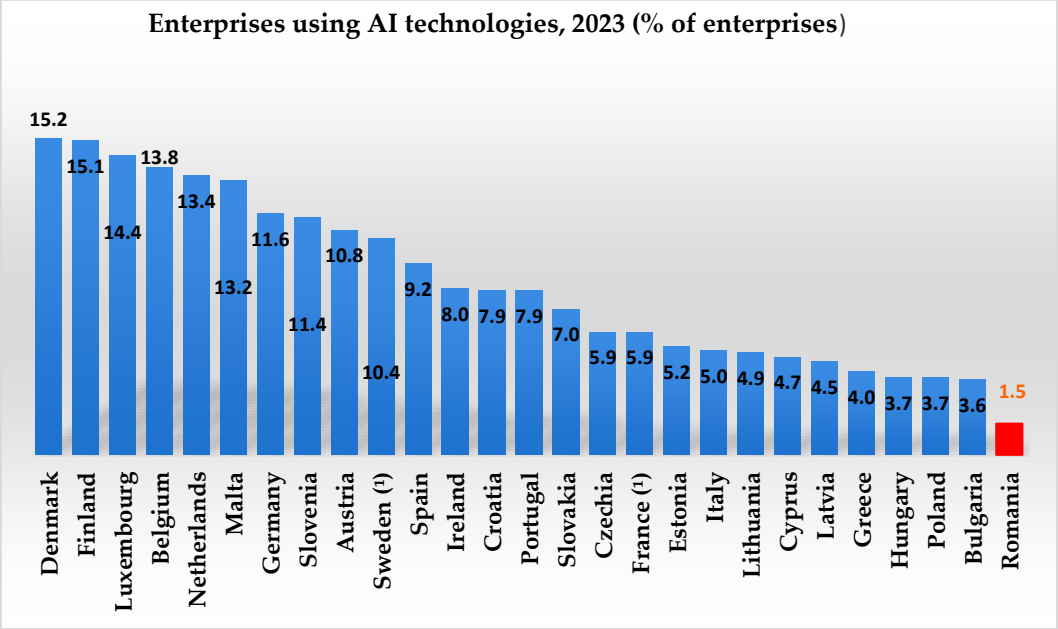


Figure 3. Enterprises using AI (EU), 2023
Source: Own projection based on Eurostat data

As shown in **Figure 4**, AI is used much more in some economic activities than in others. This could indicate that AI is more relevant to certain activities.

The chart illustrates the percentage of enterprises using AI technologies in the European Union in 2023, broken down by economic activity.

- **Information and communication** tops the list with 29.4% of enterprises utilizing AI, indicating that this sector is highly advanced in adopting AI technologies. This is likely due to the digital nature of the industry, which relies heavily on data processing, automation, and technological innovation.
- **Professional, scientific, and technical activities** rank second with 18.5%. This sector includes consulting firms, research organizations, and technical services, all of which benefit from AI's ability to analyze complex data, optimize operations, and enhance decision-making processes.

- **Electricity, gas, steam, and air conditioning supply** follows closely with 8.8%, reflecting the growing role of AI in energy management, predicting demand, and optimizing resource distribution.
- Other industries, such as **real estate (8.5%)**, **administrative and support services (8.3%)**, and **manufacturing (6.8%)**, also show moderate adoption of AI. These sectors are leveraging AI for automating tasks, improving efficiency, and enhancing customer experiences.
- At the lower end, sectors like **transportation and storage (5.2%)** and **construction (3.2%)** have comparatively lower adoption rates. These industries might face challenges in integrating AI, such as high upfront costs, the complexity of AI implementation in physical operations, or a lack of digital infrastructure.
- Overall, the chart reveals that **8% of enterprises** across all activities in the EU use AI technologies, showcasing the increasing role of AI in enhancing productivity and efficiency in various economic sectors. However, adoption rates vary significantly, with technology-intensive industries leading the way.

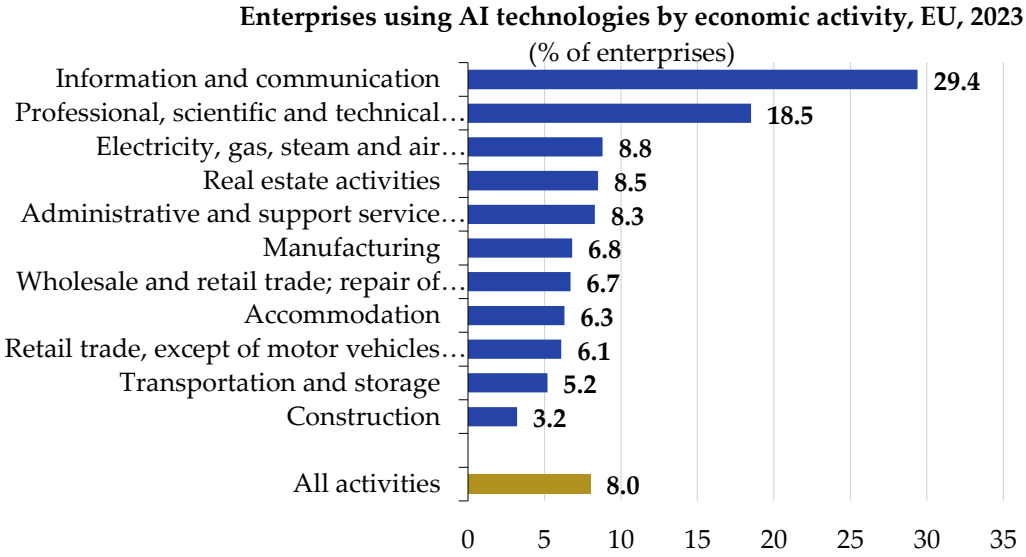


Figure 4. The use of AI depending on the economic activity, 2023
Source: Eurostat

Conclusion

Artificial Intelligence plays a crucial role in transforming economies and businesses, offering significant opportunities for increased productivity, innovation, and improved customer experiences. However, its implementation comes with a set of challenges, such as the impact on the workforce, data ethics, and economic inequalities. To maximize the benefits of AI and minimize the risks, it is essential for both governments and businesses to collaborate towards a fair and sustainable transition.

Artificial intelligence and automation can, on one hand, facilitate the massive scaling of organizations and, on the other hand, enable smaller players and even individuals to carry out activities that are currently mostly performed by larger companies.

As AI technology becomes increasingly accessible and digital infrastructure expands, the use of AI in the economy is expected to grow significantly. Sectors such as e-commerce, financial services, and manufacturing will continue to benefit from AI solutions, offering businesses new opportunities for

growth and innovation. Furthermore, the increase in competition in the local market will drive the adoption of AI solutions to improve efficiency and better meet consumer needs.

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Ranking of Criteria Used in Production Planning Software Selection: The Case of Ordu Province

Rangiranje kriterijuma korišćenih u izboru softvera za planiranje proizvodnje: slučaj provincije Ordu

Selçuk Korucuk[1], Ahmet Aytekin[2]

[1]*Giresun University, Bulancak Kadir Karabas Vocational School, Department of Logistics Management, Giresun, Turkey, selcuk.korucuk@giresun.edu.tr*
[2]*Samsun University, Faculty of Political Sciences, Depart Department of International Trade and Business, Samsun, Turkey, ahmet.aytekin@samsun.edu.tr*

Abstract: *With technological transformation, businesses have begun to carry out more effective production planning and have increasingly needed production planning software programs for short-, medium-, and long-term planning activities. Research shows that production planning software provides significant benefits to businesses in various operational areas such as time management, workforce allocation, production scheduling, overtime control, and inventory management. In addition to enhancing operational efficiency, these software systems also contribute to reducing costs, using resources more effectively, and improving overall organizational performance. However, determining the criteria used in selecting the most suitable production planning software is crucial and requires careful consideration. Within the scope of this study, the criteria used in production planning software selection in manufacturing enterprises were identified and prioritized. For this purpose, the Picture Fuzzy PIPRECIA method was applied. According to the analysis results, among the criteria used in selecting production planning software in manufacturing enterprises, the most important criteria were identified as "Security" and "Reporting and Analysis," while the least important criteria were found to be "Support and Training" and "Updating and Maintenance.*
Keywords: *Production, production planning, MCDM picture fuzzy PIPRECIA method.*

Apstrakt: *Sa tehnološkom transformacijom, preduzeća su počela da sprovode efikasnije planiranje proizvodnje i sve više im je potreban softver za planiranje proizvodnje za kratkoročne, srednjoročne i dugoročne aktivnosti planiranja. Istraživanja pokazuju da softver za planiranje proizvodnje pruža značajne koristi preduzećima u različitim operativnim oblastima kao što su upravljanje vremenom, raspodela radne snage, zakazivanje proizvodnje, kontrola prekovremenog rada i upravljanje zalihama. Pored poboljšanja operativne efikasnosti, ovi softverski sistemi takođe doprinose smanjenju troškova, efikasnijem korišćenju resursa i poboljšanju ukupnih organizacionih performansi. Međutim, određivanje kriterijuma koji se koriste pri izboru najprikladnijeg softvera za planiranje proizvodnje je ključno i zahteva pažljivo razmatranje. U okviru ove studije, identifikovani su i rangirani kriterijumi koji se koriste pri izboru softvera za planiranje proizvodnje u proizvodnim preduzećima. U tu svrhu primenjena je Picture Fuzzy PIPRECIA metoda. Prema rezultatima analize, među kriterijumima koji se koriste pri izboru softvera za planiranje proizvodnje u proizvodnim preduzećima, najvažniji kriterijumi su identifikovani kao „Bezbednost" i „Izveštavanje i analiza", dok su najmanje važni kriterijumi utvrđeni kao „Podrška i obuka" i „Ažuriranje i održavanje".*
Ključne reči*: Proizvodnja, planiranje proizvodnje, MCDM picture fuzzy PIPRECIA metoda.*

Introduction

In production, which constitutes one of the fundamental functions of a business, it has become possible to create value through data analysis, utilizing both machine data and externally collected data sources.

The successful management of production is of great significance at the firm, market, and national economy levels. An essential component of production management is production planning and scheduling (Akın & Akın, 2021). Production planning represents an economic transformation process. In this transformation, the utilization of resources and quantities, as well as the management of time, constitutes a critical process for both customers and producers (Jacobs & Chase, 2008).

Production planning is a system that determines what, when, and how to produce by utilizing the appropriate amount and quality of raw materials, equipment, labor, and other resources (Sharma, 2019). It is considered a pre-production activity that involves the prior determination of production requirements such as manpower, materials, machinery, and production processes. Production planning has also been defined as the identification, procurement, and organization of all facilities necessary for the future production of goods (Kumar & Suresh, 2009). With an effective production planning operation, any production process has the ability to utilize its full potential (Telsang, 2018). Planning and management activities related to production are of critical importance for enterprises. If the developed production plan is not carried out in a coordinated and systematic manner, it may lose its functionality. Deficiencies and disruptions in production activities and planning may lead to delays in achieving the production-related objectives of enterprises. Such delays and disruptions can reduce organizational efficiency and negatively affect the ability to foresee and analyze future conditions. To prevent these adverse outcomes, it is necessary to develop a strategic planning process (Aydın & Dursun, 2022).

According to Kumar and Suresh (2009), production planning not only provides benefits such as efficient utilization of resources, inventory management, and improvement of delivery processes, but also enhances customer satisfaction by ensuring the right products are delivered at the right time to meet customer demands. Timely deliveries increase customer loyalty and create a competitive advantage. In addition to reducing costs, balancing resources, and forecasting future needs, production planning also contributes to monitoring market trends and customer demands, thereby enabling more accurate future predictions. In this regard, production planning supports the strategic planning process of enterprises and assists in sustaining competitive advantage.

Based on the aforementioned points, the identification of the criteria influencing production planning software, which provides numerous advantages to enterprises, emerges as an issue of critical importance that requires meticulous attention. In manufacturing enterprises, the determination and ranking of the criteria used in selecting production planning software are regarded as significant indicators. Identifying and prioritizing these factors not only provides value by reducing costs and ensuring customer satisfaction but also contributes to meeting the requirements of efficiency, quality, and process improvement. Therefore, this study serves as a guide in addressing existing gaps.

In conclusion, the proposed framework for the decision-making problem addressed in this study contributes to filling the theoretical and methodological gaps in the literature and provides important insights for researchers in the field. In this context, the suggested approach for evaluating the criteria employed in production planning software selection within manufacturing enterprises establishes a reliable and robust theoretical foundation for academic studies, scientific research, and practice-oriented solutions.

Within this framework, the study aims to identify the criteria used in the selection of production planning software in manufacturing enterprises and proposes the Picture Fuzzy Subjective PIPRECIA model as a solution. The research is structured into four sections. The second section presents a literature review on production planning in firms. The third section explains the methods employed in the study. The final section concludes the research by providing policy recommendations, suggestions for future studies, and highlighting the limitations of the current study.

1. Literature

In this section, national and international studies on production planning and the criteria used in the selection of production planning software are presented:

- Wang et al. (2010) developed an integrated optimization model that incorporates traceability factors related to product safety with operational factors, thereby generating an optimal production plan.
- Feng et al. (2011) proposed a production planning optimization method for process industries, focusing on minimizing inventory costs and optimizing production load and load balancing.
- Hadidi et al. (2012) presented an integrated model covering production planning and scheduling, maintenance, and quality, offering various recommendations for future improvements.
- Organ et al. (2013) optimized integrated production planning in the manufacturing industry using goal programming.
- Gansterer et al. (2014) examined a hierarchical production planning system in a make-to-order production environment.
- Hees & Reinhart (2015) introduced a new approach to production planning in reconfigurable manufacturing systems.
- Buğday (2016) focused on forestry production practices in Turkey, production planning, and the increasingly recognized concept of precision forestry along with its process automation.
- Vogel et al. (2017) aimed to develop a hierarchical and integrated model that considers both aggregate production planning and master production scheduling.
- Akmal et al. (2018) conducted a bibliometric analysis of production planning and control between 1990 and 2016.
- Ellwein et al. (2019) proposed a new software architecture for production planning and control systems to establish a foundation for data exchange among such systems.
- Ediz & Turan (2020) investigated recommendation systems used in production planning and found that although most companies had an ERP system, only about half employed a recommendation system.
- Karabulut & Deste (2021) aimed to implement an integrated production planning application using a goal programming approach.
- Koçak & Yıldız (2022) examined the use of digital twin technology in production planning and control processes within the textile industry.
- Bründl et al. (2023) analyzed the use and implementation of software-based production planning and control systems in variant-rich make-to-order production environments.
- Elyasi et al. (2024) studied production planning under demand uncertainty with flexible manufacturing systems.
- Sheikhkhoshkar et al. (2024) developed an innovative, integrated, and multi-level production planning and control framework aligning various planning methods and control metrics across different planning levels.
- Arab Momeni & Jain (2025) proposed a model integrating production planning with the positioning of products in warehouses.

As a result of this literature review, it is observed that studies focusing specifically on the selection of production planning software are very limited. This indicates a significant gap in both theoretical

knowledge and practical applications. The aim of the present study is to contribute to filling this gap by providing new and comprehensive perspectives on the factors influencing production planning software selection, thereby promoting a deeper understanding of the topic.

2. Methodology

2.1. Picture fuzzy sets

Cuong and Kreinovich (2013) introduced Picture Fuzzy Sets (PFSs) as an extension of Intuitionistic Fuzzy Sets. PFSs provide a more realistic depiction of uncertainty by indicating degrees of membership, non-membership, and abstention. This feature allows for more flexible and accurate decision-making procedures. PFSs provide a more thorough approach by generalizing both classical and intuitionistic fuzzy sets.

Let X be a discourse universe. Eq. (1) gives a PFS G, where $\mu_G(x), \eta_G(x), \nu_G(x) \in [0,1]$ (Cuong & Kreinovich, 2013; Görçün et al., 2024):

$$\mathrm{G} = \{\langle x, \mu_G(x), \eta_G(x), \nu_G(x)\rangle | x \in X\}, \tag{1}$$

The positive membership degree is represented as $\mu_G(x)$. $\eta_G(x)$ is the neutral membership degree. The negative membership degree is depicted as $\nu_G(x)$. Furthermore, Eq. (2) should be met (Cuong & Kreinovich, 2013; Görçün et al., 2024):

$$0 \leq \mu_G(x) + \eta_G(x) + \nu_G(x) \leq 1, \forall x \in X. \tag{2}$$

$\pi_G(x) = 1 - (\mu_G(x) + \eta_G(x) + \nu_G(x))$ is the degree of refusal membership of x in G. Assume that g, g_1, and g_2 are three PF numbers (PFNs), where $g = \langle \mu_g, \eta_g, \nu_g\rangle$, $b_1 = \langle \mu_{g_1}, \eta_{g_1}, \nu_{g_1}\rangle$, and $g_2 = \langle \mu_{g_2}, \eta_{g_2}, \nu_{g_2}\rangle$. The basic operations on PFNs are provided in Eq.s (3)-(7) (Cuong & Kreinovich, 2013; Görçün et al., 2024):

$$g_1 \oplus g_2 = \langle 1 - \left(1 - \mu_{g_1}\right)\left(1 - \mu_{g_2}\right), \eta_{g_1}\eta_{g_2}, \left(\eta_{g_1} + \nu_{g_1}\right)\left(\eta_{g_2} + \nu_{g_2}\right) - \eta_{g_1}\eta_{g_2}\rangle, \tag{3}$$

$$g_1 \otimes g_2 = \langle \left(\mu_{g_1} + \eta_{g_1}\right)\left(\mu_{g_2} + \eta_{g_2}\right) - \eta_{g_1}\eta_{g_2}, \eta_{g_1}\eta_{g_2}, 1 - \left(1 - \nu_{g_1}\right)\left(1 - \nu_{g_2}\right)\rangle, \tag{4}$$

$$g_1 \otimes g_2 = \langle \left(\mu_{g_1} + \eta_{g_1}\right)\left(\mu_{g_2} + \eta_{g_2}\right) - \eta_{g_1}\eta_{g_2}, \eta_{g_1}\eta_{g_2}, 1 - \left(1 - \nu_{g_1}\right)\left(1 - \nu_{g_2}\right)\rangle, \tag{5}$$

$$\lambda \cdot g = \langle 1 - \left(1 - \mu_g\right)^{\lambda}, \left(\eta_g\right)^{\lambda}, \left(\eta_g + \nu_g\right)^{\lambda} - \left(\eta_g\right)^{\lambda}\rangle, \tag{6}$$

$$g^{\lambda} = \langle \left(\mu_g + \eta_g\right)^{\lambda} - \left(\eta_g\right)^{\lambda}, \left(\eta_g\right)^{\lambda}, 1 - \left(1 - \nu_g\right)^{\lambda}\rangle. \tag{7}$$

Assume that g_j is the collection of PFNs, where $j = 1, \ldots, n$. The PF weighted arithmetic average (PFWAO) is computed by applying Eq. (8). Moreover, the PF weighted geometric average operator (PFWGO) is calculated using Eq. (9), where $\lambda_i = (\lambda_1, \lambda_2, \ldots, \lambda_n)^T$ is the weight vector (Cuong & Kreinovich, 2013; Görçün et al., 2024):

$$\begin{aligned} PFWAO_{\lambda}(g_1, \ldots, g_n) &= \bigoplus_{j=1}^{n} \left(\lambda_j, g_j\right) \\ &= \langle 1 - \prod_{j=1}^{n}\left(1 - \mu_{g_j}\right)^{\lambda_j}, \prod_{j=1}^{n}\left(\eta_{g_j}\right)^{\lambda_j}, \prod_{j=1}^{n}\left(\eta_{g_j} + \nu_{g_j}\right)^{\lambda_j} - \prod_{j=1}^{n}\left(\eta_{g_j}\right)^{\lambda_j}\rangle. \end{aligned} \tag{8}$$

$$PFWGO_{\lambda}(g_1, \dots, g_n) = \bigotimes_{j=1}^{n} (g_j)^{\lambda_j}$$
$$= \langle \prod_{j=1}^{n} \left(\mu_{g_j} + \eta_{g_j}\right)^{\lambda_j} - \prod_{j=1}^{n} \left(\eta_{g_j}\right)^{\lambda_j}, \prod_{j=1}^{n} \left(\eta_{g_j}\right)^{\lambda_j}, 1 - \prod_{j=1}^{n} \left(1 - \nu_{g_j}\right)^{\lambda_j} \rangle. \quad (9)$$

The defuzzification of a PFN g is carried out via Eq. (10), where $\pi_g = 1 - (\mu_g + \eta_g + \nu_g)$.

$$s(g) = \mu_g + \frac{\eta_g}{2} + \frac{\pi_g(1 + \mu_g - \nu_g)}{2} \quad (10)$$

2.2. Picture fuzzy PIPRECIA

PF-PIPRECIA is implemented in the following steps.

Step 1. The sets of criteria ($C = \{C_1, \dots, C_n\}$) and the experts ($E = \{E_1, \dots, E_z\}$) are determined.

Step 2. The experts evaluate importance levels of criteria using the linguistic terms listed in Table 1. In this context, the PF importance of j-th criterion identified by k-th expert is represented by $\xi_{jk} = \langle \mu_{jk}, \eta_{jk}, \nu_{jk} \rangle$, where $j = 1, \dots, n;\ k = 1, \dots, z$.

Table 5. Linguistic expressions for evaluating importance of criteria

Codes	Linguistic expressions	Picture fuzzy number		
		μ	η	ν
VH	Very High	0.90	0.05	0.05
H	High	0.80	0.10	0.10
A	Moderate	0.50	0.20	0.20
L	Low	0.20	0.30	0.50
VL	Very Low	0.10	0.30	0.60

Step 3. The weight coefficients of experts λ_k are determined, where $\sum_{k=1}^{z} \lambda_k = 1,\ 0 \le \lambda_k \le 1$.

Step 4. The integrated PF importance of j-th criterion ξ_j is obtained via Eq. (8). After that, $\xi_j = \langle \mu_j, \eta_j, \nu_j \rangle$ is produced.

Step 5. The crisp importance value of j-th criterion $s(\xi_j)$ is calculated by appliyng Eq. (10).

Step 6. c_j values are determined by comparing the criteria in pairs according to their order in the criteria list. In this framework, Eq. (11) is applied, where $s(\xi_j)$ and $s(\xi_{j-1})$ represent the importance ratings of the j-th criterion and (j-1)-th criterion, respectively.

$$c_j = \begin{cases} 1 + s(\xi_j) - s(\xi_{j-1}), & if\ s(\xi_j) > s(\xi_{j-1}) \\ 1, & if\ s(\xi_j) = s(\xi_{j-1}) \\ 1 + s(\xi_{j-1}) - s(\xi_j), & if\ s(\xi_j) < s(\xi_{j-1}) \end{cases} \quad (11)$$

In these pairwise comparisons, c_j value of the base criterion for comparisons is assumed to be 1. For example, if comparisons are made using the C1 criterion as the base, then $c_1 = 1$.

Step 7. The relative importance values of criteria are determined by applying Eq. (12).

$$\zeta_j = \begin{cases} 1, & if\ j = 1 \\ 2 - c_j, & if\ j > 1 \end{cases} \quad (12)$$

Step 8. The initial weight coefficients of criteria are calculated using Eq. (13).

$$\vartheta_j = \begin{cases} 1, & if\ j = 1 \\ \frac{\zeta_{j-1}}{\zeta_j}, & if\ j > 1 \end{cases} \tag{13}$$

Step 9. The weight coefficients of criteria are determined by applying Eq. (14).

$$w_j = \frac{\vartheta_j}{\sum_{j=1}^{n} \vartheta_j} \tag{14}$$

3. Results

This study investigates the factors affecting the cloud computing of businesses. To achieve this purpose, the Picture Fuzzy PIPRECIA method has been employed. The identified factors are presented in Table 2.

Table 2. The list of criteria

Codes	Criteria	Source(s)
C1	Functionality and Ease of Use	Ramayah & Lo, (2007)
C2	Integration Capability and Scalability	Oluyisola,et., al., (2022)
C3	Cost	Caputo, et., al., (2009)
C4	Support and Training	Chen & Li, (2013)
C5	Security	Oluyisola,et., al., (2022)
C6	Reporting and Analysis	Bartoszewicz & Wdowicz,(2019)
C7	Updates and Maintenance	Caputo, et., al., (2009)
C8	Reviews and References	Junior & Filho, (2012)
C9	Flexibility and Customization	Bartoszewicz & Wdowicz,(2019)

Six experts with extensive knowledge and experience on the problem are consulted about the importance of criteria. Table 3 provides the linguistic assessments of experts on criteria.

Table 3. The linguistic evaluations of criteria

	C1	C2	C3	C4	C5	C6	C7	C8	C9
E1	H	H	A	H	H	H	A	A	VH
E2	VH	A	H	A	VH	H	A	A	A
E3	H	H	H	L	VH	VH	H	A	A
E4	H	A	A	A	H	VH	L	A	L
E5	H	H	A	L	VH	H	A	H	A
E5	H	H	L	H	H	L	L	L	A

Table 4 presents the PF- integrated importance of criteria.

Table 4. The results of PF- subjective weighting approach

	C1			**C2**			**C3**		
	μ	η	ν	μ	η	ν	μ	η	ν
ξ_j	0.8218	0.0891	0.0891	0.7286	0.1260	0.1260	0.6016	0.1698	0.1865
$s(\xi_j)$	0.8664			0.8071			0.7163		
	C4			*C5*			*C6*		
	μ	η	ν	μ	η	ν	μ	η	ν
ξ_j	0.5691	0.1817	0.2183	0.8586	0.0707	0.0707	0.8000	0.0953	0.1047
$s(\xi_j)$	0.6808			0.8939			0.8477		
	C7			**C8**			**C9**		
	μ	η	ν	μ	η	ν	μ	η	ν
ξ_j	0.4980	0.2040	0.2450	0.5358	0.1906	0.2094	0.5865	0.1698	0.1865
$s(\xi_j)$	0.6332			0.6737			0.7114		

The results of PF-PIPRECIA are given in Table 5.

Table 5. The results of PF- PIPRECIA

Criteria	$s(\xi_j)$	c_j	ζ_j	ϑ_j	w_j	Rank
C1	0.8664		1.0000	1.0000	0.1200	3
C2	0.8071	0.9408	1.0592	0.9441	0.1133	4
C3	0.7163	0.9091	1.0909	0.8654	0.1038	7
C4	0.6808	0.9646	1.0354	0.8358	0.1003	9
C5	0.8939	1.2131	0.7869	1.0622	0.1274	1
C6	0.8477	0.9537	1.0463	1.0152	0.1218	2
C7	0.6332	0.7855	1.2145	0.8359	0.1003	8
C8	0.6737	1.0405	0.9595	0.8712	0.1045	6
C9	0.7114	1.0377	0.9623	0.9054	0.1086	5

"C5-Security" is the most important criterion as seen Table 5. The second most important criterion is "C6- Reporting and Analysis."

Conclusion

Production planning in manufacturing enterprises is a critical management process that provides a competitive advantage by ensuring that products are manufactured in the desired quantities, at the specified time, and with the required quality. This process is not limited to determining the production volume and timing; it also aims to ensure that the production process is effective, efficient, and cost-sustainable. Achieving this requires accurate cost estimations as a fundamental step. In production planning, all cost components—from raw materials and labor to energy consumption and machine capacity—must be predicted accurately and realistically. Moreover, the enterprise's production policies must be aligned with these plans; strategic decisions such as which products will be prioritized, which production methods will be employed, and how production capacity will be allocated should be integrated into the planning process. For these reasons, production planning software becomes highly significant, with software selection emerging as a particularly critical area.

Within this framework, the study examined the factors determining the criteria used in the selection of production planning software in manufacturing enterprises located in Samsun. According to the study results, the most important criteria in selecting production planning software were identified as "*Security"* and "*Reporting and Analysis"*. The least significant criteria were found to be "*Support and Training*"and "*Updates and Maintenance"*.

This study should be evaluated with certain limitations in mind. First, the research was confined to manufacturing enterprises located in Samsun; therefore, the generalizability of the findings to other provinces or different sectors may be limited. Second, the study relies on specific measurement tools and criteria to determine the importance levels of the factors; alternative methodological approaches or data collection techniques might yield different results. Furthermore, the study focuses solely on the current situation, and the temporal changes or long-term effects of the factors have not been comprehensively examined. The findings of this study highlight the criteria relevant to the production planning software selection process in manufacturing enterprises and provide guidance for managers. In addition, future research could extend this work by employing multi-criteria decision-making methods or other parametric and non-parametric approaches for a more comprehensive assessment.

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Contemporary Challenges and Perspectives of Gastronomy: From Personalized Nutrition to a Return to Tradition

Savremeni izazovi i perspektive gastronomije: od personalizovane ishrane do povratka tradiciji

Dušan Miletić[1]

[1]*Banja Luka College, Banja Luka, Bosnia and Hercegovina, dusan.miletic@blc.edu.ba*

Abstract: *The paper discusses contemporary trends in nutrition and gastronomy, with special emphasis on innovative and sustainable approaches that shape the culinary practice of the 21st century. The development of molecular gastronomy and fusion cuisine is analyzed as an example of the interdisciplinary synthesis of science, art and culture, with a critical review of their social and aesthetic impact. Special attention is paid to the transformative role of the media and social networks in popularizing new trends and shaping consumer habits. The paper explores the importance of sustainability through veganism and zero waste philosophy, and considers the perspectives of innovative technologies such as 3D food printing and laboratory-grown meat. Also, the concept of personalized nutrition and nutrigenetics is discussed, as well as the return to local practices and traditions in the context of globalization. It is concluded that new paradigms in nutrition represent a complex combination of scientific achievements, cultural dynamics and ethical issues, with strong implications for the future development of gastronomy and the food industry.*
Keywords: *Gastronomy, sustainability, zero waste, 3D food printing, nutrigenetics, tradition.*

Apstrakt: *Rad raspravlja o suvremenim trendovima u prehrani i gastronomiji, s posebnim naglaskom na inovativne i održive pristupe koji oblikuju kulinarsku praksu 21. vijeka. Razvoj molekularne gastronomije i fuzijske kuhinje analizira se kao primjer interdisciplinarne sinteze nauke, umjetnosti i kulture, s kritičkim osvrtom na njihov društveni i estetski uticaj. Posebna se pažnja posvećuje transformativnoj ulozi medija i društvenih mreža u popularizaciji novih trendova i oblikovanju potrošačkih navika. Rad istražuje važnost održivosti kroz veganstvo i filozofiju nultog otpada, te razmatra perspektive inovativnih tehnologija poput 3D štampanja hrane i mesa uzgojenog u laboratoriju. Također, raspravlja se o konceptu personalizirane prehrane i nutrigenetike, kao i o povratku lokalnim praksama i tradicijama u kontekstu globalizacije. Zaključuje se da nove paradigme u prehrani predstavljaju složenu kombinaciju naučnih dostignuća, kulturne dinamike i etičkih pitanja, s jakim implikacijama za budući razvoj gastronomije i prehrambene industrije.*
Ključne riječi: *Gastronomija, održivost, nulti otpad, 3D ispis hrane, nutrigenetika, tradicija.*

Introduction

Food has always been much more than a biological need - it represents a cultural, social and identity marker, a symbol of value and belonging, but also a field for scientific and technological research. In the 21st century, gastronomy is developing in a direction that goes beyond traditional culinary patterns, becoming an interdisciplinary area where natural and social sciences, art, economics and media meet. In this sense, cooking today cannot be viewed exclusively through the prism of food preparation, but as a complex phenomenon that shapes and reflects global social processes.

Contemporary culinary trends testify to the dynamic between innovation and tradition. Molecular gastronomy, based on scientific experiments and the application of chemistry and physics in cooking, pushes the boundaries of taste and texture, while fusion cuisine expresses global cultural flows and the interpenetration of different identities through food. These phenomena are not only technical or

aesthetic innovations, but also signs of a wider socio-cultural process in which globalization, migration and intercultural exchange shape new models of nutrition.

In parallel with scientific and culinary innovations, the media and social networks play an important role in the transformation of gastronomy. Culinary shows, blogs and digital platforms like Instagram and TikTok have made gastronomy a globally accessible and visually oriented discipline. Food becomes a media event, an aesthetic product and a status symbol, and consumer habits are shaped according to algorithms and viral trends. This process brings the democratization of cooking, but also challenges, because it often leads to a superficial understanding of gastronomy, neglect of nutritional value and commercialization of traditional recipes.

At the same time, growing environmental challenges and ethical dilemmas related to food production impose a need for sustainable food models. In this context, veganism, zero waste philosophy, the use of seasonal and local ingredients, as well as new technologies such as 3D printing of food and laboratory-grown meat are gaining importance. These innovations not only offer potential solutions to the problem of global food security and reduction of the ecological footprint, but also raise a number of questions about the acceptability, availability and ethical consequences of their application.

Another important trend is personalized nutrition, based on nutrigenetics and microbiome analysis, which emphasizes an individual approach to health and disease prevention. In this sense, the concept of a universal diet is losing its importance, while personalization is becoming a new paradigm of nutritional practice and health prevention. However, this direction also brings challenges in terms of genetic data privacy, test availability and regulation.

Contrary to the processes of globalization and digitalization, the return to tradition and local practices is increasingly pronounced. Traditional food preparation techniques, seasonal products and local recipes are experiencing a renaissance, as they represent a response to the homogenization of tastes and the loss of cultural diversity. In this way, gastronomy is confirmed as a field of struggle for the preservation of identity, sustainability and authenticity.

Starting from the mentioned trends, the aim of this paper is to present and analyze new paradigms in nutrition and gastronomy, especially in the context of personalized nutrition, laboratory-grown meat and a return to tradition. The work seeks to point out the complexity of the relationship between innovation and tradition, between science and culture, and between global and local practices, in order to see the perspectives and challenges that shape the gastronomy of the future.

The main goal of the work is to analyze contemporary trends and new paradigms in nutrition and gastronomy through the prism of scientific achievements, cultural dynamics and ethical challenges. Special attention is focused on considering the relationship between innovation and tradition, as well as on the influence of social networks, media and global processes on the formation of gastronomic identity.

1. Work methodology

The research presented in this paper is based on a qualitative approach and interdisciplinary analysis, with the aim of looking at new paradigms in nutrition and gastronomy. The methodological framework includes several steps: analysis of secondary sources, descriptive-analytical approach, comparative method and synthesis of interdisciplinary perspectives.

The first step involved the collection, selection and systematization of data from scientific and professional publications. Sources from the fields of gastronomy, nutrition, media and cultural studies, as well as contemporary literature on sustainability and innovative technologies in food production were used. Special attention is paid to scientific journals such as International Journal of Gastronomy and Food Science, Appetite, Food Research International and Trends in Food Science & Technology. In

this way, the relevance and topicality of the collected material was ensured (García-Segovia, Harrington, & Seo, 2015; Spence & Piqueras-Fiszman, 2014).

In the second step of the research, a descriptive analysis was applied to clarify the basic characteristics of contemporary culinary trends: molecular gastronomy, fusion cuisine, sustainable food models, laboratory-grown meat, 3D food printing and personalized nutrition. The analytical approach enabled the identification of specific methods and techniques, as well as the perception of their social, cultural and ethical implications (This, 2006; Lipson & Kurman, 2013; Poore & Nemecek, 2018).

The third methodological procedure involved comparing innovations in gastronomy with traditional practices, in order to determine the extent to which new technologies and food models can coexist with cultural heritage and local practices. The comparative method was applied in the analysis of the phenomenon of globalization and homogenization of taste in relation to the "slow food" movement and the return to tradition (Petrini, 2007; DeSoucey, 2010).

The final methodological step is the synthesis of knowledge from various disciplines - gastronomy, nutrition, genetics, sociology and media studies - in order to obtain a complete picture of contemporary trends in nutrition. This approach enables the connection of scientific achievements with the social and cultural context, whereby gastronomy is viewed not only as a culinary, but also as an economic, ethical and cultural phenomenon (Bryant & Barnett, 2018; Johnston & Goodman, 2015).

The paper used the deductive-inductive method - starting from theoretical assumptions about modern gastronomy, and then based on examples from the literature, conclusions about new paradigms were drawn inductively. Next, content analysis – used to study scientific papers, media articles and documentaries about gastronomy and food practices. A case study method was also applied, where specific examples of restaurants and gastronomic movements (e.g. El Bulli, Noma, Silo) were analyzed, which served as an illustration of innovations and sustainable practices in cooking (Myhrvold, Young, & Bilet, 2011; Massimo Bottura, 2017). In this way, the methodological framework enables a comprehensive analysis of new paradigms in gastronomy and nutrition, taking into account the scientific, technological, social and cultural dimensions of the phenomenon.

2. Review of previous literature

In recent decades, nutrition and gastronomy have become much more than a biological necessity or a cultural practice – they are the subject of multidisciplinary research that includes natural sciences, social-humanistic disciplines and technological innovations. Previous literature indicates that food functions as a space of interweaving of science, identity and social values, and that new paradigms in gastronomy reflect the key challenges of modern society: globalization, climate change, digitization and personalization of health. Culinary innovations, the development of new technologies and the return to tradition are closely related to the social, cultural and economic processes of the globalized world (Montanari, 2006; Counihan & Van Esterik, 2012).

Molecular gastronomy is recognized in the literature as an example of an interdisciplinary meeting between culinary arts and natural sciences, where chemistry and physics are used to redefine the texture and taste of food (This, 2006). Pioneers like Ferran Adrià and Heston Blumenthal have shown that cooking can become an experimental laboratory, where sensory innovation is linked to aesthetics and functionality (Myhrvold, Young, & Bilet, 2011). Research confirms that such techniques influence the perception of innovation and the emotional experience of food among consumers (García-Segovia, Harrington, & Seo, 2015). However, the literature also emphasizes the risk of elitism of gastronomy, where innovations can be perceived as "unnatural" or too far from traditional values (Spence & Piqueras-Fiszman, 2014).

Fusion cuisine, as another dominant direction, is researched in the context of globalization and cultural exchanges. It unites elements of different national cuisines, thus creating a new culinary identity, but at the same time opens up the question of authenticity and cultural appropriation (DeSoucey, 2010). As

Yamaguchi (2011) states, fusion cuisine can represent a creative synthesis, but without understanding the cultural context it can lead to a superficial mixing of traditions.

The literature emphasizes the transformative role of the media in the popularization of gastronomy. From television shows and celebrity chefs to digital platforms, food is turning into a global spectacle (Johnston & Goodman, 2015). Instagram and TikTok have created a new aesthetic of food, where the visual aspect becomes primary, often more important than the nutritional value (Abidin, 2016). This "visualization of gastronomy" shapes consumer habits and creates standards that are algorithmically driven (Lewis, 2018). Research indicates that the media is a double actor - on the one hand, they democratize cooking, enabling everyone to become a content creator, while on the other hand, they encourage commercialization and a superficial understanding of food (Johnston & Goodman, 2015).

One of the central themes of contemporary literature is related to the sustainability of food systems. Poore and Nemecek (2018) showed that switching to a plant-based diet can reduce greenhouse gas emissions and resource consumption, which highlights the importance of veganism as an ethical and environmental choice. Zero waste approaches, described in Reardon, J. (2020), Yusoff, N. I. B. M., et al. (2024). Sustainability is also interpreted in the literature as a means of preserving local communities and fair distribution of resources (Counihan & Van Esterik, 2012).

The role of technology in the future of nutrition is much discussed in modern literature. Lipson and Kurman (2013) emphasize the importance of 3D food printing in personalizing meals and rationalizing the use of resources. In parallel, laboratory-grown meat is recognized as an alternative to industrial production, with the potential to reduce animal suffering and ecological footprint (Bryant & Barnett, 2018). However, studies point to psychological barriers - a feeling of unnaturalness and mistrust of new technologies (Stephens et al., 2018). The literature emphasizes that transparency and consumer education will be key to the social acceptability of these innovations.

Personalized nutrition is recognized in the literature as one of the most significant trends in nutrition and preventive medicine (Ordovas et al., 2007). Studies show that individual reactions to food depend on genetic predispositions and the microbiome (Zeevi et al., 2015). This opens up possibilities for personalized dietary recommendations, but also raises issues of privacy of genetic data and fair availability of tests (Ronteltap, van Trijp, & Renes, 2009). The literature indicates that personalized nutrition can reduce the risk of chronic diseases, but requires regulatory and ethical frameworks.

The return to tradition represents another important direction. Montanari (2006) and Trubek (2008) point out that local and seasonal food is the answer to the homogenization of globalized tastes. The Slow Food movement (Petrini, 2007) promotes the idea of preserving cultural heritage and authentic recipes. However, the literature also points to the risk of commercialization of tradition and the emergence of the so-called "folkloric gastronomy", where authenticity is lost in the process of tourist exploitation (DeSoucey, 2010). Therefore, in contemporary research, tradition is viewed as both a cultural and a political-ecological practice.

An overview of previous research confirms that contemporary gastronomy is not an isolated phenomenon, but a field where innovation, ethics, globalization and tradition intersect. Scientific works consistently emphasize the need for a balance between technological achievements and cultural authenticity, between sustainability and commercialization, as well as between personalized approaches and universal standards. This literature lays the foundation for understanding gastronomy as an interdisciplinary field that shapes not only the way we eat, but also the way we live and communicate in a globalized society.

3. Contemporary trends in gastronomy as a multidisciplinary phenomenon

Contemporary gastronomy is developing in a direction that goes beyond the traditional understanding of cuisine and food preparation. It is shaped through the combination of science, technology, culture and social practices, which is confirmed by the literature that increasingly describes gastronomy as an

interdisciplinary field (Montanari, 2006; Counihan & Van Esterik, 2012). Analysis of available sources indicates that modern trends can be grouped into several dominant areas: molecular gastronomy and fusion cuisine, digital mediatization of food, sustainability and ethics in nutrition, innovative technologies in cooking, personalized nutrition and a return to tradition. Each of these areas does not act in isolation, but in mutual interaction shapes the gastronomic identity of the 21st century.

3.1. Molecular gastronomy and fusion cuisine – innovation and hybridity

Molecular gastronomy, pioneered by the works of Herman This (2006), is based on the application of scientific principles in food preparation. It introduces new textures, flavors and forms, creating a culinary experience that combines scientific experiment and artistic presentation (Myhrvold, Young, & Bilet, 2011). This practice is often linked to emotional reactions of consumers and the perception of innovation (García-Segovia, Harrington, & Seo, 2015), but also to criticisms of elitism and moving away from "natural" food (Spence & Piqueras-Fiszman, 2014).

Fusion cuisine, on the other hand, reflects the processes of globalization, the mixing of cultures and the creation of hybrid identities. It is analyzed in the literature as a space of creative synthesis, but also as a field of potential cultural appropriation (DeSoucey, 2010). Examples such as Japanese-Peruvian cuisine (Nikkei cuisine) or Mediterranean-Asian combinations show how fusion simultaneously creates new gastronomic experiences and opens the discussion about the limits of authenticity.

3.2. Media, social networks and digital aesthetics of food

Today's gastronomy cannot be viewed outside the context of media representation. Food has become a global cultural phenomenon thanks to media and social networks, where digital aesthetics often take precedence over nutritional value (Johnston & Goodman, 2015). The so-called trend Instagrammable food shows that the visual presentation of food shapes consumer perception and market value (Abidin, 2016).

Lewis (2018) points out that digital platforms function as new "taste brokers", creating trends and consumer patterns through algorithms and viral content. Thus, gastronomy is transformed into a spectacle, while consumers increasingly participate in the global culinary culture through the sharing of content, reviews and visual narratives. This mediatization of food democratizes the approach to cooking, but at the same time leads to a superficial understanding of gastronomy and its commercialization.

3.3. Sustainability and ethics in gastronomy

Contemporary literature strongly emphasizes the role of gastronomy in sustainable development. Poore and Nemecek (2018) indicate that switching to a plant-based diet significantly reduces the ecological footprint, while Yusoff, N. I. B. M., Hashim, H., & Hassim, M. H. (2024) highlights zero waste practices as an important step towards responsible consumption. In this sense, restaurants and the food industry are increasingly introducing the principles of circular economy, using local and seasonal ingredients and minimizing waste.

Sustainable gastronomy also has an ethical dimension, as it includes issues of animal welfare, fair distribution of resources and responsibility towards future generations (Counihan & Van Esterik, 2012). These practices show that gastronomic innovation is not only a matter of taste and aesthetics, but also of social and environmental responsibility.

3.4. Innovative technologies: 3D printing and lab-grown meat

The importance of new technologies in shaping the future of nutrition is increasingly emphasized in the literature. Lipson and Kurman (2013) emphasize the potential of 3D food printing in creating personalized meals and optimizing nutritional values. On the other hand, laboratory-grown meat is recognized as an alternative solution that can reduce dependence on industrial animal husbandry and environmental consequences (Bryant & Barnett, 2018).

Stephens et al. (2018) point, however, to a number of barriers to social acceptability: from feelings of "unnaturalness" to lack of trust and high costs. The analysis shows that process transparency and consumer education will be crucial factors in the spread of these technologies. These innovations are not only redefining food, but also opening up discussions about ethics, availability and global food security.

3.5. Personalized nutrition and nutrigenetics

The development of nutrigenetics and personalized nutrition opens up a new field of research that connects genetics, medicine and cooking. Ordovas et al. (2007) point out that genetic predispositions significantly influence food metabolism and disease risk. Research by Zeevi et al. (2015) confirms that individual reactions to the same foods depend on the microbiome and genetic profile, which opens the possibility for personalized diets.

However, the literature warns of ethical dilemmas – privacy of genetic data, potential discrimination and uneven availability of technologies (Ronteltap, van Trijp, & Renes, 2009). Personalized nutrition thus represents a promising trend, but also requires clearly defined regulatory frameworks and standards.

4. A return to tradition and local practices

In parallel with globalization and technological innovations, there is an increasingly pronounced trend of returning to local practices and traditions. Montanari (2006) emphasizes that food represents cultural memory, while Trubek (2008) points to the concept of terroir as an expression of the connection between the environment and gastronomic identity. The Slow Food movement (Petrini, 2007) symbolizes this return to authenticity, promoting local recipes and seasonal foods as a response to the homogenization of tastes.

However, DeSoucey (2010) warns of the danger of "gastronationalism" and the commercialization of tradition, where cultural heritage can be instrumentalized for tourism or marketing purposes. The analysis shows that today tradition is not static, but a dynamic element of gastronomy that is reinterpreted in the context of contemporary social needs and environmental challenges.

Based on all of the above, it can be concluded that modern trends in gastronomy are multi-layered and interconnected. Innovations such as molecular gastronomy and 3D printing of food are complemented by digitization and mediatization, while sustainability and a return to tradition represent a corrective to global trends. Personalized nutrition, on the other hand, heralds a new paradigm where gastronomy and medicine are increasingly intertwined.

All of the above confirms that modern gastronomy today stands at the crossroads between science and culture, innovation and tradition, global and local, aesthetics and ethics. This complexity makes it one of the most significant phenomena of modern society.

5. Discussion

The analysis of contemporary culinary trends and innovations in nutrition showed that gastronomy in the 21st century goes beyond the scope of cooking and grows into a field of interdisciplinary research. Its development cannot be understood only through technical innovations or changes in eating habits, but through the broader dynamics of globalization, ethics, ecology and digitalization. This confirms the view that gastronomy is a mirror of social transformations, but also an active actor in shaping new value systems (Montanari, 2006; Counihan & Van Esterik, 2012).

Molecular gastronomy and fusion cuisine confirm that scientific experiments and cultural exchanges can redefine the culinary experience (This, 2006; García-Segovia et al., 2015; DeSoucey, 2010). Scientific reflection in this context leads to the question: does food remain primarily a nutritional and biological resource or does it become an aesthetic and emotional construct? It is pointed out that innovations do

not operate in a vacuum, but are subject to cultural interpretations, which can legitimize or reject them. This opens the possibility for gastronomy to become a space of epistemological debate - between "natural" and "constructed".

According to Johnston and Goodman (2015), the digital mediatization of food shows that the visual dimension is increasingly replacing the nutritional one. Scientific reflection dictates that the question be asked: does the digital aestheticization of food encourage new forms of participation or does it create the illusion of democratization, while actually reinforcing market logic and algorithmic control? Food in the digital space is no longer just a physical object, but becomes a "semiotic sign" that carries cultural messages and shapes identities (Abidin, 2016; Lewis, 2018).

Literature emphasizes the importance of sustainability (Poore & Nemecek, 2018), but scientific reflection here opens a broader question: can gastronomy become an instrument of social transformation in the direction of environmental justice? Sustainability in gastronomy is not only a technical concept, but also a normative framework that reflects value attitudes about what it means to live in harmony with nature. Gastronomy thus acquires the role of an ethical agent, which mediates between individual choices and global climate challenges.

The development of laboratory meat and 3D food printing (Lipson & Kurman, 2013; Bryant & Barnett, 2018) illustrates how scientific innovation can change the very ontology of food. Scientific reflection suggests that this is not just about replacing one product with another, but about changing the definition of food. If food is no longer a "natural" product, but the result of biotechnological processes, then an epistemological question arises: what makes food "real food"? Stephens et al.'s (2018) findings on the perception of unnaturalness show that technology must be accompanied by ethical and social legitimation.

Personalized nutrition (Ordovas et al., 2007; Zeevi et al., 2015) opens a new field where genetics and medicine directly shape dietary practices. Scientific consideration here leads to reflection: does the transition to personalized diets mean the end of universal nutritional recommendations and the beginning of biological individualism in nutrition? Thus, gastronomy becomes a personalized science, but also an ethical challenge - because the issue of equal access to technologies remains unresolved (Ronteltap et al., 2009).

The return to tradition (Montanari, 2006; Trubek, 2008; Petrini, 2007) shows that gastronomy also functions as a field of resistance to globalization. However, scientific reflection here raises the question: is the return to tradition an authentic practice of preserving identity or a form of cultural marketing under the pressure of global tourism? In this sense, the gastronomic tradition must be viewed not only as a static value, but also as a dynamic construct, exposed to processes of reinterpretation and commercialization (DeSoucey, 2010).

Scientific reflection indicates that contemporary gastronomy is not only a subject of empirical analysis, but also an epistemological challenge. It requires the integration of natural sciences, social humanities disciplines and ethics in order to understand the complex processes that shape food, identity and society. The findings of this paper confirm that today's gastronomy is developing at the crossroads between innovation and tradition, global and local, individual and collective.

The key scientific consideration is: gastronomy is not only a reflection of society, but also its transformative actor - a space in which new knowledge, values and models of sustainability are shaped. As such, it represents an important field for further interdisciplinary research.

Conclusion

Contemporary gastronomy today develops at the crossroads between science, culture, technology and ethics, confirming that food goes beyond its biological function and becomes a multidisciplinary phenomenon. The analysis showed that molecular gastronomy, fusion cuisine, digital aesthetics of food,

sustainability, innovative technologies, personalized nutrition and a return to tradition are intertwined directions that shape the gastronomy of the 21st century. These directions are not just culinary innovations, but deeply social and cultural processes with powerful implications for identity, health, and the future of food systems.

The scientific implications of this research point to the need to view gastronomy as a field of interdisciplinary studies, in which natural sciences cooperate with social and humanistic disciplines. The introduction of technologies such as 3D food printing and laboratory-grown meat opens up fundamental questions about the definition and perception of food, while personalized nutrition requires the integration of genetics, nutrition and bioethics. Sustainable gastronomy, with a focus on veganism, zero waste philosophy and local foods, shows that gastronomy can be a significant instrument in the fight against climate change and environmental crises.

Contemporary problems of gastronomy are manifested on several levels: digital aestheticization of food encourages commercialization and loss of nutritional values; innovation faces skepticism and socioeconomic barriers; the tradition risks becoming folklorized or commercialized. These challenges require critical thinking, but also clear regulations, education and social responsibility.

Future research should focus on three key directions. Interdisciplinary integration, as the development of models that connect natural sciences, medicine, social sciences and digital technologies in the study of gastronomy. Then, the indispensable sustainability and ethics, a detailed analysis of how gastronomic practices can contribute to environmental justice, waste reduction and sustainable use of resources. And as a third direction, personalization and global availability. Exploring the potential of nutrigenetics and personalized nutrition, with critical reflection on equality of access and possible social inequalities.

The gastronomy of the future will not only be a space of hedonistic pleasure, but a field of scientific innovation, social transformation and ethical reflection. As such, it requires constant questioning and openness to new research, because it is through food that it is possible to understand and shape the modern world.

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Overcoming Online Teaching Drawbacks

Prevazilaženje nedostataka onlajn nastave

Silvia Madincea Pascu[1], Tania Petcovici[2], Iosif Török[3]

[1]*"Tibiscus" University of Timisoara, Timișoara, Romania, silvia_madincea76@yahoo.com*
[2]*"Tibiscus" University of Timisoara, Timișoara, Romania, taniapetcovici@gmail.com*
[3]*"Tibiscus" University of Timisoara, Timișoara, Romania, iosif_torok@yahoo.com*

Abstract: *As a new stage in the organization of the educational process, online teaching and learning have become an important alternative to reforming the entire traditional education system. Even though online classes have allowed people access to quality courses from all over the world, there are multiple drawbacks which need to be addressed and overcome. The paper discusses several drawbacks as well as solutions to improve the online learning based on a questionnaire applied to 54 students of different age groups, who reached different levels of education in Romania (high school graduates, undergraduates, second degree and master's degree graduates). Computer literacy of the respondents has also been considered. The survey showed that the modernization of the educational institutions is highly necessary, and it should involve the training of teachers and school managers for the transformation of the subjects into digital learning programs and the development of online lessons.*
Keywords: *Online, teaching, learning, modernization, drawbacks, educational institutions.*

Apstrakt: *Kao nova faza u organizaciji obrazovnog procesa, onlajn nastava i učenje postali su važna alternativa reformi celokupnog tradicionalnog obrazovnog sistema. Iako su onlajn časovi omogućili ljudima pristup kvalitetnim kursevima iz celog sveta, postoji više nedostataka koje treba rešiti i prevazići. U radu se razmatra nekoliko nedostataka, kao i rešenja za unapređenje onlajn učenja na osnovu upitnika primenjenog na 54 učenika različitih starosnih grupa, koji su dostigli različite nivoe obrazovanja u Rumuniji (maturanti srednjih škola, apsolventi, diplomci drugog stepena i master studija). Takođe je uzeta u obzir kompjuterska pismenost ispitanika. Anketa je pokazala da je modernizacija obrazovnih institucija veoma neophodna i da bi trebalo da obuhvati obuku nastavnika i škola za transformaciju predmeta u digitalne programe učenja i razvoj onlajn časova.*
Ključne reči: *Onlajn nastava, učenje, modernizacija, nedostaci, obrazovne institucije.*

Introduction

Nowadays, online learning has allowed us to access quality courses from anywhere in the world and adapted to the needs of the students, who self-manage their learning. So, it is a very comfortable and flexible method that has allowed many people to resume their training successfully and as an alternative to traditional learning. However, there are still many important issues that we need to continue working on in order to increase the benefits of the teaching-learning process.

1. Several observations on online courses

Distance learning has helped all educational actors to better understand what true authentic learning means, beyond the written curriculum, programs and tests, grades, controls or rigid rules. Education should be based on characteristics and needs closest to the students: curiosity, autonomy, satisfaction of being part of a group, contributing to the factor of change, to be appreciated. The current situation in recent years, especially since the year 2020, with the radical restructuring of the distance education process, compared to the organization of online learning in quarantine conditions, it is necessary to substantially review educational policies, particularly those related to local communities and civil

society organizations in ensuring and evaluating the quality of education, both at the institutional level and at the national level.

Online school, being a new and specific stage in the organization of the educational process, has become an important alternative to reforming the entire traditional education system. Beyond the accumulation of knowledge and skills development, it has been shown that the education institutions should be prepared to adapt to various contexts of reality. Elements that have worked well in distance learning can serve as benchmarks for improving traditional school-based education. These elements are:

a) emphasis on higher motivation of students and capitalization of their intelligence;

b) more active involvement of students in organizing the interactive learning process;

c) the use of effective digital tools for online and traditional in-school learning;

d) the use of a multitude of materials and products, mainly from the Internet (Google, YouTube etc.), along with textbooks and methodological guides;

e) studying and capitalizing on good practices in the country and abroad.

Distance learning has made a key contribution to changing the quality of the educational system, including the attitude towards the curriculum, especially towards the contents. Development has focused on distance learning, the skills of students closer to life and their interests, as well as the formation of values and attitudes towards what is happening in society and with the person himself.

There are many online teaching and learning resources, but it is important to select the ones that are captivating and interesting for students, but also known to teachers.

Online school has provided an opportunity to define both the role of the student as an active part in learning, as well as of the teacher, who should be primarily the facilitator, inspire learning and guide it rather than control it. Some of the students were not involved in online learning, not so much because they did not have the technical ability, but because they were not motivated, they benefited from a different learning environment than the one based on fear, control and authority within school, often manifesting forms of protest, due to the complicated and multiple tasks offered by teachers, but often without giving detailed explanations.

The distance learning exercise has shown that digital skills need to be developed, to contribute to a series of new inventions and discoveries, creating creativity and tasks for efficient communication. Many teachers mentioned that an effective method used in the classroom, however and in distance learning is that of investigation, which encourages students to find solutions on their own to the problems identified and train them to think freely, critically and constructively.

Using this method creatively, students are not treated as mere recipients of information from teacher or textbooks, but they come up with solutions on their own, set hypotheses and then test them. As learning based on the method of investigation usually takes longer, the digital tools can be used to convey information, topics and details to students in a timely manner. It also brings a substantial contribution to strengthening learning autonomy, developing self-employment skills, promoting a culture of trust and empowerment.

2. Drawbacks of online teaching and solutions

In order to identify the main drawbacks of online classes, as well as to find some solutions to overcome them, a questionnaire has been administered to 54 students (see table below). The questionnaire seeks students' perspective related to online education and emphasizes the commonly used platforms and applications.

Table 1. Online teaching questionnaire

1. Indicate the age group you belong to:

a.	18-22	
b.	22-30	
c.	30-40	
d.	40-50	
e.	over 50	

2. Indicate the highest degree received:

a. high school	
b. undergraduate (first degree)	
c. undergraduate (second degree)	
d. master's degree	
e. PhD	

3. Indicate the level of your computer skills:

a. proficient	
b. excellent	
c. good	
d. basic	
e. low	

4. If you could choose, which type of course would you prefer?

a. Face to face (in the classroom)	
b) Online	

5. What are the disadvantages you can identify with the online courses held so far? (check all the options you consider)

a. Lack of adequate technology (computer, laptop, tablet, phone)	
b. Technical problems (internet, electricity)	
c. External temptations (phone, TV, emails, people in the house)	
d. Lack of direct contact with colleagues and the teacher	
e. Inadequacy of the course for online teaching	
f. Teacher's low computer skills	
g. Student's low computer skills	
h. Inability of the teacher to control / guide the class	
i. Other: (specify)	

6. What should teachers do to overcome the disadvantages of online classes?

a. To improve their computer skills / knowledge	
b. Establish clear rules from the beginning (webcam turned on, the order of speaking, etc.)	
c. To give up traditional teaching	
d. Use attractive applications and platforms	
e. To involve students more in the teaching activity	
f. Other: (specify)	

7. What could students do to overcome the disadvantages of online classes?

a. To improve their computer skills / knowledge	
b. To follow the rules established by the teachers (webcam started, speaking in turns, etc.)	
c. To show up in an appropriate outfit and posture for an educational environment	
d. To take part in the course without other interferences (chat discussions, job-related activities, games, TV, etc.)	
e. Other: (specify)	

8. Indicate the platforms and applications you have heard about:

a. Google Classroom	
b. Google Meet	
c. Zoom.us	
d. Moodle.org	
e. Edmondo	
f. Mentimeter	
g. Kahoot	
h. Wordwall	
i. Socrative	
j. ISLCollective	
k. Liveworksheets	
l. Other: (specify)	

9. Indicate the platforms and applications you have used at least once during the courses:

a. Google Classroom	
b. Google Meet	
c. Zoom.us	
d. Moodle.org	
e. Edmondo	
f. Mentimeter	
g. Kahoot	
h. Wordwall	
i. Socrative	
j. ISLCollective	
k. Liveworksheets	
l. Other: (specify)	

The respondent students belong to different age groups from 18-22 (13%), 22-30 (11%), 30-40 (37%), 40-50 (33%) and over 50 years old (6%). The participants reached different levels of education in Romania: 4% are high school graduates, 32% are undergraduates (first degree), 62% are graduates of a second degree and 2% own a master's degree. Computer literacy of the respondents has also been taken into account resulting in answers such as proficient level (6%), excellent level (17%), good level (50%), basic level (23%) and poor level (6%). Regardless of their age and education, most students (76%) would rather choose online education to face-to-face classes (24%).

The above survey disclosed multiple drawbacks of online teaching, some not provided in the questionnaire but brought up by the respondents. The most selected disadvantage, chosen by 27% was related to technical problems such as low internet connections or lack of electricity, closely followed (24%) by the lack of direct contact with the colleagues and teachers in the virtual class (body language, direct facial expressions as well as lack of socialization). 17% of the participants selected external temptations as distractions caused by phone calls or messages, TV, emails, other people or pets. The next drawbacks selected by 13% were the inability of teachers to control and guide the class (more students mean less control) and students' low computer skills with 5%. On the other hand, 4% of the students chose lack of adequate technology or inappropriate equipment (an old computer, laptop, tablet, phone, headset). Even though on many occasions teachers turn into IT specialist, losing precious time of the class with technical explanations, 3% of the participants considered teachers' low computer skills as an important disadvantage. Only 2% of the participants selected the inadequacy of courses for online teaching (too many courses based on traditional methods).

Apart from the disadvantages provided in the questionnaire, there were also a few others mentioned by 5% of the respondents such as lack of long-term focus (staying in front of a screen for 2 hours may result difficult), lack of control over the answers and exams of the students (they communicate on what's app during the classes and exams).

In order to overcome these drawbacks, students have different suggestions for the teachers. 23% of the respondents thought of clear rules established by the teacher from the beginning, rules regarding a continuously active webcam, the order of speaking, the use of microphone and so on. Other two solutions, chosen by the same percentage of students (20.5%) were giving up traditional teaching with lots of monologues and using attractive applications and platforms (there are numerous apps teachers could choose from and use for different parts of the course). Turning classes more interactive through a major involvement of students in the teaching activity was selected by 17% of the students while 13% chose improving computer skills and knowledge of teachers. Other 6% of the participants came up with different solutions for the online classes, such as adapting the course to the available online resources, involving their students more in the class activities, keeping them focused and motivated, and not reading slides.

On the other hand, the respondents could identify a few activities that students could do to overcome the disadvantages of online teaching. 33% thought that students should follow the rules established by the teachers (webcam started, speaking in turns, etc.), while 29% of them considered that students should take part in the course without other interferences (chats, job-related activities, games, TV, or pets). Another solution, selected by 22% was to improve their computer skills and knowledge and 13% mentioned that they should show up in an appropriate outfit and posture for an educational environment. Only 2% of the participants stated that students should be actively present in the course, not just turning on the microphone and camera while doing their own business.

The last two questions of the questionnaire were meant to highlight the most known and used platforms, giving the respondents the possibility to choose from a list, as well as to add other platforms and applications. For the participants Google Classroom is the most used platform (36%), closely followed by Zoom.us with 35% and Google Meet (19%). Other applications such as Kahoot are used by 3%, while Mentimeter, Moodle.org and Wordwall by 2% of the students. 1% of them mentioned a few platforms that were not included in the questionnaire: Teams, Desire2Learn, Groovepages, and Kajabi.

A similar questionnaire has also been administered to 62 teachers of different subject matters. For a detailed description of the results see Pascu (2021: 207)

Too many applications and platforms confuse students. It is obvious that the school - even repositioned in digital area - must continue to be a safe resource for the student and continuity. When too many platforms are used there is a risk that unity, the element of emotional security to be disrupted, because students may have a feeling of insecurity caused by moving from one platform to another.

Here are some steps that may be followed in order to reform the educational system:

- Assessing the needs of the real situation and identifying problems, conducting and analysing studies in the field, organizing working groups with national and local experts, organizing debates in the media and civil society, analysing suggestions from educational institutions, NGOs, state and private institutions, foreign experts.
- Elaboration, revision and approval of normative acts, regulations and instructions regarding the reorganization and reconceptualization of the educational system.
- Development and implementation of a concept, such as "Partnership for Education", through more active involvement of all members of the educational community: students, parents, teachers (https://www.edu.ro/sites/default/files/SMART.Edu%20%20document%20 consultare.pdf).

Conclusion

The modernization of the educational institutions is highly necessary, and it should involve a team of specialists-programmers who will contribute to the training of teachers and school managers for the transformation of the subjects into digital learning programs and the development of online lessons

with predetermined steps, where students receive real-time feedback. Students should be provided with tablets connected to the Internet, where textbooks can be uploaded in electronic format, assignments, and even the possibility to organize the assessment online. Time should also be set aside for individual study and work on the development of individual or group projects and the organization of their implementation. Some other useful solutions to improve online teaching might be the following:

- conforming to the contexts of life and reorganizing the process of distance learning, taking into account the new conditions, learning from mistakes and showing openness to a change of quality;
- development of video lessons and educational programs for various learning situations;
- As there are a multitude of work platforms and digital tools for the organization of distance learning, it is important to start activities with those that are known and possible to use, both by students and teachers.

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Analysis of Key Economic Indicators of Central Asian Countries

Analiza ključnih ekonomskih indikatora zemalja Centralne Azije

Vokhidova Mekhri Khasanovna[1]

[1]*Tashkent State University of Oriental Studies, Tashkent, Uzbekistan, mehrivoxidova@gmail.com*

Abstract. *This article examines the key economic indicators of Central Asian countries within the framework of classical and modern integration theories. Drawing on Balassa's stages of integration, Viner's customs union theory, and Tinbergen's gravity model, the study highlights the importance of macroeconomic fundamentals for successful regional integration. Using recent statistical data from Kazakhstan, Uzbekistan, Turkmenistan, Kyrgyzstan, and Tajikistan, the analysis compares GDP, growth rates, inflation, remittances, human capital, and trade openness. The findings reveal significant disparities in income levels and institutional capacities, with Kazakhstan emerging as the most advanced economy, while Kyrgyzstan and Tajikistan remain highly dependent on remittances. Uzbekistan demonstrates a rapid transformation in trade openness, while Turkmenistan exhibits declining integration. Intra-regional trade remains modest despite positive growth, reflecting the absence of strong institutionalized cooperation. The study concludes that sustainable regional integration requires not only geographic proximity but also macroeconomic convergence, institutional strengthening, and diversification strategies.*

Keywords: *Central Asia, economic integration, macroeconomic indicators, GDP growth, remittances, trade openness, Balassa, gravity model, regional cooperation.*

Apstrakt: *Ovaj članak ispituje ključne ekonomske indikatore zemalja Centralne Azije u okviru klasičnih i modernih teorija integracije. Oslanjajući se na Balasine faze integracije, Vinerovu teoriju carinske unije i Tinbergenov gravitacioni model, studija ističe važnost makroekonomskih osnova za uspešnu regionalnu integraciju. Koristeći nedavne statističke podatke iz Kazahstana, Uzbekistana, Turkmenistana, Kirgistana i Tadžikistana, analiza upoređuje BDP, stope rasta, inflaciju, doznake, ljudski kapital i otvorenost trgovine. Rezultati otkrivaju značajne razlike u nivoima prihoda i institucionalnim kapacitetima, pri čemu se Kazahstan pojavljuje kao najnaprednija ekonomija, dok Kirgistan i Tadžikistan ostaju u velikoj meri zavisni od doznaka. Uzbekistan pokazuje brzu transformaciju u otvorenosti trgovine, dok Turkmenistan pokazuje opadajuću integraciju. Intraregionalna trgovina ostaje skromna uprkos pozitivnom rastu, što odražava odsustvo snažne institucionalizovane saradnje. Studija zaključuje da održiva regionalna integracija zahteva ne samo geografsku blizinu već i makroekonomsku konvergenciju, institucionalno jačanje i strategije diverzifikacije.*

Ključne reči: *Centralna Azija, ekonomska integracija, makroekonomski indikatori, rast BDP-a, doznake, otvorenost trgovine, Balasa, gravitacioni model, regionalna saradnja.*

Introduction

The economies of Central Asia—Kazakhstan, Uzbekistan, Turkmenistan, Kyrgyzstan, and Tajikistan—occupy a unique position at the crossroads of Europe and Asia. Since gaining independence in 1991, these states have undergone fundamental structural transformations, moving from centrally planned systems to market-oriented economies. Their geographic proximity, shared Soviet legacy, and strong trade complementarities create a natural basis for economic cooperation. However, disparities in resource endowments, institutional development, and policy choices have resulted in divergent trajectories of growth and integration.

The objective of this paper is to analyze the key economic indicators of Central Asian countries—GDP, growth rates, inflation, remittances, human capital, and trade openness—within the theoretical framework of classical integration and development economics. By combining empirical evidence with theoretical insights, the paper provides an assessment of the region's integration potential and economic sustainability.

1. Literature review

Economic integration is one of the most controversial phenomena in developing international economic relations among countries to enhance competitiveness, growth, and development.

Like many other socio-economic trends, economic integration has witnessed several attempts to conceptualize it. According to Balassa (1961), Economic integration is "The abolition of discrimination within an area". Similarly, Kahnert Et Al De (1969) describes economic integration as "the process of removing progressively those discriminations which occur at national borders". Moreover, Machlup (1977) provided a theory that integration is the process of combining separate economies into a larger economic region. Machlup (1977) and Staley (1977, p.243) further argue that integration is concerned with the "utilization of all potential opportunities of efficient division of labor". To strengthen the economic aspect of integration, Viner (1950) and Meade (1955) researched the evaluation of economic integration and its implications for international trade.

Most theorists consider that the theory of economic integration evolves in two stages, each of which addresses the political and economic concerns of its period. The initial stage encompasses traditional economic integration theories, which describe the potential gains from integration and are typically referred to as static analysis. The second phase entails contemporary economic integration theories, which are formulated in response to new economic conditions and trade situations; the theories are referred to as a dynamic study of economic structures.

Balassa's (1961) integration stages suggest that successful economic integration requires compatible macroeconomic fundamentals among participating countries, while Viner's (1950) static analysis emphasizes the importance of economic size and complementarity in determining integration outcomes. Tinbergen's (1962) gravity model posits that trade flows depend critically on the economic mass (GDP) of trading partners, making the analysis of economic indicators essential for understanding integration potential.

Following the dissolution of the Soviet Union in 1991, Central Asian republics faced the dual challenge of economic transformation and regional integration. The initial attempt at institutionalized cooperation emerged with the Central Asian Union (CAU) in 1994, established by Kazakhstan, Uzbekistan, and Kyrgyzstan. The CAU aimed to create a "single economic space" facilitating the free movement of goods, services, capital, and labor-objectives that align with Balassa's (1961) conception of a common market stage.

However, the CAU's limited success illustrates what Shams (2003) identified as the fundamental challenge for developing country integration: the insufficient coordination of macroeconomic policies and institutional frameworks. Despite shared historical legacies and geographic proximity, divergent national priorities, and underdeveloped institutional capacity prevented the realization of deeper integration goals. This early experience underscores the critical importance of understanding economic fundamentals before attempting integration initiatives.

2. Methodology

This study applies a comparative and descriptive statistical approach. Data are drawn from national statistical agencies of Kazakhstan, Uzbekistan, Kyrgyzstan, Tajikistan, and Turkmenistan, as well as from the World Bank, WTO, and EBRD. Key indicators analyzed include:

- Macroeconomic size: GDP (nominal, per capita)
- Intraregional trade of Central Asia
- Trade integration: trade openness index and intra-regional trade flows

The indicators are presented in comparative tables, allowing both cross-country and temporal analysis.

3. Analysis and results

Table 1 shows that Kazakhstan dominates in economic size, with a GDP of USD 288.4 billion and per capita income exceeding USD 14,000 in 2024. Uzbekistan, the most populous country (36.4 million), has rapidly expanded its GDP to USD 115 billion but still lags behind in per capita terms. Turkmenistan's hydrocarbon wealth ensures relatively high per capita income, while Kyrgyzstan and Tajikistan remain low-income, with per capita GDP of USD 2,419 and USD 1,341, respectively.

Table 1. The main macroeconomic indicators of Central Asia

Country	Population (2024, millions)	GDP 2023 (USD billions)	GDP 2024 (USD billions)	GDP per Capita 2023 (USD)	GDP per Capita 2024 (USD)
Kazakhstan	20.6	262.64	288.4	12,918.9	14,005.3
Uzbekistan	36.4	101.59	115.0	2,849.5	3,161.7
Turkmenistan	7.5	60.63	64.2	8,232.7	8,571.6
Kyrgyzstan	7.2	13.99	17.5	1,970.2	2,419.3
Tajikistan	10.6	12.06	14.2	1,160.8	1,341.2

Source: The table was created by author using national statistic sites

Kazakhstan dominates with a GDP per capita of $14,005.3 in 2024, having crossed the upper-middle-income threshold. This achievement reflects what the World Bank characterizes as Kazakhstan's ambition to "double its economy by 2030 from 2023 levels" through reduced state intervention and enhanced competitiveness.

In contrast, the remaining countries exhibit significantly lower per capita incomes: Turkmenistan ($8,571.6), Uzbekistan ($3,161.7), Kyrgyzstan ($2,419.3), and Tajikistan ($1,341.2). These disparities reflect what Pomfret identifies as the "varieties of market-based economies" that have emerged, with each country's development trajectory shaped by its unique combination of resource endowments, institutional capacity, and policy choices.

Table 2. GDP growth in Central Asia (202) and its forecast for 2025

Country	2024 GDP Growth Rate	2025 Forecast	Economic Outlook
Kazakhstan	4.8%	4.5%	Driven by strong consumer spending and investment
Uzbekistan	6.5%	5.9%	Led by centralized investment and foreign direct investment
Turkmenistan	2.3%	N/A	Economy showing signs of recovery, driven by hydrocarbons sector
Kyrgyzstan	9.0%	6.8%	GDP forecasted to continuously increase between 2023 and 2028
Tajikistan	8.4%	6.5%	Strong domestic demand and remittances

The growth rates for 2024 demonstrate the region's continued dynamism despite global uncertainties. Kyrgyzstan leads with 9.0% growth, followed by Tajikistan (8.4%), Uzbekistan (6.5%), Kazakhstan (4.8%), and Turkmenistan (2.3%). These figures align with World Bank projections indicating that

Central Asia will remain "one of the world's fastest-growing regions," though momentum is expected to moderate in coming years. The European Bank for Reconstruction and Development (EBRD) attributes this robust performance to "economic diversification efforts, an upsurge in Russian emigrants, and substantial remittances". This analysis highlights the importance of external factors, particularly the spillover effects of geopolitical tensions, in shaping regional economic dynamics.

Kazakhstan illustrates effective resource curse mitigation through a "developmental state" model. With minimal remittance dependency (0.1% of GDP) and strong investment, it demonstrates how institutional capacity and technology integration can prevent rentier state outcomes. By contrast, Turkmenistan displays classical resource curse features, as Dutch disease effects reduce non-resource exports despite vast energy wealth.

Table 3. Central Asian countries macroeconomic indicators

Country	Inflation Rate	Remittances (% of GDP)	Human Capital Index (2020)	Investment Rate	Trade Balance
Kazakhstan	8.6% (2024)	0.1%	0.6	High	Current account deficit narrowed to 1.5% of GDP
Uzbekistan	9% (2024)	14.4%	0.6	FDI accounting for 30.5% of total investment	Current account deficit 5.0% of GDP
Turkmenistan	3.8% (December 2024)	0.0%	N/A	Investment increased by 9.1% in nominal terms	Total export reduced by 8% in 2024
Kyrgyzstan	10.8% (2016)	18.8%	0.6	Moderate	Remittances account for over 20% of GDP
Tajikistan	6.0% (2016)	47.9%	0.5	Moderate	Remittances account for nearly 40% of GDP

Tajikistan and Kyrgyzstan exemplify remittance-dependent economies. Tajikistan's heavy reliance on remittances (47.9% of GDP) creates what Ratha terms a "remittance trap," where external labor migration substitutes for domestic development. A low Human Capital Index (0.5) further constrains growth potential.

These divergences confirm Pomfret's (2021) argument on the emergence of "varieties of market economies" in post-Soviet Central Asia. Kazakhstan and Uzbekistan (HCI 0.6) show stronger institutions and attract significant FDI in resource sectors, while Kyrgyzstan and Tajikistan remain dependent on limited domestic investment, reflecting weaker integration with global capital.

Policy implications are evident in inflation dynamics. Kazakhstan's higher inflation (8.6%) compared to Turkmenistan (3.8%) highlights differing monetary policy effectiveness, supporting the view that stronger institutions and higher human capital underpin better macroeconomic management and economic diversification.

Central Asia's trade openness varies, but generally, it faces challenges in deepening trade integration despite its strategic location and potential. While the region is at a crossroads between Asia, Europe, and the Middle East, offering opportunities for economic integration and joining global value chains, its trade remains concentrated on a few products, and regional trade initiativeshaven't yielded significant results yet.

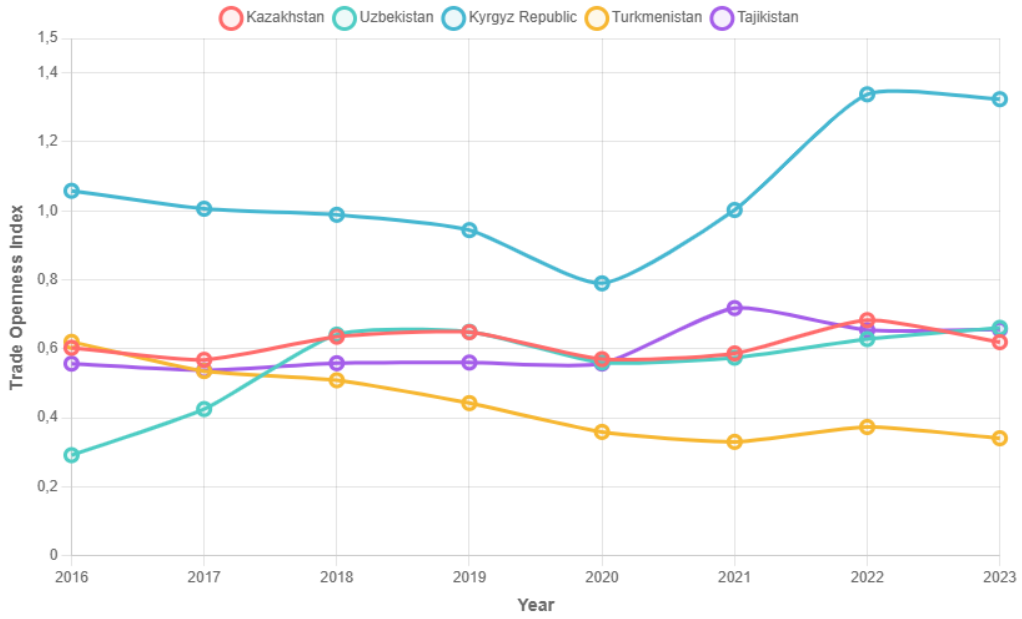


Figure 1. Trade openness flow between from 2016 to 2023
Source: The line graph was made by author

Trade openness indicators reveal the most dramatic transformation in regional integration patterns. Kyrgyzstan consistently maintains the highest openness levels, with trade volumes exceeding GDP throughout the analysis period, peaking at 1.34 in 2022. This reflects the country's limited domestic market size, strategic transit location, and WTO membership since 1998, which has facilitated comprehensive trade liberalization. Uzbekistan's integration trajectory represents the most significant transformation in the region. The country's trade openness index increased by 126% from 0.29 in 2016 to 0.66 in 2023, reflecting comprehensive economic reforms including currency liberalization, removal of trade barriers, and diplomatic opening. This transformation demonstrates how policy reforms can rapidly alter a country's integration profile. Kazakhstan's openness profile remains stable around 0.6, reflecting its large domestic market and substantial internal consumption capacity. The country's moderate openness despite significant export volumes indicates the importance of domestic economic activity and consumption patterns in determining integration metrics. Turkmenistan exhibits a concerning decline in openness from 0.62 to 0.34, representing a 45% decrease over the analysis period. This trend reflects the country's increasingly inward-oriented economic policies and limited diversification of trading partners, raising questions about long-term economic sustainability and regional integration potential.

Table 4. Intraregional trade of Central Asia

Year	Total Regional Trade (USD billion)	Intra-Regional Trade (USD billion)	Intra-Regional Share (%)	Growth Rate (%)
2022	245.8	16.2	6.6%	-
2023	267.3	17.3	6.5%	6.8%
2024	289.7	18.5	6.8%	7.2%

Source: Compiled from World Bank, WTO, and national statistical offices

The data reveals several critical insights. First, while absolute intra-regional trade grows moderately, its share of total trade remains stagnant, indicating that external trade partnerships continue to dominate. Second, the low base effect means that even substantial percentage growth translates to modest absolute increases in trade volume.

From Viner's (1950) perspective, this stagnation reflects insufficient trade creation mechanisms. The region lacks the preferential arrangements necessary to redirect trade flows from higher-cost external suppliers to more efficient regional partners. Moreover, Balassa's (1961) integration stages framework suggests Central Asia remains trapped in the earliest preferential trade agreement phase, unable to progress toward free trade area status due to institutional and political constraints.

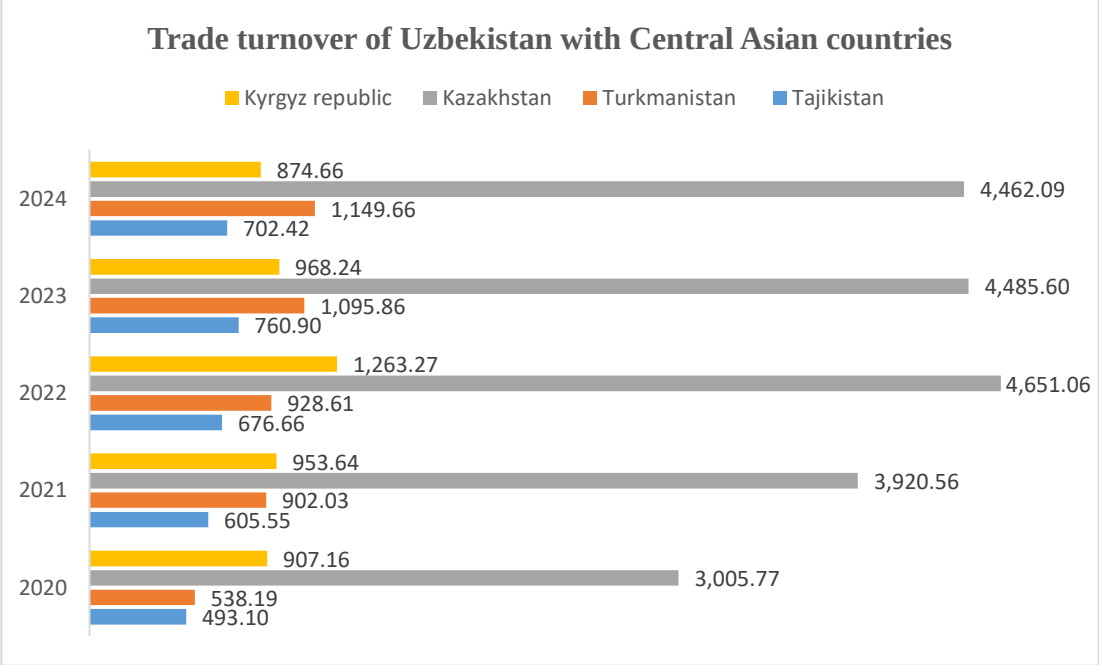


Figure 2. Trade turnover of Uzbekistan with Central Asian countries

The comparative dynamics of Uzbekistan's trade turnover with Kazakhstan, Kyrgyzstan, Turkmenistan, and Tajikistan between 2020 and 2024 can be explained through Balassa's (1961) stages of economic integration. According to this framework, integration advances from preferential trade arrangements to customs unions, common markets, and economic unions. The data indicates that Uzbekistan's regional trade remains within the early phases, where tariff reductions, partial border facilitation, and sectoral agreements dominate, rather than fully institutionalized integration.

A comparison of Kazakhstan and Kyrgyzstan reveals two distinct forms of integration. Kazakhstan's turnover with Uzbekistan, consistently above $4.4 billion, illustrates the effects of "negative integration," in Balassa's terms, where the removal of trade barriers allows oil, grain, and metals to circulate alongside Uzbek textiles and agricultural goods. Kyrgyzstan, with a smaller but expanding turnover of $875 million in 2024, demonstrates more localized progress, shaped by border markets, re-exports, and simplified customs procedures. While Kazakhstan represents integration based on scale and infrastructure, Kyrgyzstan reflects early steps toward "positive integration," where institutional mechanisms gradually promote cooperation beyond mere barrier removal (Balassa, 1961).

The contrast between Kazakhstan and Turkmenistan illustrates divergence in integration depth. Kazakhstan has moved toward closer customs coordination and infrastructural alignment with Uzbekistan, while Turkmenistan's turnover declined by 22% during 2020–2024. This stagnation reflects reliance on a narrow commodity base and limited participation in regional frameworks, which confines the relationship to the preferential trade stage. Kazakhstan's diversified trade and service linkages, by comparison, indicate gradual progress toward the customs union stage envisioned by Balassa (1961).

Comparing Kyrgyzstan and Tajikistan highlights different developmental trajectories. Kyrgyzstan's 62% increase in turnover is grounded in consumer goods and border trade, signifying modest progress toward integration but still characterized by informality and weak institutionalization. Tajikistan's 133% growth demonstrates a more structural transformation, where cooperation in electricity and

construction materials has stimulated broader trade expansion. This aligns with Balassa's (1961) argument that sectoral policy coordination can gradually extend integration into additional areas, even in the absence of full customs harmonization.

The divergence between Tajikistan and Turkmenistan further reflects uneven regional dynamics. Tajikistan has advanced toward sectoral positive integration through joint energy projects and water management agreements, while Turkmenistan remains constrained by limited openness and dependence on a narrow set of commodities. Balassa's framework clarifies that geographic proximity alone does not guarantee integration; rather, progress depends on the willingness of states to institutionalize cooperation and extend economic ties beyond basic goods exchange (Balassa, 1961).

Conclusion

The comparative assessment of Central Asian economies reveals both shared opportunities and persistent divergences. Kazakhstan has consolidated its role as the region's economic leader, demonstrating successful resource management, institutional strength, and sustained GDP growth that positions it firmly in the upper-middle-income category. Uzbekistan's recent policy reforms, particularly in trade liberalization and investment attraction, highlight its trajectory as a dynamic and reform-driven economy with growing regional influence. In contrast, Kyrgyzstan and Tajikistan remain heavily dependent on remittances, reflecting structural vulnerabilities that limit long-term growth potential and integration capacity. Turkmenistan's reliance on hydrocarbons and inward-oriented economic policies underscores the risks of the resource curse and weak institutional openness.

Despite robust growth across the region—often outpacing global averages—the analysis underscores that Central Asia remains in the early stages of regional integration as outlined by Balassa (1961). Intra-regional trade accounts for less than 7% of total trade, indicating that geographic proximity and historical ties alone are insufficient for deeper cooperation. Viner's (1950) concerns about limited trade creation are evident in the region's continued dependence on extra-regional markets, while Tinbergen's (1962) gravity model explains Kazakhstan's dominant trade role due to its economic mass.

To move toward sustainable and balanced development, Central Asia must address three pressing challenges: (1) reduce reliance on volatile external factors such as remittances and resource exports, (2) strengthen institutions and macroeconomic policy coordination, and (3) expand intra-regional cooperation through harmonized trade and investment frameworks. Prioritizing human capital development, technological modernization, and economic diversification will be critical for enhancing resilience and integration.

In sum, Central Asia possesses strong growth potential and strategic positioning but requires deliberate policy alignment and institutional reforms to transform its economic dynamism into sustainable regional integration and long-term prosperity.

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Blockchain Technology as an Infrastructure for Next-Generation Business Information Systems

Blockchain tehnologija kao infrastruktura za poslovne informacione sisteme naredne generacije

Goran Jocić[1], Kristina Jauković Jocić [2], Dušan Rajčević[3]

[1]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, goran.jocic@mef.edu.rs*
[2]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, kristina.jaukovic@mef.edu.rs*
[3]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, dusan@mef.edu.rs*

Abstract: *Blockchain technology has quickly transitioned from a foundational element for cryptocurrency to a disruptive innovation across various industries. Its decentralized, secure, and transparent nature is reshaping how businesses manage data, conduct transactions, and optimize operations. By removing intermediaries, lowering operational costs, and ensuring greater data integrity, blockchain is becoming a vital tool for modernizing business information systems. Despite its numerous advantages, challenges such as scalability, regulatory uncertainty, and integration with existing infrastructures remain significant barriers to widespread adoption. This paper explores the core principles of blockchain, its practical applications in business, the benefits it brings, and the hurdles businesses encounter when implementing this technology. Through an analysis of its impact on sectors like finance, supply chain management, and healthcare, the paper demonstrates blockchain's potential to revolutionize business processes and provide a secure, efficient, and transparent infrastructure for future business systems.*
Keywords: *Blockchain, business information systems, decentralization, smart contracts, supply chain management, finance, data security, scalability, digital transformation, blockchain applications.*

Apstrakt: *Blockchain tehnologija je brzo prešla iz temeljnog elementa za kriptovalute u disruptivnu inovaciju koja menja različite industrije. Njena decentralizovana, sigurna i transparentna priroda transformiše način na koji preduzeća upravljaju podacima, sprovode transakcije i optimizuju operacije. Uklanjanjem posrednika, smanjenjem operativnih troškova i obezbeđivanjem veće integriteta podataka, blockchain postaje ključni alat za modernizaciju poslovnih informacionih sistema. Iako nudi brojne prednosti, izazovi poput skalabilnosti, regulatorne nesigurnosti i integracije sa postojećim infrastrukturnim sistemima i dalje predstavljaju značajne prepreke širokoj primeni. Ovaj rad istražuje osnovne principe blockchain tehnologije, njene praktične primene u poslovanju, prednosti koje donosi i prepreke sa kojima se preduzeća suočavaju prilikom implementacije ove tehnologije. Analizom njenog uticaja na sektore kao što su finansije, lanac snabdevanja i zdravstvo, rad pokazuje potencijal blockchain-a da revolucionizuje poslovne procese i obezbedi sigurno, efikasno i transparentno infrastrukturno rešenje za buduće poslovne sisteme.*
Ključne reči: *Blockchain, poslovni informacioni sistemi, decentralizacija, pametni ugovori, lanac snabdevanja, finansije, bezbednost podataka, skalabilnost, digitalna transformacija, primene blockchain-a.*

Introduction

Blockchain technology has emerged as a revolutionary force, transforming industries and business models globally. Initially developed as the backbone of cryptocurrencies like Bitcoin, its impact has rapidly expanded beyond digital currencies, influencing a wide range of sectors, including finance,

supply chain, healthcare, and more. Blockchain offers a decentralized, transparent approach to data management, eliminating the need for intermediaries, reducing operational costs, and ensuring enhanced data integrity and security. These attributes make blockchain an invaluable tool for fostering trust in digital transactions, enabling businesses to optimize processes and improve operational efficiency. At its core, blockchain is a distributed ledger system that records transactions across a network of computers, ensuring that data cannot be altered without the agreement of all participants. This decentralized and transparent model is especially beneficial for industries where trust, data accuracy, and verifiability are critical. However, despite its many advantages, blockchain adoption faces several challenges, such as scalability, regulatory uncertainties, and the complexities of integrating with existing technologies. Addressing these obstacles is crucial for blockchain to reach its full potential as a mainstream solution for business information systems.

This paper delves into the fundamental principles of blockchain technology, its practical applications in business, the benefits it offers to organizations, and the challenges that hinder its widespread adoption. It also explores how blockchain is revolutionizing various industries, from finance to supply chain management, and outlines the steps businesses must take to successfully implement this transformative technology. By understanding both the opportunities and challenges associated with blockchain, organizations can better navigate its integration and unlock its full potential in the digital era.

1. Fundamental technological and conceptual principles of blockchain systems

Blockchain is structured as a decentralized ledger architecture where transaction records are distributed across a network of independent nodes, providing transparency, tamper-resistance, and cryptographic security (Casino et al., 2019). Each validated transaction is grouped into a block and cryptographically connected to the previous one through hashing, forming a permanent and non-modifiable chain designed to prevent data manipulation and unauthorized alterations (Kim & Laskowski, 2018). The integrity and reliability of this system are maintained through consensus protocols such as Proof of Work, Proof of Stake, and Byzantine Fault Tolerance, which eliminate dependence on central authorities and ensure trust among participants in decentralized environments (Dinh et al., 2020).

In organizational and enterprise contexts, blockchain functions as a distributed trust infrastructure that synchronizes secure data exchange between multiple stakeholders, minimizes vulnerability to centralized system failures, and reduces the need for intermediaries (Xu et al., 2021). Smart contracts further enhance blockchain's utility by enabling programmable and autonomous execution of business logic, ensuring consistent enforcement of contractual rules and increasing operational transparency (Wang et al., 2022). Contemporary studies emphasize that blockchain shifts trust mechanisms from institutional governance to cryptographically enforced consensus and transparent verification, contributing to the development of advanced information governance and secure digital transaction systems (Farouk et al., 2023).

In sum, blockchain's core attributes — decentralized architecture, immutable ledgers, cryptographic verification, and automated computational logic — form a foundation for next-generation business information systems. These characteristics allow organizations to achieve verifiable trust, automated workflows, and robust data integrity, affirming blockchain as a critical infrastructure component for resilient, transparent, and future-oriented digital ecosystems.

1.1. Structural and operational foundations of decentralized blockchain systems

Blockchain systems are structured on decentralized networks where the responsibilities of data storage, transaction validation, and governance are distributed across multiple nodes, eliminating the need for a centralized authority (Casino et al., 2019). Each node in the network maintains a synchronized copy of the ledger and participates in the verification process, ensuring network resilience, data transparency, and protection against tampering.

The architecture of blockchain is underpinned by cryptographically secured blocks, which are linked through hash functions to form a secure, immutable chain. Once transactions are confirmed, the chain prevents unauthorized modifications, ensuring data integrity (Kim & Laskowski, 2018).

The key components of blockchain architecture include:

- Distributed ledger structure
- Cryptographic identifiers (hashing, digital signatures)
- Time-stamped chained blocks
- Transparent and auditable transaction logs

Blockchain's core security features rely on asymmetric encryption, digital signatures, and Merkle tree structures, collectively enhancing data authenticity, integrity, and traceability (Xu et al., 2021). These cryptographic techniques ensure that data stored within the blockchain cannot be altered without detection, making it an ideal solution for industries where data accuracy and transparency are critical.

The consensus mechanism is central to blockchain's operation, enabling distributed decision-making and transaction validation. Consensus models can be classified as follows:

- Proof-based models
- Proof of Work (PoW)
- Proof of Stake (PoS)
- Fault-tolerant models
- Byzantine Fault Tolerance (BFT)
- Hybrid and next-generation models
- Energy-efficient consensus protocols
- Adaptive consensus protocols tailored for enterprise environments (Dinh et al., 2020; Wang et al., 2022)

Smart contracts represent the programmable layer of blockchain technology, allowing the automatic execution of rules and transactional logic without requiring intermediaries. This feature significantly enhances operational transparency, reliability, and reduces administrative overhead (Farouk et al., 2023). Through smart contracts, blockchain can automate business processes, ensuring compliance with predefined rules and regulations, and eliminating the risk of human error.

Blockchain networks are typically categorized based on governance structures and access control mechanisms:

- Public blockchains — Open, trustless, permissionless environments where anyone can participate
- Private blockchains — Controlled by a single organization, offering more privacy and centralization
- Permissioned blockchains — Systems that require identity verification and are typically used in regulated industries
- Hybrid blockchains — A combination of both public and private characteristics, allowing flexibility in governance while maintaining decentralization (Alam et al., 2024)

These diverse configurations enable businesses to adapt blockchain infrastructures to their specific operational, regulatory, and performance needs, creating flexible and scalable systems for a variety of use cases.

Ultimately, the integration of decentralized ledger technology, cryptographic validation, consensus protocols, and programmable smart contracts forms a robust foundation for next-generation business information systems. As enterprises continue to adopt multi-cloud architectures, Internet of Things (IoT) technologies, and interconnected digital services, blockchain is positioned as a vital enabler of secure, transparent, and autonomous digital infrastructures (Zhang et al., 2023). Blockchain not only streamlines operations but also provides an immutable and trusted environment that fosters innovation across.

2. Blockchain as an infrastructure for business information systems

Blockchain is increasingly recognized as a foundational digital infrastructure in business information systems, grounded in decentralized data management, cryptographic security, and transparent validation of transactions across distributed networks (Tapscott & Tapscott, 2020; Iansiti & Lakhani, 2020). Unlike centralized IT models that rely on a single trusted authority, blockchain introduces a verification mechanism driven by network-wide consensus and immutable records (Casino et al., 2019). This ensures synchronized, verifiable, and tamper-resistant business event logs across multiple stakeholders without the need for intermediaries or centralized control points (Xu et al., 2021).

Compared to traditional databases and ERP platforms, blockchain infrastructure provides several strategic advantages:

- Distributed control and data storage without a single point of failure (Kim & Laskowski, 2018)
- Consensus-based validation, ensuring systemic integrity and eliminating centralized decision-makers (Dinh et al., 2020)
- Immutable ledger and transparent auditability, enhancing traceability and trust (Wang et al., 2022; Yli-Huumo et al., 2018)
- Cryptographically secured and verifiable transactions, strengthening resistance to manipulation and malicious attacks (Farouk et al., 2023; Garfatta et al., 2022)

Blockchain capabilities are further extended by smart contracts, which automate the execution of business rules and transactional logic, minimizing manual intervention and operational risk while ensuring consistent fulfillment of predefined conditions (Alam et al., 2024; Mohanta et al., 2020). With the increasing adoption of cloud systems and IoT environments, blockchain also serves as a critical layer for secure data exchange, digital identity management, and device authentication in distributed ecosystems (Zhang et al., 2023; Novo, 2018).

Through these characteristics, business information systems transition from a traditional centralized control model to a decentralized, cryptographically verified trust framework, enabling higher levels of security, transparency, and data reliability. This architectural shift supports the development of advanced digital ecosystems that demand strong data integrity, automated process execution, and compliant multi-stakeholder information exchange.

2.1. Blockchain compared to traditional databases, ERP systems, and business process automation

Blockchain technology brings a significant shift in data management compared to traditional databases and ERP systems. While traditional systems rely on centralized databases that store information at a single location controlled by a central authority, blockchain uses a decentralized ledger, where data is distributed across a network of independent nodes. This structure enhances transparency, data integrity, and security, as each participant maintains a copy of the ledger, and all data changes are validated through a consensus mechanism (Xu et al., 2021; Nakamoto, 2008).

In comparison to traditional databases, which rely on central servers for managing and storing data, blockchain provides an alternative that allows for real-time data updates, improves traceability, and

reduces errors in the data validation process (Kim & Laskowski, 2018; Tapscott & Tapscott, 2020). While ERP systems, though centralized and designed to facilitate data sharing across departments, still depend on traditional databases, making them vulnerable to attacks, system errors, and less resilient to failures.

Blockchain also enables smart contracts, which are automated business logics that execute automatically, reducing the need for human intervention and administrative costs, while simultaneously increasing the efficiency and accuracy of business processes. Smart contracts are particularly useful in industries that require transparent and auditable transactions, such as finance, supply chain, and healthcare (Farouk et al., 2023; Wang et al., 2022; Mohanta et al., 2020).

In addition to replacing traditional databases and ERP systems, blockchain integrates successfully with modern technologies such as cloud computing, the Internet of Things (IoT), and digital identity management systems. Blockchain enables decentralized control of data and secure transfer of information between devices, which enhances the security and functionality of cloud systems and IoT ecosystems (Zhang et al., 2023; Novo, 2018). This integration is crucial for industries that rely on large amounts of real-time data, such as logistics, healthcare, and smart cities, where ensuring data accuracy, security, and accessibility is critical.

Ultimately, the combination of decentralized ledger technology, automated business processes through smart contracts, and integration with other digital technologies makes blockchain a powerful foundation for modern business information systems, offering advantages in terms of efficiency, security, and transparency compared to traditional systems (Garfatta et al., 2022; Yli-Huumo et al., 2018; Kumar et al., 2024).

3. Blockchain in business systems: applications, benefits, and implementation challenges

Blockchain technology is revolutionizing the management of data, business processes, and transactions. By offering enhanced transparency, security, and operational efficiency, blockchain enables organizations to optimize their business models across various industries. Its decentralized structure, coupled with the ability to maintain data integrity and automate workflows through smart contracts, establishes a reliable foundation for contemporary business systems. Compared to traditional centralized architectures, blockchain supports more secure, scalable, and autonomous processes, driving innovation in sectors ranging from finance and logistics to public administration and digital identity systems (Casino et al., 2019; Tapscott & Tapscott, 2020).

In the financial services industry, blockchain streamlines settlement processes, increases transaction transparency, and reduces counterparty risk, significantly improving institutional trust and reducing processing time (Kumar & Sharma, 2024). In supply chain ecosystems, blockchain supports real-time product tracking, fraud prevention, and inventory traceability, enabling verifiable sourcing and enhanced logistics coordination (Lee & Kim, 2021). Furthermore, healthcare systems benefit from tamper-proof patient records and secure medical data exchange, strengthening patient safety and interoperability standards (Mohanta & Patel, 2020). As organizations increasingly adopt digital identity frameworks, blockchain-based identity management systems provide secure, user-controlled authentication mechanisms that reduce identity theft risks and enhance privacy (Novo, 2018).

However, despite its potential, the adoption of blockchain technology introduces several technical, regulatory, and operational challenges. Scalability remains a major concern, especially in environments requiring high-volume, real-time transactions, as consensus mechanisms can create performance bottlenecks (Ghosh & Sharma, 2022). Integration with legacy IT infrastructure requires significant restructuring efforts, new governance models, and specialized workforce training, posing substantial organizational barriers (Pustokhina, 2021). Regulatory ambiguity also complicates deployment, as jurisdictions differ in their legal frameworks for distributed ledger technologies, affecting compliance

and risk-management strategies (Alam & Ahmed, 2024). Additionally, energy-intensive consensus protocols and partial centralization risks in permissioned networks challenge the decentralization ethos and sustainability of enterprise blockchain adoption (Zhang & Li, 2023; Farouk et al., 2023; Wang et al., 2022).

This section has highlighted the primary applications of blockchain technology across industries, emphasizing its value in improving operational transparency, data security, and system reliability. Nonetheless, successful implementation requires overcoming structural and regulatory barriers and ensuring alignment between technological capabilities and business objectives. As blockchain continues to evolve, addressing scalability, governance, and interoperability constraints will be essential for achieving sustainable enterprise-grade deployment and realizing the full potential of decentralized information ecosystems.

3.1. Corporate applications of blockchain technology

Blockchain is gaining traction in the financial sector, where it enables secure, faster, and more cost-effective transactions, eliminating the need for intermediaries and significantly lowering operational expenses (Farouk et al., 2023). In supply chain management, blockchain offers real-time product and resource tracking, improving transparency and minimizing fraud or data manipulation risks (Zhang et al., 2023). Moreover, blockchain plays a critical role in asset tokenization, verifying ownership rights and facilitating secure asset transfers, thereby enhancing market liquidity and accessibility (Wang et al., 2022).

The integration of blockchain into business information systems provides numerous benefits, such as:

- Enhanced security: Blockchain employs robust cryptographic protocols to safeguard data, reducing the likelihood of unauthorized modifications and cyberattacks (Casino et al., 2019).
- Improved data integrity: Blockchain's immutable records and transparent transaction history guarantee higher accuracy and trustworthiness of business data (Kim & Laskowski, 2018).
- Increased operational efficiency: By eliminating intermediaries, blockchain streamlines business processes, reduces operational costs, and accelerates transaction times (Farouk et al., 2023).

3.2. Challenges in implementing blockchain technology

Despite its numerous advantages, blockchain adoption faces several obstacles:

Scalability: Although blockchain is effective in processing transactions within distributed networks, current consensus mechanisms like Proof of Work (PoW) can result in slower transaction speeds, posing a scalability challenge for large enterprises (Dinh et al., 2020).

Regulatory uncertainty: Various countries have distinct approaches to blockchain regulation and cryptocurrencies, creating legal complexities that may hinder blockchain adoption across international business environments (Alam et al., 2024).

Organizational barriers: Implementing blockchain requires substantial adjustments to existing IT infrastructure, as well as employee retraining. These factors can be particularly challenging for businesses lacking the necessary resources or technical knowledge. Additionally, the high initial investment required for blockchain deployment can deter many organizations from embracing this technology (Wang et al., 2022).

In conclusion, blockchain technology provides significant advantages in terms of security, operational efficiency, and transparency. However, its adoption is hindered by challenges such as scalability limitations, regulatory uncertainty, and organizational adjustments. To ensure the widespread implementation of blockchain in business systems, it is crucial to address these challenges and establish a framework for its long-term viability and growth.

Conclusion

Blockchain technology has quickly transitioned from a specialized innovation in cryptocurrency to a key enabler of transformation across various industries, driving improvements in data management, transparency, and operational efficiency. As a decentralized infrastructure, blockchain allows for secure and transparent transactions without the need for intermediaries, fundamentally changing business information systems by ensuring data integrity, traceability, and security. Its applications in sectors like finance, supply chain management, and asset tokenization illustrate its ability to streamline processes, lower operational costs, and expand market access. However, the widespread adoption of blockchain technology faces challenges, particularly in areas like scalability, regulatory uncertainty, and organizational adaptation. While blockchain provides a more secure and efficient alternative to traditional systems, businesses must address these obstacles in order to fully realize its potential. Evolving regulatory frameworks and investments in infrastructure and training will be critical to successfully integrating blockchain into existing business models. In summary, although blockchain has proven its value in enhancing business operations, broader adoption and integration depend on overcoming these challenges. As the technology matures and solutions for scalability and regulatory issues continue to develop, blockchain has the potential to reshape the future of business systems and become a foundational element in digital business infrastructure.

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The Impact of Information Technologies on the Innovativeness of Organizations

Uticaj informacionih tehnologija na inovativnost organizacija

Verica Gluvakov[1], Mila Kavalić[2], Milan Nikolić[3], Snežana Mirković[4], Sanja Stanisavljev[5]

[1]*University of Novi Sad, Technical faculty „Mihajlo Pupin“, Zrenjanin, Serbia, verica.gluvakov@uns.ac.rs*
[2]*University of Novi Sad, Technical faculty „Mihajlo Pupin“, Zrenjanin, Serbia, mila.kavalic@uns.ac.rs*
[3]*University of Novi Sad, Technical faculty „Mihajlo Pupin“, Zrenjanin, Serbia, milan.nikolic@uns.ac.rs*
[4]*University of Novi Sad, Technical faculty „Mihajlo Pupin“, Zrenjanin, Serbia, snezana.mirkovic@tfzr.rs*
[5]*University of Novi Sad, Technical faculty „Mihajlo Pupin“, Zrenjanin, Serbia, sanja.stanisavljev@uns.ac.rs*

Abstract: *The aim of this research was to examine the impact of information technologies (IT) on organizational innovativeness. Starting from modern theoretical assumptions about digital transformation, the study analyzed the relationship between the extent of IT implementation and various dimensions of innovation. An empirical study was conducted on a sample of 406 organizations from different sectors. Data were collected through a questionnaire and analyzed in SPSS using correlation and regression analyses. The results show that information technologies have a positive and statistically significant impact on organizational innovativeness ($r = 0.531$; $p < 0.001$), whereby IT explains 28.2% of the innovation variance. The greatest impact was recorded in administrative innovations, while multiple regression analysis indicates the importance of IT dimensions related to digital collaboration and knowledge management. The obtained findings confirm that information technologies are not just a technical tool, but a key driver of innovation and business transformation, which indicates the need for their strategic integration into development policies and innovation strategies of organizations.*
Keywords: *Information technologies, organizational innovativeness, digital transformation, process innovation, administrative innovation.*

Apstrakt: *Cilj ovog istraživanja bio je da se ispita uticaj informacionih tehnologija (IT) na inovativnost organizacija. Polazeći od savremenih teorijskih postavki o digitalnoj transformaciji, istraživanje je analiziralo povezanost između stepena primene IT rešenja i različitih dimenzija inovativnosti. Empirijsko istraživanje sprovedeno je na uzorku od 406 organizacija iz različitih sektora. Podaci su prikupljeni anketnim upitnikom i obrađeni pomoću softvera SPSS primenom korelacione i regresione analize. Rezultati pokazuju da informacione tehnologije imaju pozitivan i statistički značajan uticaj na inovativnost organizacija ($r = 0,531$; $p < 0,001$), pri čemu IT objašnjava 28,2% varijanse inovativnosti. Najveći uticaj zabeležen je kod administrativnih inovacija, dok višestruka regresiona analiza ukazuje na značaj dimenzija IT-a koje se odnose na digitalnu saradnju i upravljanje znanjem. Dobijeni nalazi potvrđuju da informacione tehnologije nisu samo tehnički alat, već ključni pokretač inovacija i transformacije poslovanja, što ukazuje na potrebu njihovog strateškog integrisanja u razvojne politike i inovacione strategije organizacija.*
Ključne reči: *Informacione tehnologije, organizaciona inovativnost, digitalna transformacija, procesne inovacije, administrativne inovacije.*

Introduction

The modern business environment is characterized by a high degree of dynamism, global connectivity and continuous technological changes. Information technologies (IT) have become one of the key drivers of the transformation of organizations, enabling faster access to information, more efficient communication and the creation of new business models. The connection between information technologies and innovation is increasingly seen through technical aspects, as well as through

organizational, cultural and human dimensions, which together shape the capacity of organizations to create, implement and spread innovations. The use of these technologies expands the possibilities of knowledge distribution and creative learning, which encourages the development of competences and increases the engagement of individuals in organizational processes (Vesić et al., 2023). At the same time, organizations face the challenge of managing complex IT environments and policies that often limit user flexibility. Haag et al. (2022) indicate that employees, in an effort to achieve their goals, often use the so-called deviant IT practices, i.e. deviations from prescribed policies, which, although formally undesirable, can contribute to innovative and productive outcomes. This emphasizes that information technologies are an important tool, as well as a space of interaction between individual initiatives and organizational structures.

In addition, research indicates that information technologies strongly influence the professional identity and behavior of employees. Dinger et al. (2022) show that embedding IT professionals in organizational structures shapes their values and professionalism, indirectly enhancing innovation capacity, while Tomer and Mishra (2023) emphasize that technological features influence employees' career perceptions and foster creativity and adaptability. In digitally oriented sectors, where changes are constant, the relationship between technology, employees and innovation becomes a two-way process, which means that technology encourages innovation, but also requires continuous innovation of the work environment itself. On the other hand, innovation is today increasingly seen as a complex organizational phenomenon that includes individual, team and organizational levels of action. Gan et al. (2023) highlight that knowledge diversity and sharing strongly influence innovation performance, while Wang and Duan (2025) note that open innovation and diverse teams generate creative solutions through constructive conflict. Similarly, Wijaya et al. (2024) find that employees' emotional intelligence and transformational leadership foster collaboration, knowledge sharing and risk-taking in digital organizations.

Studying the impact of IT on innovation helps understand how technology affects creativity and adaptability. IT improves communication, speeds up information flow, connects knowledge, and builds a culture of innovation, all of which strengthen organizational performance in a changing market.

1. Theoretical background

Information technologies (IT) represent a set of technological solutions and systems intended for the collection, processing, storage, transmission and use of information. They include a wide range of tools, from computer hardware and software, through network infrastructures and cloud services, to digital platforms and artificial intelligence, which enable efficient data management and support business processes. In modern business conditions, IT has become a basic element of the functioning and development of organizations, because it enables automation, digitization and integration of various business functions (Sima et al., 2020). The importance of information technologies is reflected in their role as drivers of productivity, innovation and competitiveness. Tallon et al. (2018) indicate that organizations increasingly use IT to respond to unforeseen changes in the environment and increase their agility. In this sense, agility implies the ability of an organization to quickly perceive and exploit opportunities or adapt to threats through flexible management of resources and processes. Also, Ravichandran (2017) points out that high IT competence and innovation capacity jointly contribute to organizational agility, which, in turn, has a positive impact on company performance. Information and communication technologies (ICT), according to Chege et al. (2019), are a key factor in modern job creation and the interconnection of people through innovation. The adoption of IT depends on factors such as entrepreneurial innovation, which enhances its impact on organizational performance, while the development of ICT infrastructure support remain key drivers of economic progress. Overall, IT should be viewed as a technical resource, as well as a socio-economic phenomenon that transforms work, communication and value creation (Sima et al., 2020).

Organizational innovativeness can be defined as the ability to create and implement new ideas, products, processes or business models that contribute to increasing its efficiency, competitiveness and sustainable development. Innovation is the result of a creative process, as well as its ability to be successfully operationalized in a specific business context. Oliva et al. (2018) emphasize that innovation includes different forms, technical, organizational and marketing innovations, which develop in accordance with the sector, size and strategy of the company. The importance of innovation is reflected in its impact on the long-term performance of the organization. Azeem et al. (2021) showed that innovation, together with organizational culture and knowledge sharing, contribute to the creation of competitive advantage. Innovative organizations develop a culture of learning, collaboration and trust that encourages employees to experiment, take risks and create new value. Gan et al. (2023) further point out that knowledge heterogeneity and effective information sharing within a team increase innovation performance, as different perspectives and experiences create fertile ground for creativity. Donbesuur et al. (2020) indicate that technological and organizational innovativenesss act synergistically in improving the international performance of small and medium-sized enterprises. In an environment characterized by specific institutional factors, it is precisely the combination of innovations in technology and organization that enables companies to better take advantage of opportunities in the global market. These findings confirm that innovation is the result of the interaction of knowledge, technology, culture and institutional environment. Innovations, according to Wijaya et al. (2024), increasingly depend on "soft" factors, such as emotional intelligence and transformational leadership. These elements contribute to the formation of an organizational climate that stimulates knowledge sharing, collaboration and creative problem solving, thus increasing the organization's capacity for continuous innovation. In the digital age, innovation becomes a means of survival in a changing, globally connected market.

The relationship between information technologies and innovation has become an important topic of contemporary research in the field of management, information systems and organizational development. Existing studies confirm that IT infrastructure, capabilities and resources represent the basis for the development of innovations, as they enable more efficient access to knowledge, collaboration and digital transformation of business processes (Kubrak et al., 2023). Soto-Acosta et al. (2018) show that managing information and knowledge improves innovation by helping organizations use existing resources and explore new ones. Ravichandran (2017) and Chege et al. (2019) confirm that IT competence and entrepreneurial innovation enhance agility and company performance, while De Reuver et al. (2017) highlight digital platforms as key for creating new markets. Tallon et al. (2018) and Sima et al. (2020) add that digitization builds adaptability, human capital and long-term innovative potential. Based on a review of existing studies, it is concluded that information technologies facilitate innovation processes and redefine the way organizations create value, manage knowledge and achieve competitive advantage. The relationship between information technologies and innovation is bidirectional, meaning that technology enables innovation, while innovation encourages further development and application of technology. This cycle continuously improves organizational performance.

2. Methodology

2.1. Research problem

The modern business environment is characterized by rapid technological changes, global competition and an increasing need for innovation. Organizations that successfully integrate information technologies (IT) into their business processes achieve greater efficiency, flexibility and the ability to innovate. However, in practice there are still differences in the degree of application of IT solutions and their real contribution to innovation. That is why it is necessary to empirically examine how much and in what way information technologies influence the innovativeness of organizations, that is, whether their application really represents a driver of innovative activities and competitive advantages.

2.2. Research subject and research questions

The subject of this research is the analysis of the connection and impact of information technologies (IT) on the level of innovation in organizations of different sectors. The research starts from the following research questions:

1. Do information technologies significantly affect the innovativeness of organizations?
2. Which dimensions of innovation are most influenced by information technologies?
3. To what extent do information technologies contribute to the overall level of innovation in organizations?

2.3. Research goal and research hypotheses

The aim of this research is to examine the impact of information technologies on organizational innovativeness. Special emphasis is placed on understanding the relationship between the degree of application of IT solutions and different dimensions of innovation, i.e. product and service innovation, process innovation and administrative innovation. The aim of the research is to determine, by applying quantitative analysis, the degree of influence of information technologies on the innovativeness of organizations.

Based on the set goals and theoretical framework, a basic hypothesis and two auxiliary hypotheses were formulated:

H1: There is a positive and statistically significant relationship between the application of information technologies and innovativeness of organizations.

H2: Information technologies significantly contribute to the innovation of products and services.

H3: Information technologies have a positive effect on process innovation and administrative innovation.

2.4. Sample and data collection

An empirical study was conducted on a sample of 406 organizations (N = 406). Data were collected through a survey questionnaire, which included items on the degree of use of information technologies and levels of innovation in the organization. The questionnaire was distributed electronically and filled in anonymously. The sample includes companies of different sizes and sectors (manufacturing, service and administrative sectors), which enables wider generalization of the results and increases the representativeness of the sample.

2.5. Variables and operationalization

Independent variable: Information technologies (IT) - measured through the respondent's perception of the degree of application of IT solutions in business processes, communication, knowledge management and digital tools. The questionnaire contains 6 items and was used in the research by Mitić et al. (2017).

Dependent variable: Innovativeness - operationalized through three dimensions: product and service innovation, process innovation and administrative innovation. The questionnaire contains 8 items and was developed by Pedromo-Ortiz et al. (2009), Jiménez-Jiménez & Sanz-Valle (2005) and Huang & Li (2009).

All indicators were measured on a seven-point Likert scale (1 – completely disagree, 7 - completely agree).

2.6. Methods and techniques of data analysis

The research is of a quantitative type and is based on a deductive approach, where the methods of inferential statistics were used to verify the hypotheses. Data were analyzed using SPSS (Statistical Package for the Social Sciences) software. The following statistical methods were applied:

1. Correlation analysis (Pearson) – to determine the connection between IT and innovation,

2. Regression analysis (linear and multiple) - to examine the impact of IT on innovation and identify significant predictors. The combined application of linear and multiple regression analysis provides greater precision in the assessment of the direct and partial impact of information technologies on the innovativeness of organizations.

3. Results

3.1. Correlation analysis

In order to examine the relationship between information technologies (IT) and the innovativeness of organizations, a correlation analysis was conducted, which enabled the determination of the strength of the connection between the variables (Table 1).

Table 1. Correlations between information technologies and dimensions of innovation

Variables	Product and service innovation	Process inovation	Administrative innovation
Information technologies	0,484**	0,475**	0,527**

Source: authors' research

Note: $p < 0.01$ () – significant correlation at the 1% level**

Table 1 shows a positive and significant link between IT and all types of innovation. The strongest correlation is with administrative innovation ($r = 0.527$), followed by product ($r = 0.484$) and process innovation ($r = 0.475$), confirming that IT improves both internal operations and business activities ($p < 0.01$).

3.2. Regression analysis

For a deeper understanding of the impact of information technologies on innovation, a regression analysis was conducted. The results are presented in three sections: model summary (Table 2a), ANOVA significance test (Table 2b) and regression coefficients (Table 2c).

Table 2a. Summary of the regression analysis model

Model	R	R^2	Adjusted R^2	Std. Error
1	0,531	0,282	0,280	1,21666

Source: authors' research

As shown in Table 2a, information technologies explains 28.2% of the variance of innovativeness ($R^2 = 0.282$). This result indicates a moderately strong and statistically significant impact of IT on the innovativeness of organizations, which confirms the basic hypothesis about the connection between the application of IT solutions and the level of innovation.

Table 2b. ANOVA significance test of the regression model

Source of variation	SS	df	MS	F	Sig.
Regression	234,421	1	234,421	158,364	0,000
Residual	598,027	404	1,480		
Total	832,447	405			

Source: authors' research

The results of the ANOVA test shown in Table 2b show that the model is statistically significant ($F = 158.364$; $p < 0.001$). This means that information technologies have a measured and reliable impact on the innovativeness of organizations, that is, that the change in the level of IT use has a statistically significant effect on the overall innovativeness.

Table 2c. Regression analysis coefficients

Predictor	B	Std. Error	Beta	t	Sig.
(Constant)	2,064	0,230	—	8,986	0,000
Information technologies	0,551	0,044	0,531	12,584	0,000

Source: authors' research

According to the results in Table 2c, the coefficient B = 0.551 and the standardized coefficient Beta = 0.531 indicate that an increase in the degree of IT application by one unit leads to an increase in innovation by 0.551 units. The impact is high and statistically significant ($p < 0.001$), which confirms the hypothesis that IT has a direct and positive effect on the innovativeness of organizations.

3.2.1. Multiple regression analysis of information technologies factors

In order to take a more detailed look at the individual effects of different dimensions of information technologies on the innovativeness of organizations, a multiple regression analysis was conducted with six independent variables (IT factors). Multiple regression results are shown in Tables 3a, 3b and 3c, which include a model summary, ANOVA significance test and regression coefficients for each factor.

Table 3a. Summary of multiple regression analysis models

Model	R	R^2	Adjusted R^2	Std. Error
1	0,546	0,298	0,287	1,21027

Source: authors' research

As shown in Table 3a, the six analyzed information technologies factors together explain 29.8% of the variance of organizations' innovativeness ($R^2 = 0.298$). This result indicates a moderately strong model and confirms that the combination of several aspects of IT implementation contributes significantly to the prediction of innovativeness.

Table 3b. ANOVA test of significance of the multiple regression model

Source of variation	SS	df	MS	F	Sig.
Regression	248,013	6	41,336	28,220	0,000
Residual	584,434	399	1,465		
Total	832,447	405			

Source: author's research

The results shown in Table 3b show that the model is statistically significant ($F = 28.220$; $p < 0.001$). This means that the analyzed information technologies factors as a whole are reliable predictors of organizational innovativeness. The obtained result confirms the justification of the application of multiple regression in this research.

Table 3c. Multiple regression analysis coefficients for information technologies factors

Predictor	B	Std. Error	Beta	t	Sig.
(Constant)	2,074	0,238	—	8,728	0,000
VAR00058	-0,302	0,505	-0,307	-0,598	0,550
VAR00059	0,343	0,514	0,351	0,666	0,505
VAR00060	0,187	0,080	0,204	2,326	0,021
VAR00061	0,091	0,075	0,103	1,214	0,226
VAR00062	-0,004	0,074	-0,004	-0,053	0,957
VAR00063	0,228	0,061	0,256	3,744	0,000

Source: authors' research

Note: $p < 0,05$ *; $p < 0,01$ **

As seen in Table 3c, only two variables show a statistically significant impact on innovativeness:

- VAR00060 ($B = 0,187$; $\beta = 0,204$; $p = 0,021$)

- VAR00063 (B = 0,228; β = 0,256; p = 0,000)

These results indicate that precisely these information technologies factors have the strongest contribution to the innovativeness of organizations. Positive and significant coefficients suggest that an increase in the application of these IT dimensions leads to a proportional increase in innovation. The greatest contribution is made by those IT factors related to digital support of business processes and knowledge management, which indicates that innovation depends on the way in which IT is used, and not only on its presence in the organization.

4. Discussion

The results clearly show that information technologies have a significant and positive impact on the innovativeness of organizations. Correlation and regression analyzes have confirmed that greater application of IT solutions contributes to the development of all forms of innovation, i.e. products and services, processes and administrative innovations. These findings are consistent with modern theoretical approaches that view information technologies as a driver of innovation processes and a key element of digital business transformation (Chen & Kim, 2023; Li et al., 2023; Lee & Yeo, 2024). The results show that there is a moderately strong and statistically significant relationship between IT and product and service innovation ($r = 0.484$, $p < 0.001$). This finding indicates that digital solutions, information systems and software platforms contribute to the development and faster placement of new products and services. IT enables businesses to better understand customer needs through data analytics, feedback and offer personalization. In this way, information technologies become a key tool for creating a competitive advantage. The findings are consistent with research that points out that digital technologies accelerate innovation and increase market agility (Yao & Li, 2023; Vărzaru & Bocean, 2024; Zhang & Yuan, 2023). The relationship between IT and process innovation ($r = 0.475$, $p < 0.001$) confirms that information technologies play a significant role in improving internal business activities. The results are in line with theoretical models that recognize IT as a mechanism of process optimization and digital integration (Bitkowska et al., 2022; Kubrak et al., 2023). The highest degree of association was observed between IT and administrative innovations ($r = 0.527$, $p < 0.001$). This finding indicates that information technologies have the greatest impact in the field of management, organization and administration, especially through digitization of documents, electronic communication and automated data management. This reduces the bureaucratic burden, increases transparency and speeds up the exchange of information within the organization. The results are in line with the concept of digital transformation, according to which IT changes the way organizations work and becomes the basis for the development of flexible, innovative and agile business structures (Lee & Yeo, 2024; Yang et al., 2024; Kurniadi et al., 2025). A simple regression model showed that information technologies explained 28.2% of the variance of innovativeness ($R^2 = 0.282$), which represents a moderately strong effect. This finding confirms that IT has a direct, quantitatively measurable and statistically significant impact on organizational innovativeness. In the multiple regression model ($R^2 = 0.298$), two dimensions of IT (VAR00060 and VAR00063) proved to be statistically significant predictors of innovation, implying that digital collaboration and knowledge management have the greatest contribution to innovation processes. Other factors did not show a significant impact, which indicates that the technological infrastructure in itself is not enough, but that the way of its use, as a support for communication, learning and creativity of employees, is crucial.

Based on the obtained results, it can be concluded that all three hypotheses are confirmed, i.e. H1: „There is a positive and statistically significant relationship between the application of information technologies and innovativeness of organizations“ ($r = 0.531$; $p < 0.001$), H2: „Information technologies significantly contribute to product and service innovation“ ($r = 0.484$; $p < 0.001$) and H3: „Information technologies have a positive effect on process innovation and administrative innovation“ as partially confirmed because IT shows a statistically significant effect on both dimensions (process and administrative innovations), with the influence being more pronounced in the administrative segment ($r = 0.527$; $p < 0.001$). Based on the findings of the research, the practical implications that can be singled

out are the integration of information technologies into the innovation strategy, the development of the digital competence of employees, the encouragement of cooperation and knowledge sharing, the digitization of processes and administration, and the monitoring of technological trends. Technology within the organization has corresponding effects if it is accompanied by digital literacy and employees' readiness for change. Also, IT tools should be used to strengthen teamwork, communication and joint problem solving, and the automation of documentation and business procedures can increase efficiency and free up resources for innovation.

Conclusion

The empirical findings of the conducted research confirm that information technologies represent a key factor of innovation in modern organizations. Their influence proved to be multidimensional, as it includes the development of new products and services, the optimization of business processes and the digitization of administrative activities. The obtained results are in accordance with the theoretical assumptions about digital transformation and can serve as a basis for formulating modern strategies that integrate technological and innovation management. This research contributes to the scientific literature by empirically confirming theoretical claims about the positive relationship between digitization and innovation. The results complement existing models of innovation and indicate that the role of information technologies is reflected in technical support for business, as well as in the creation of new values, knowledge and competitive advantages. Organizations that recognize and strategically use the potential of information technologies gain a competitive advantage because they can innovate faster, adapt to market changes, and create additional value for users. For future research, it is recommended to expand the model by including additional variables, such as organizational culture, type of industry and level of digital maturity, as well as applying a longitudinal approach to monitor changes over time. Comparisons between sectors and regions could contribute to the understanding of specificities in the application of information technologies, while qualitative analyzes of examples of good practice would further shed light on the ways in which IT contributes to innovation in different contexts. The practical implications of the research indicate that organizations should view investments in information technologies as an investment in innovation, not just in technical support. It is especially important to develop digital competencies of employees and organizational capacities for using IT in innovation activities. The focus should be on digital collaboration, knowledge management and the use of data as key drivers of innovation.

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Case Study on the Methodology of Conducting the Internal Public Audit Mission: Improving the Continuous Professional Development of Personnel

Studija slučaja o metodologiji sprovođenja misije interne javne revizije: Unapređenje kontinuiranog stručnog razvoja osoblja

Mladin Franca[1], Nagy Cristina Mihaela[2]

[1] *"Tibiscus" University of Timișoara, Faculty of Economics, Timisoara, Romania, frankamladin@yahoo.com*
[2] *"Tibiscus" University of Timișoara, Faculty of Economics, Timisoara, Romania, c.nagy@tibiscus.ro*

Abstract: *The paper on the internal public audit mission regarding the improvement of continuous professional development activities for personnel was developed by following specific procedures and documents structured according to the stages of conducting an internal audit mission, as established by general norms. The objectives of the internal public audit mission regarding "Improving the Continuous Professional Development of Personnel" were as follows: adequacy and sufficiency of the continuous professional development programs for personnel; ensuring the performance of the continuous professional development process for personnel; ensuring appropriate competencies and responsibilities to efficiently conduct the professional training activities.*
Keywords: *Internal public audit, auditors 'report, risks, internal control.*

Apstrakt: *Rad o ulozi interne javne revizije u vezi sa unapređenjem aktivnosti kontinuiranog stručnog usavršavanja zaposlenih razvijen je prateći specifične procedure i dokumente strukturirane prema fazama sprovođenja misije interne revizije, kako je utvrđeno opštim normama. Ciljevi misije interne javne revizije u vezi sa „Unapređenjem kontinuiranog stručnog usavršavanja zaposlenih" bili su sledeći: adekvatnost i dovoljnost programa kontinuiranog stručnog usavršavanja zaposlenih, obezbeđivanje sprovođenja procesa kontinuiranog stručnog usavršavanja zaposlenih, obezbeđivanje odgovarajućih kompetencija i odgovornosti za efikasno sprovođenje aktivnosti stručnog usavršavanja.*
Ključne reči: *Interna javna revizija, izveštaj revizora, rizici, interna kontrola.*

Introduction

Within the dynamics of a public entity, human resources represent the most valuable asset, naturally driving its development and competitive progress.

„The human resources audit evaluates the activity of the human resources in an organization having the goal of improving those activities. In the same time the audit provides feedback towards the personnel, especially towards the way in which the activities are performed" (Lepadat & Turnea, 2015).

The professional training of staff constitutes a continuous learning process through which employees acquire theoretical knowledge and practical skills necessary for the effective performance of their activities.

Continuous professional training contributes directly to individual and organizational performance, as highlighted by Erasmus, Grobler, & Van Niekerk, who emphasize the strategic role of training and development in improving workplace effectiveness (Gramling et al., 2004).

The training process must assess both the accumulation of knowledge and the behavioral changes at the individual level, based on the analysis of modifications in employees' conduct at the workplace, the evaluation results, and data concerning individual productivity.

The responsibility for evaluating the practical application of the knowledge acquired during professional training courses rests with the management of the organizational structures to which the public servant belongs. These outcomes should also be communicated to the Professional Training Service, in order to be considered in future assessments of training needs. However, such a system of record does not currently exist within the Professional Training Service.

In the current context, in which public administration faces challenges generated by globalization, digitalization, and the increasing demands of citizens, the continuous professional training of staff becomes a decisive factor for institutional performance. Human resources represent a strategic element, and investment in their development is directly reflected in the quality of public services delivered.

Internal public audit, regulated by Law no. 672/2002 and subsequent regulations, is designed to ensure, through a systematic and objective approach, the evaluation and improvement of organizational processes. This study analyzes the methodology for conducting an internal public audit mission focused on improving the activity of continuous professional training of personnel, highlighting the relevance of procedural stages, the risks identified, and the recommendations formulated to strengthen the efficiency and effectiveness of the training process.

Internal audit, as underlined in the literature, plays a significant role in strengthening corporate governance and ensuring accountability within organizations (Erasmus et al., 2015).

1. Methodology for conducting the internal public audit mission: improving continuous professional development activities for personnel

The purpose of a public internal audit mission is to provide assurance on how the legal activity is conducted and to represent in court in such a way as to support the interests of an entity, according to the legislative framework and the normative framework (Ghica, 2024).

The methodology for conducting the internal public audit mission on "Improving Continuous Professional Development Activities for Personnel" includes the following stages:

- **Preparation phase** (Government Decree No. 1,086 of December 11, 2013 approving the General Norms regarding the exercise of internal public audit activity): The documents required by regulations were prepared, with clarifications provided regarding the specific procedures for collecting and processing information, analyzing risks, evaluating internal control, and determining the sequence of documents.
- **On-site intervention phase**: Documents were drafted to present how different audit techniques were used to establish the findings, which will be included in the report of the internal public audit mission.
- **Reporting phase**: A model report of the internal public audit mission was drafted, structured according to the objectives set for the audit. It includes the audit findings, conclusions, and formulated recommendations.
- **Follow-up phase**: The appropriateness, effectiveness, and timeliness of actions taken to implement the recommendations were monitored.

In accordance with the provisions of Article 13(c) of Law No. 672/2002 regarding internal public audit (republished with subsequent amendments) and Government Decision No. 1086/2013 for the approval of the General Norms regarding the exercise of internal public audit activities, as well as the Annual Internal Public Audit Plan for 2024, an internal public audit mission titled "Improving Continuous

Professional Development Activities for Personnel" will be conducted from February 3, 2024, to February 28, 2024.

The purpose of the mission is to analyze the responsibilities assumed by the management of the Human Resources Directorate – Professional Training Service regarding the efficient and effective organization and implementation of activities. It should be noted that an internal public audit of the performance of continuous professional development activities will be carried out.

The service order was issued by the head of the internal audit department based on the annual internal audit plan. It represents the intervention mandate granted by the internal audit structure to the auditor/audit team conducting the internal public audit mission and assigns tasks to the nominated auditors for carrying out the mission (Law No. 672 of December 19, 2002 (*republished*) on internal public audit updated). It defines the scope of the audit and informs those responsible for the mission about the following:

- The legal framework for conducting the internal public audit mission;
- The audit scope;
- The general objectives of the internal public audit mission;
- The period during which the internal public audit mission will take place;
- The names of the auditors designated to carry out the internal public audit mission.

2. Auditors` indenpendence

The independence of the internal auditors designated to carry out a mission must be declared, which is why each member of the internal audit team prepared a Declaration of Independence (Danescu & Prozan, 2020). The Declaration of Independence must ensure: elimination of incompatibilities between the internal auditor and the management of the audited structure and the employees whose activities are being audited; independence from the activities being audited, meaning that the auditor must not have been involved in these activities for at least three years; the professional competence of the internal auditor, with appropriate knowledge and skills to achieve the mission's objectives and obtain the expected results (Government Decree No. 1,086 of December 11, 2013 approving the General Norms regarding the exercise of internal public audit activity).

The head of the internal audit department ensured that no auditor was assigned where there were personal incompatibilities, and objectivity could not be demonstrated for the audited entity. If a real or perceived incompatibility arises during the internal public audit mission, the auditors are obliged to inform the head of the internal audit department immediately.

3. General mission objectives

The general objectives of the mission are:

- The adequacy and sufficiency of continuous professional development programs for personnel;
- Ensuring the performance of the continuous professional development process for personnel;
- Ensuring appropriate competencies and responsibilities to efficiently conduct professional training activities.

Additionally, the date and organization of the mission's opening meeting were agreed upon, during which the following were considered (Law No. 672 of December 19, 2002 (*republished*) on internal public audit updated):

a. Presentation of the auditors;

b. Presentation and documentation of the general objectives of the mission;

c. The purpose of the mission;

d. The method of conducting the mission, and the contact persons;

e. Other aspects.

Documentation was also requested regarding: planning, organizing, and controlling the auditable activities; the regulatory framework and applicable regulations for the audited domain; the list of general and specific objectives related to the activity of the Professional Training Service; plans for continuous professional development of personnel; strategies and policies for continuous professional development of personnel; organizational charts, operational manuals, regulations on organization and functioning, and job descriptions; performance indicators/goals/quantification methods; internal audit reports related to the auditable domain, operational procedures underlying the activities, statistics on seminars and courses organized, topics, and participants.

In the preparation phase of the mission, external public auditors analyzed risks and evaluated internal control for the three objectives (Government Decree No. 1,086 of December 11, 2013 approving the General Norms regarding the exercise of internal public audit activity). The identified risks for each objective were as follows:

Objective 1: Adequacy and sufficiency of continuous professional development programs

- Training needs expressed by the entity's structures contain incomplete and unsubstantiated information;
- The database contains exhaustive and irrelevant information for analyzing training needs;
- Training actions are incorrectly determined concerning individual and entity objectives;
- The absence of a formalized training plan tailored to needs;
- The inadequacy and non-prioritization of the training needs of the annual training program concerning the financial resources allocated to the activity.

Objective 2: Ensuring the performance of the continuous professional development process

- Resources allocated to training are used inadequately compared to needs;
- The training process disrupts the optimal conduct of the public entity's current activities;
- Internal and external professional training services are used inappropriately;
- The expected results from the training process are not achieved.

Objective 3: Ensuring appropriate competencies and responsibilities

- Ambiguous organizational relationships within the Professional Training Service;
- Professional Training Service activities are inadequately assigned to personnel;
- Non-implementation of operational and reciprocal control;
- Failure to assess the professional training needs of personnel.

Following the review of the documents submitted to the internal public auditors regarding the three general objectives of the mission—namely: the adequacy and sufficiency of continuous professional training programs for staff; ensuring the performance of the continuous professional training process; and ensuring appropriate competencies and responsibilities for the efficient implementation of professional training activities—together with the risks identified, a series of Tests and Problem Identification and Analysis Sheets (FIAP) were elaborated.

The Problem Identification and Analysis Sheet (FIAP) is generally drafted for one or more issues, deviations, irregularities, or dysfunctions identified, provided they share the same underlying cause. The FIAP includes the following elements: the problem, the finding, the cause, the consequence, as well as the recommendation formulated by the internal auditors.

It is important to note that all findings and recommendations formulated by the internal public auditors are discussed and analyzed with the management of the audited high school institution. Representatives of the audited entity are required to sign for acknowledgment of all FIAPs. Should the representatives refuse to sign for acknowledgment, the audit team continues its procedures and simultaneously transmits all prepared documents through the entity's registry office.

As an example, the following section presents Test no. 1 corresponding to the objective "Adequacy and sufficiency of continuous professional training programs for staff."

A test includes information on the mission objective, the test objective, the sampling method, the test description, findings, and conclusions.

Test no. 1

- Mission objective: Adequacy and sufficiency of the annual professional training programs for staff.
- Test objective: Optimization of staff training needs ensured through the quality of the professional training programs developed.
- Sampling method: For this test, all documents that formed the basis for the elaboration of the annual professional training programs for 2022 and 2023 were analyzed (necessity reports of organizational structures, their supporting notes, staff evaluation reports, proposals of course topics from participants, etc.).
- Test description: The test aimed to assess the process of drafting and substantiating the annual professional training programs, as well as the effectiveness of actions undertaken to address identified training needs.

Findings

For the analyzed period, requests were sent to organizational structures, but they were not formalized, and the responses received were generally vague, lacking justification or deadlines. Out of an average of 60 annual requests for training topics, only 15 (25%) were included in the final plans, with the remainder being established exclusively by the Professional Training Service.

Specialized departments did not consistently request the organization of professional training courses during the year to support theoretical and practical grounding of legislative changes. Consequently, training plans included such topics, some proposed by the Professional Training Service, but not always yielding the desired outcomes (e.g., the organization of courses after the entry into force of new regulations led to diminished interest among specialized departments).

At the level of the public entity, three training programs are underway, targeting three specialized departments, with the Professional Training Service responsible for logistical support. Within beneficiary departments, all staff members are included in the training programs by rotation, over a two-year period.

The analysis of 500 staff evaluation reports for 2021 revealed that in 53 reports (10.6%), managers requested three training topics for their subordinates, in 65 reports (13%) two topics, in 170 reports (34%) one topic, and in the remaining 42.4% no training needs were indicated. For 2022 and 2023, the percentages remained nearly identical: 12% of evaluations included three training topics, 12% two topics, 36% one topic, and 40% contained no proposals. The topics suggested were reflected to a very limited extent in subsequent departmental proposals or in the final professional training plans.

The process of substantiating training plans has proven ineffective. It is, however, vital to the entire training activity, particularly for ensuring an effective assessment of training needs. Effectiveness relies on a clear understanding and acknowledgment of the objectives pursued through this activity.

When correlating performance measurement indicators with the objective of optimizing training activities through the analysis of staff training needs, the limited number and representativeness of indicators did not allow for a performance-oriented interpretation of results. For example, the indicator "existence of an annual training plan," achieved at 100%, does not guarantee the effective planning and delivery of training activities with measurable performance outcomes. Therefore, it is necessary to introduce new performance indicators regarding the optimization of professional training activities, such as:

- number of responses aligned with requests / number of responses received / number of requests issued – target: 100%;
- number of priority items in requests from organizational structures / number of planned actions – target: 100%;
- number of training sessions conducted through digital methods / total planned actions – target: 50%;
- number of actions carried out with internal trainers / number of actions with external trainers / total planned actions – target: 80%.

Problem identification and analysis sheet no. 1

Problem: Inadequate and insufficient substantiation of the annual professional training program for staff in the public entity.

Finding: During the analyzed period, requests from organizational structures were not formalized, and the responses received were vague, lacking justification and deadlines.

Specialized departments did not request professional training courses throughout the year to support regulatory updates. Staff evaluation reports, including managers' recommendations regarding training needs, were not prioritized in the planning process.

Cause: Inadequate feedback between training service organizers and beneficiaries; orientation of training activities toward cost reduction rather than professionalism; lack of innovative, digitalized training methods; insufficient motivational tools for staff career development.

Consequence: The process of substantiating training plans has proven ineffective. Annual training plans largely reflected the perspective of the Professional Training Service, rather than actual training needs, leading to activities being implemented without fully achieving their intended objectives or performance indicators.

Recommendation: Establish a permanent dialogue with staff regarding their training requests, and design a viable, formalized, and continuously updated offer at the level of each organizational structure, monitored by the responsible manager.

Organize quarterly debate groups, and whenever requested by a responsible officer, with the participation of all training coordinators from the public entity.

Conclusion

The results of the research confirm that continuous professional training is a sine qua non condition for achieving institutional performance objectives. The audit mission analysis revealed shortcomings in the foundation of training programs, in the integration of needs expressed by organizational structures, and in the application of modern training methods. Furthermore, the lack of rigorous mechanisms for monitoring training outcomes limits their impact on organizational activity.

It is therefore necessary to rethink policies and procedures regarding human resource development, by strengthening the dialogue between professional training services and beneficiaries, defining relevant performance indicators, and diversifying training methods. In this way, internal public audit asserts its role as a tool of modern governance, contributing to the optimization of resource use and the improvement of the quality of public services.

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Evaluation of the Criteria Affecting Cloud Computing in Manufacturing Enterprises with Corporate Identity: The Case of Samsun Province

Evaluacija kriterijuma koji utiču na cloud computing u proizvodnim preduzećima sa korporativnim identitetom: slučaj provincije Samsun

Selçuk Korucuk[1], Ahmet Aytekin[2]

[1]*Giresun University, Bulancak Kadir Karabas Vocational School, Department of Logistics Management, Giresun, Turkey, selcuk.korucuk@giresun.edu.tr*
[2]*Samsun University, Faculty of Political Sciences, Depart Department of International Trade and Business, Samsun, Turkey, ahmet.aytekin@samsun.edu.tr*

Abstract: *One of the most significant transformations that businesses face today is expanding into new markets and increasing their competitiveness by leveraging the opportunities offered by technology. In this context, cloud technology has become a strategic tool for enterprises. Cloud computing enhances business efficiency and transforms business processes by providing its users with crucial benefits such as cost advantage, flexibility, scalability, and rapid access. This technology, which fundamentally affects the way businesses operate, not only optimizes operational processes but also becomes central to innovation and digital transformation strategies. Moreover, through cloud computing, enterprises can enhance their data management and analytical capacity, enabling faster and more accurate decision-making and strengthening their competitive advantage. Therefore, cloud technology plays a critical role in modern enterprises' goals of sustainable growth and competitiveness in global markets, making the identification of factors affecting cloud computing increasingly important. In this context, the factors affecting cloud computing have gained importance and become issues that need to be addressed with great care. Within the scope of this study, the factors influencing cloud computing in manufacturing enterprises were identified and ranked. For this purpose, the Picture Fuzzy SWARA method was applied. According to the analysis results, the most important criteria among the factors affecting cloud computing in manufacturing enterprises were determined as 'Flexibility,' 'Wide Network Access,' and 'Cost,' while the least important criterion was found to be 'On-Demand Service.*
Keywords: *Cloud computing, factors affecting cloud computing, MCDM, picture fuzzy SWARA method.*

Apstrakt: *Jedna od najznačajnijih transformacija sa kojima se preduzeća danas suočavaju jeste širenje na nova tržišta i povećanje njihove konkurentnosti iskorišćavanjem mogućnosti koje nudi tehnologija. U tom kontekstu, cloud tehnologija je postala strateški alat za preduzeća. Cloud računarstvo poboljšava poslovnu efikasnost i transformiše poslovne procese pružajući svojim korisnicima ključne prednosti kao što su troškovna prednost, fleksibilnost, skalabilnost i brz pristup. Ova tehnologija, koja fundamentalno utiče na način na koji preduzeća posluju, ne samo da optimizuje operativne procese, već postaje i centralna za inovacije i strategije digitalne transformacije. Štaviše, putem cloud računarstva, preduzeća mogu poboljšati svoje upravljanje podacima i analitičke kapacitete, mogu brže i preciznije donositi odluke i unaprediti svoju konkurentsku prednost. Stoga, cloud tehnologija igra ključnu ulogu u ciljevima modernih preduzeća u pogledu održivog rasta i konkurentnosti na globalnim tržištima, što identifikaciju faktora koji utiču na cloud računarstvo čini sve važnijom. U ovom kontekstu, faktori koji utiču na cloud računarstvo dobili su na značaju i postali su pitanja kojima se treba pozabaviti sa velikom pažnjom. U okviru ove studije, identifikovani su i rangirani faktori koji utiču na cloud računarstvo u proizvodnim preduzećima. U tu svrhu primenjena je Picture Fuzzy SWARA metoda. Prema rezultatima analize,*

najvažniji kriterijumi među faktorima koji utiču na cloud computing u proizvodnim preduzećima su „Fleksibilnost“, „Široki pristup mreži“ i „Cena“, dok je najmanje važan kriterijum „Usluga na zahtev“.
***Ključne reči**: Cloud računarstvo, faktori koji utiču na klaud računarstvo, VKO, picture fuzzy SWARA Method.*

Introduction

Recent technological advancements have ushered in a new era with the emergence of cloud computing, which is anticipated to bring about significant developments. Cloud computing services have increasingly become the backbone of many organizations' commercial activities, where dimensions such as availability, reliability, cost, scalability, and security are regarded as critical considerations (Saratchandra & Shrestha, 2022). According to IBM (2022), cloud computing refers to the on-demand utilization of computing resources—such as applications, servers (both physical and virtual), data storage, development tools, and networking capabilities—hosted in a remote data center managed by a cloud service provider. Another definition conceptualizes cloud computing as a model that enables easy access to computing resources, including servers, networks, and applications, which can be rapidly provisioned with minimal management effort. By offering flexible solutions tailored to organizational needs, cloud computing simplifies the management of vast volumes of data and supports enterprises in enhancing operational efficiency and adaptability (Kumari & Kaur, 2021).

Cloud computing enables cost savings for both consumers and companies, while simultaneously enhancing collaboration, scalability, availability, and agility. In other words, cloud computing encompasses the utilization of a wide range of applications, information, infrastructure, networks, storage, information resources, and distributed services (Vinoth et al., 2022). The storage and processing of data in cloud computing hold significant importance for data owners. If data is considered valuable enough to be stored, then its processing and interpretation are also likely to generate benefits. Therefore, a comprehensive examination of data within cloud computing is crucial for individuals and organizations planning to adopt cloud computing infrastructures (Dokuz & Çelik, 2017).

In daily life, cloud computing—widely adopted by individuals—offers advantages such as scalability, flexibility, agility, and simplicity, which explains its rapidly increasing use within enterprises (Garrison et al., 2012). These applications also facilitate business operations such as data storage, backup, and recovery. In addition, cloud infrastructures enable enterprises to access their data across different geographical regions and ensure business continuity. Consequently, with the widespread adoption of cloud technologies, organizations are able to build larger business ecosystems and foster collaboration more effectively (Mell & Grance, 2011).

These systems not only contribute to minimizing operational costs but also provide advantages such as efficient services, data security, product registration and payment, and the optimal utilization of resources (Shah, 2014). Through this technology, organizations can quickly access the resources they need without requiring substantial hardware and software investments, while managing their business processes more dynamically with scalable solutions. In this context, cloud computing has become a strategic tool particularly for small and medium-sized enterprises (SMEs), as it facilitates the digitalization process and enhances competitive advantage (Marston et al., 2011).

Based on the aforementioned aspects, identifying the criteria that influence cloud computing applications, which provide numerous advantages to businesses, is of critical importance and must be addressed with great care. The identification and ranking of factors affecting cloud computing applications in manufacturing enterprises is considered a significant indicator. Determining and prioritizing these relevant factors not only adds value to the business processes and strategies of manufacturing firms but also contributes to meeting performance, efficiency, and cost requirements. Therefore, this study serves as a guide in addressing existing gaps. Consequently, the proposed framework for the decision-making problem examined in this study contributes to filling theoretical and methodological gaps in the literature and provides important insights for researchers in the field. In this context, the proposed approach for evaluating the criteria affecting cloud computing applications

in manufacturing enterprises establishes a reliable and robust theoretical foundation for academic studies, scientific research, and practical solutions. In this respect, the study serves as a critical reference source, particularly for researchers focusing on decision-making problems in the relevant domain.

Within this framework, the study aims to identify the criteria affecting cloud computing applications in manufacturing enterprises and proposes the Picture Fuzzy Subjective SWARA model as a solution. The research is organized into four sections. The second section presents a literature review on cloud computing applications in firms. The third section explains the methods employed in the study. The final section concludes the research by providing policy recommendations, suggestions for future research, and outlining the limitations of the current study.

1. Literature

This section presents national and international studies on cloud computing applications:

- Wu et al. (2010) examined the fundamental technologies in cloud computing and cloud storage, discussed various types of cloud services, introduced a cloud storage reference model, and then explained the advantages and challenges of cloud storage.
- Marston et al. (2011) identified the strengths, weaknesses, opportunities, and threats of the cloud computing industry and examined various issues affecting different stakeholders.
- Aljabre (2012) investigated existing cloud computing services, presenting both the advantages and disadvantages of cloud computing in business.
- Abdollahzadegan et al. (2013) evaluated the impact of organizational factors on cloud computing adoption in SMEs.
- Avram (2014) analyzed the factors that a company should consider when deciding to use cloud computing.
- Yarlıkaş & Bilgen (2015) assessed the problems faced by cloud computing users in terms of their importance levels and provided various recommendations.
- Xue et al. (2016) examined the advantages and disadvantages of cloud computing in business contexts.
- Dokuz & Çelik (2017) investigated different dimensions of data on cloud computing infrastructures and the strategies employed in these dimensions.
- Lou et al. (2018) synthesized the strengths of the Diffusion of Innovations theory and the Dynamic Capabilities theory into a framework to determine the applicability of cloud computing as a source of competitive advantage.
- Amron et al. (2019) aimed to review and identify the factors affecting the adoption of cloud computing in enterprises.
- Atan (2020) examined the literature regarding the positive and negative aspects of cloud platforms, focusing on risks and challenges highlighted in previous studies.
- Cai & Chen (2021) developed a human resources archival decision support system by leveraging cloud computing features such as large-scale capacity, high reliability, versatility, and scalability within management and decision-making applications.
- Gülburun & Dener (2022) conducted a review of the challenges and recent studies on cloud computing security.
- Koşar & Atak (2023) investigated a multi-criteria decision support model for selecting cloud-based virtual server products.

- Odukaya (2024) provided a comprehensive analysis of the transformative impact of cloud computing on SMEs, emphasizing its role as a catalyst for operational efficiency, agility, and competitive advantage in today's digital environment.
- Ulutürk (2024) examined the impact of cloud computing technologies on the sustainability of enterprises.
- Reis et al. (2025) conducted a systematic literature review covering 2018–2023 to comprehensively describe the barriers associated with cloud computing adoption and classify them.

As a result of this comprehensive literature review, it was observed that studies addressing the factors influencing the adoption and effective use of cloud computing are quite limited. This indicates a significant gap in both theoretical knowledge and practical applications. The purpose of the present study is to contribute to bridging this gap by offering new and comprehensive perspectives on the determinants of cloud computing, while also promoting a deeper understanding of the topic. In this context, the study aims to provide meaningful contributions to the academic literature and guide enterprises in developing their cloud computing strategies.

2. Methodology

2.1. Picture fuzzy sets

Cuong & Kreinovich (2013) proposed Picture Fuzzy Sets (PFSs) as an extension of Intuitionistic Fuzzy Sets. PFSs model uncertainty more realistically by simultaneously expressing degrees of membership, non-membership, and abstention. This feature enables more flexible and accurate decision-making processes. PFSs also offer a more comprehensive approach by generalizing classical and intuitionistic fuzzy sets.

Assume that X is a discourse universe. Then, a PFS B can be defined in Eq. (1), where $\mu_B(x), \eta_B(x), \nu_B(x) \in [0,1]$ (Cuong & Kreinovich, 2013; Görçün et al., 2024):

$$\mathrm{B} = \{\langle x, \mu_B(x), \eta_B(x), \nu_B(x)\rangle | x \in X\}, \tag{1}$$

Here $\mu_B(x)$ denotes the positive membership degree, $\eta_B(x)$ denotes the neutral membership degree, and $\nu_B(x)$ represents the negative membership degree. On the other hand, Eq. (2) should be satisfied (Cuong & Kreinovich, 2013; Görçün et al., 2024):

$$0 \leq \mu_B(x) + \eta_B(x) + \nu_B(x) \leq 1, \forall x \in X. \tag{2}$$

The degree of refusal membership of x in B is expressed as $\pi_B(x) = 1 - (\mu_B(x) + \eta_B(x) + \nu_B(x))$. Let b, b_1, and b_2 be three PF numbers (PFNs), where $b = \langle \mu_b, \eta_b, \nu_b \rangle$, $b_1 = \langle \mu_{b_1}, \eta_{b_1}, \nu_{b_1} \rangle$, and $b_2 = \langle \mu_{b_2}, \eta_{b_2}, \nu_{b_2} \rangle$. Accordingly, the basic operations on PFNs are given in Eq.s (3)-(7) (Cuong & Kreinovich, 2013; Görçün et al., 2024):

$$b_1 \oplus b_2 = \langle 1 - \left(1 - \mu_{b_1}\right)\left(1 - \mu_{b_2}\right), \eta_{b_1}\eta_{b_2}, \left(\eta_{b_1} + \nu_{b_1}\right)\left(\eta_{b_2} + \nu_{b_2}\right) - \eta_{b_1}\eta_{b_2} \rangle, \tag{3}$$

$$b_1 \otimes b_2 = \langle \left(\mu_{b_1} + \eta_{b_1}\right)\left(\mu_{b_2} + \eta_{b_2}\right) - \eta_{b_1}\eta_{b_2}, \eta_{b_1}\eta_{b_2}, 1 - \left(1 - \nu_{b_1}\right)\left(1 - \nu_{b_2}\right) \rangle, \tag{4}$$

$$b_1 \otimes b_2 = \langle \left(\mu_{b_1} + \eta_{b_1}\right)\left(\mu_{b_2} + \eta_{b_2}\right) - \eta_{b_1}\eta_{b_2}, \eta_{b_1}\eta_{b_2}, 1 - \left(1 - \nu_{b_1}\right)\left(1 - \nu_{b_2}\right) \rangle, \tag{5}$$

$$\lambda \cdot \mathrm{b} = \langle 1 - (1 - \mu_b)^\lambda, (\eta_b)^\lambda, (\eta_b + \nu_b)^\lambda - (\eta_b)^\lambda \rangle, \tag{6}$$

$$b^\lambda = \langle (\mu_b + \eta_b)^\lambda - (\eta_b)^\lambda, (\eta_b)^\lambda, 1 - (1 - \nu_b)^\lambda \rangle. \tag{7}$$

Let b_j be the collection of PFNs, where $j = 1, \dots, n$. The PF weighted arithmetic average (PFWAO) is calculated via Eq. (8). Furthermore, the PF weighted geometric average operator (PFWGO) is computed via Eq. (9), where $\lambda_i = (\lambda_1, \lambda_2, \dots, \lambda_n)^T$ is the weight vector (Cuong & Kreinovich, 2013; Görçün et al., 2024):

$$PFWAO_\lambda(b_1, \dots, b_n) = \bigoplus_{j=1}^{n} (\lambda_j, b_j)$$
$$= \langle 1 - \prod_{j=1}^{n} \left(1 - \mu_{b_j}\right)^{\lambda_j}, \prod_{j=1}^{n} \left(\eta_{b_j}\right)^{\lambda_j}, \prod_{j=1}^{n} \left(\eta_{b_j} + \nu_{b_j}\right)^{\lambda_j} - \prod_{j=1}^{n} \left(\eta_{b_j}\right)^{\lambda_j} \rangle. \tag{8}$$

$$PFWGO_\lambda(b_1, \dots, b_n) = \bigotimes_{j=1}^{n} \left(b_j\right)^{\lambda_j}$$
$$= \langle \prod_{j=1}^{n} \left(\mu_{b_j} + \eta_{b_j}\right)^{\lambda_j} - \prod_{j=1}^{n} \left(\eta_{b_j}\right)^{\lambda_j}, \prod_{j=1}^{n} \left(\eta_{b_j}\right)^{\lambda_j}, 1 - \prod_{j=1}^{n} \left(1 - \nu_{b_j}\right)^{\lambda_j} \rangle. \tag{9}$$

Eq. (10) is used to defuzzify a PFN, where $\pi_b = 1 - (\mu_b + \eta_b + \nu_b)$.

$$s(\mathrm{b}) = \mu_b + \frac{\eta_b}{2} + \frac{\pi_b(1 + \mu_b - \nu_b)}{2}, \tag{10}$$

2.2. Picture fuzzy SWARA

The steps below are used to apply PF-SWARA.

Step 1. The lists of criteria ($C = \{C_1, \dots, C_n\}$) and the experts ($E = \{E_1, \dots, E_z\}$) are identified.

Step 2. Importance levels of criteria are evaluated by experts using the linguistic terms provided in Table 1. Accordingly, $\text{ع}_{jk} = \langle \mu_{jk}, \eta_{jk}, \nu_{jk} \rangle$ denotes the PF importance of j-th criterion identified by k-th expert, where $j = 1, \dots, n;\ k = 1, \dots, z$.

Table 5. Linguistic terms for evaluating importance of criteria

Codes	Linguistic terms	Picture fuzzy number		
		μ	η	ν
VH	Very High	0.90	0.05	0.05
H	High	0.80	0.10	0.10
A	Moderate	0.50	0.20	0.20
L	Low	0.20	0.30	0.50
VL	Very Low	0.10	0.30	0.60

Step 3. The weights of experts λ_k is assigned, where $\sum_{k=1}^{z} \lambda_k = 1,\ 0 \le \lambda_k \le 1$.

Step 4. The integrated PF importance of j-th criterion ع_j is obtained via Eq. (8). After that, $\text{ع}_j = \langle \mu_j, \eta_j, \nu_j \rangle$ is produced.

Step 5. The crisp importance value of j-th criterion $s(\text{ع}_j)$ is calculated by appliyng Eq. (10).

Step 6. The ranking order of criteria is identified based on their $s(\text{ع}_j)$ values. The criterion has the largest $s(\text{ع}_j)$ value is placed in the first order.

Step 7. In the pairwise comparison based on the criteria rankings, the comparative importance of each criterion c_j is calculated by subtracting the $s(\text{ع}_j)$ value of the second significant criterion from $s(\text{ع}_j)$

value of the first important criterion. Each ordered pair of criteria goes through the same procedure. In this context, $c_j = 1$ is assigned to the criterion that is placed in the first ranking order.

Step 8. The modified comparative importance of each criterion ζ_j is computed using Eq. (11)

$$\zeta_j = \begin{cases} 1, & \text{if j} = 1, \\ c_j + 1, & \text{if j} \neq 1. \end{cases} \tag{11}$$

Step 9. For each criterion, $\digamma_j$ is calculated using Eq. (12).

$$\digamma_j = \begin{cases} 1, & \text{if j} = 1, \\ \frac{\digamma_{j-1}}{\zeta_j}, & \text{if j} \neq 1. \end{cases} \tag{12}$$

Step 10. The weight coefficients of criteria are determined via Eq. (13).

$$w_j = \frac{\digamma_j}{\sum_{j=1}^{n} \digamma_j}. \tag{13}$$

3. Results

This study investigates the factors affecting the cloud computing of businesses. To achieve this purpose, the Picture Fuzzy SWARA method has been employed. The identified factors are presented in Table 2.

Table 2. The list of criteria

Codes	Criteria	Source(s)
C1	Flexibility	Bharadwaj & Lal, (2012).
C2	On-Demand Service	Mohammed & Zeebaree (2021).
C3	Resource Pooling	Haurech, & Martinez (2021)
C4	Wide Network Access	Omwenga vd. (2014)
C5	Measured Service	Simmon (2018)
C6	Cost	Mohammed & Zeebaree (2021).
C7	Scalability	Omwenga vd. (2014)
C8	Reliability and Privacy	Simmon (2018)

Five experts with extensive knowledge and experience on the issue are contacted about how to solve the problem. Table 3 shows the linguistic evaluations of experts on criteria.

Table 3. The linguistic evaluations of criteria

	C1	C2	C3	C4	C5	C6	C7	C8
E1	H	A	H	H	A	H	H	H
E2	VH	L	A	H	A	VH	A	H
E3	H	L	L	H	H	VH	A	H
E4	H	A	A	VH	H	H	A	H
E5	VH	H	H	VH	H	H	H	VH

Table 4 displays the PF- integrated importance of criteria.

Table 4. The results of PF- subjective weighting approach

	C1			**C2**			**C3**			**C4**		
	μ_j	η_j	ν_j	μ_j	η_j	ν_j	μ_j	η_j	ν_j	μ_j	η_j	ν_j
ع_j	0.8484	0.0758	0.0758	0.4976	0.2048	0.2547	0.6193	0.1644	0.1838	0.8484	0.0758	0.0758
$s(\text{ع}_j)$	0.8863			0.6267			0.7248			0.8863		
	C5			**C6**			**C7**			**C8**		
	μ_j	η_j	ν_j	μ_j	η_j	ν_j	μ_j	η_j	ν_j	μ_j	η_j	ν_j
ع_j	0.7115	0.1320	0.1320	0.8484	0.0758	0.0758	0.6534	0.1516	0.1516	0.8259	0.0871	0.0871
$s(\text{ع}_j)$	0.7969			0.8863			0.7618			0.8694		

The results of PF-SWARA are presented in Table 5.

Table 5. The results of PF- SWARA

	$s(\text{ع}_j)$	c_j	ζ_j	ظ_j	w_j	**Rank**
C1	0.8863		1.0000	1.0000	0.1348	1
C4	0.8863	0.0000	1.0000	1.0000	0.1348	1
C6	0.8863	0.0000	1.0000	1.0000	0.1348	1
C8	0.8694	0.0169	1.0169	0.9834	0.1326	4
C5	0.7969	0.0725	1.0725	0.9169	0.1236	5
C7	0.7618	0.0351	1.0351	0.8858	0.1194	6
C3	0.7248	0.0370	1.0370	0.8542	0.1151	7
C2	0.6267	0.0981	1.0981	0.7779	0.1049	8

"C1-Flexibility, C4- Wide Network Access, and C6-Cost" are determined the most important criteria based on the findings of PF-SWARA.

Conclusion

Digital technological transformation has significantly enhanced performance in business processes, contributed to the efficient use of resources, and improved product quality. Beyond these operational benefits, it has enabled supply chain processes to be effectively planned and managed using real-time data, smart devices, and intelligent systems, making the entire system more flexible, responsive, and efficient. The adoption of digital technologies also supports advanced decision-making processes, predictive analytics, and process optimization, allowing businesses to rapidly adapt to changing market demands and operational challenges. Moreover, digitalization fosters innovation, increases organizational agility, and provides enterprises with a sustainable competitive advantage. One of the most prominent applications of this digital transformation is cloud computing technology. Cloud technologies integrate various business functions, provide scalable IT infrastructure, and support seamless collaboration across different organizational levels and geographic regions. By offering on-demand access to computing resources, cloud computing enables businesses to reduce operational costs, ensure data security, and optimize resource utilization, thereby creating a more agile and resilient business environment.

Within this framework, the study examined the criteria affecting cloud computing applications in manufacturing enterprises with corporate identity in the province of Samsun. According to the findings, the most important criteria affecting cloud computing applications in manufacturing enterprises were

identified as 'Flexibility,' 'Wide Network Access,' and 'Cost,' all sharing the same level of importance. The least important criterion was determined to be 'On-Demand Service.'

This study has several limitations. Firstly, the research was limited to manufacturing enterprises with corporate identity in the province of Samsun; therefore, the generalizability of the findings to other provinces, different geographic regions, or enterprises in other sectors may be restricted. Consequently, the results are valid only within the context of the examined sample and may vary under different conditions. Secondly, the importance levels of the factors were determined using specific measurement tools and criteria; employing different methodological approaches, data collection techniques, or evaluation models may yield different results. Furthermore, the study focused solely on presenting the current situation, and the changes, interactions, or long-term effects of the factors were not comprehensively examined. In this context, the findings reflect a snapshot evaluation, and future research should be designed to address these limitations by considering different time periods and dynamic environments. In conclusion, the limitations of this study indicate that the interpretation of the findings should be approached with caution and also highlight potential areas for further research.

The findings of the study reveal the current state of the criteria affecting cloud computing applications in manufacturing enterprises and provide managers with various strategic recommendations. In this context, the results offer a roadmap for prioritizing these factors and guide efforts to fill a significant gap in the field. Furthermore, in the future, this study can be evaluated more comprehensively using multi-criteria decision-making approaches or other parametric and non-parametric methods.

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Literature Based Heuristic Evaluation of SAP Fiori User Interface

Heuristička evaluacija korisničkog interfejsa SAP Fiori zasnovana na literaturi

Marijana Petrović[1]

[1]*Academy of Technical and Art Applied Studies, Department School of Information and Communication Technologies, Belgrade, Serbia, marijana.petrovic@ict.edu.rs*

Abstract: *This paper presents a secondary heuristic evaluation of the SAP Fiori user interface, based on an analysis of texts from scientific and professional literature, aimed at assessing the extent to which SAP Fiori meets the ERP system usability heuristics defined by Asif et al. (2022). The findings confirm that SAP Fiori offers a high level of usability, intuitiveness, and alignment with end-user needs, with minor areas for improvement in enabling more flexible adaptation of user tasks and providing clearer guidance throughout task flows.*
Keywords: *SAP Fiori, user interface, heuristic evaluation.*

Apstrakt: *Ovaj rad predstavlja sekundarnu heurističku evaluaciju SAP Fiori korisničkog interfejsa, kroz analizu tekstova pronađenih u naučnoj i stručnoj literaturi, kako bi se procenilo u kojoj meri SAP Fiori ispunjava heuristike upotrebljivosti ERP sistema definisane prema Asif et al. (2022)**.** Rezultati potvrđuju da SAP Fiori pruža visok nivo upotrebljivosti, intuitivnosti i usklađenosti sa potrebama krajnjih korisnika, uz manja područja za optimizaciju u oblast*i *fleksibilnijeg prilagođavanja zadacima korisnika i jasnijeg vođenja korisnika kroz tok zadataka.*
Ključne reči: *SAP Fiori, korisnički interfejs, heuristička evaluacija.*

Introduction

SAP Fiori is a design and user interface framework that provides templates, tools, and guidelines for creating SAP business applications tailored to the specific needs of users. Its implementation ensures a consistent look and behavior across SAP business applications, whether accessed on mobile devices or desktop computers (SAP, n.d.). To simplify user interactions, SAP has broken down complex transactions within its ERP solutions into smaller, more focused applications designed for specific user tasks (Valaboju, 2019), accessible via the web. This shift marks a move away from traditional, monolithic systems toward more flexible, lightweight applications better suited to user needs (Ясницкий, 2019). At the center of this approach is the Fiori Launchpad, a personalized hub interface that provides streamlined access to applications tailored to users' roles and interests (Choli & Mudhol, 2024).

A high-quality user interface is essential for reducing errors, shortening training time, minimizing frustration, and enhancing efficiency and user satisfaction. For this reason, following established best practices is crucial. According to SAP, Fiori is built around five core design principles: role-based, delightful, coherent, adaptive, and simple (SAP, n.d.). However, it remains important to examine the extent to which Fiori truly adheres to fundamental user interface design guidelines. Widely recognized frameworks for such evaluations include Nielsen and Molich's (1990) 10 heuristics, Shneiderman's (1986) eight golden rules of design, and the ISO 9241 standards (Pierre, 2015). In the ERP domain, Asif et al. (2022) adapted established guidelines into a set of 12 heuristics specifically aimed at identifying usability issues. This research adopts their framework to categorize findings from the literature on the SAP Fiori user interface, with the goal of pinpointing potential weaknesses and opportunities for

improvement, enabling organizations to gain greater value from the SAP Fiori solution. The following sections outline the methodology and assessment framework, followed by the results of the literature-based heuristic analysis and conclusion.

1. Methodology

Heuristic evaluation is one of the most widely used methods in both academic research and industrial practice for assessing the user interfaces of software products (Paz et al., 2023), typically conducted by experienced evaluators (Capdevila et al., 2025). This method was first formally introduced by Nielsen and Molich (1990), who described a process in which usability experts assess a product's interface against a predefined set of heuristics, identifying problems and potential areas for design improvement. Although no universally accepted formal framework exists for the formulation, validation, and refinement of usability heuristics (Quinones & Rusu, 2017), two components are generally considered essential for the effective application of this method: 1. a set of heuristics or guidelines that are sufficiently precise and operationalized for practical use; and 2. a defined process that evaluators follow during the analysis, particularly when the evaluation is based on documentation (Kantner et al., 2002), as is the case in this study.

Following the approach outlined by Kantner et al. (2002), this research conducts a heuristic evaluation on structured online documentation using content analysis, without directly testing the user interface. Specifically, it applies a secondary heuristic evaluation, analyzing content from scientific and professional literature (including research papers, online forums, and technical documentation) to determine the extent to which the SAP Fiori software meets the usability heuristics defined by Asif et al. (2022), as reported by other authors. The analysis examines relevant scientific and professional sources that describe the user experience, design, and usability of SAP Fiori from two perspectives: end users, and users who develop and customize Fiori applications. The identified findings are thematically grouped and mapped to the corresponding heuristics to assess SAP Fiori's compliance with the proposed ERP system usability criteria. For each heuristic, the evaluation indicates whether SAP Fiori meets, partially meets, or does not meet the specified criteria.

2. 12 heuristics framework

Asif et al. (2022) adapted Nielsen's ten heuristics, Shneiderman's eight golden rules, and general usability principles to address the specific interface requirements of ERP systems, proposing the following set of guidelines:

1. **Customization** – The system should support straightforward configuration and end-user–level customization, as well as adjustments to the user interface without disrupting the system's core business logic.
2. **Task support** – The system should clearly present the flow of activities, provide an intuitive sequence of steps, and offer features that enhance users' efficiency in completing their daily tasks.
3. **Privacy** – Confidential data should only be stored when necessary, with well-defined authentication measures and secure access to sensitive areas of the system.
4. **Visibility of system status** – Users should always be kept informed about the current state of the system through timely, clear feedback that supports easier navigation and decision-making.
5. **Alignment between system and practical environment** – The interface should use language and terminology familiar to users, following real-world patterns. Information presentation should align with the natural flow of users' understanding and work processes.
6. **User control and freedom** – The system should allow users to easily return to previous steps, exit unwanted states, and make use of intuitive functionalities for undoing and redoing actions.

7. **Error prevention** – The system should present options, commands, and interface elements clearly, and include safeguards such as default values and warnings before performing potentially risky actions.
8. **Recognition rather than recall** – The interface should minimize the need for users to remember past information by keeping instructions, commands, and relevant content visible and easily accessible at all times.
9. **Flexibility and efficiency of use** – The system should be equally usable for both novice and experienced users, providing quick access to essential functionalities without unnecessary clutter in the work environment.
10. **Aesthetic and minimalist design** – The user interface should be clean and focused on essential information, avoiding superfluous elements.
11. **Documentation and help** – Support resources should be easy to access, clearly organized, and searchable. Error descriptions and instructions should be written in plain language, avoiding technical codes.
12. **Helping users recognize, diagnose, and recover from errors** – The system should provide clear error messages along with concrete, actionable suggestions for resolving issues through simple, user-friendly dialogs.

3. Evaluation of SAP Fiori user interface

3.1. Customization

SAP Fiori offers a range of basic and advanced configuration options, with step-by-step procedures available as pre-delivered content on the SAP Learning site (www.learning.sap.com) (SAP, n.d.). When developing SAP Fiori applications, organizations can choose among three implementation strategies, which differ in the degree of customization required. The first involves using an existing application without modification; the second extends an existing application through predefined extension points; and the third entails fully redeveloping the application to meet specific user requirements (Moller & Ketterer, 2018). Fiori application development is based on HTML5, which serves as a JavaScript framework for building web applications (Kumar, 2023) and provides a high degree of flexibility for adapting applications to individual business needs. Companies can modify the look and feel of applications—including colors, fonts, and other visual elements—to align with their corporate branding (Geisel, 2018).

The Fiori design philosophy is user-centered, focusing on user needs, work habits, and expectations (Ясницкий, 2019). Access to core business functions is granted according to user roles (Choli & Mudhol, 2024). SAP Fiori operates independently of the underlying platform or ecosystem (Windows, Android, or iOS) (Sipayung & Yanuartha, 2024) and offers a high degree of personalization, from theme selection and layout configuration to action recommendations based on the user's role, past behavior, and current context (Sirse, 2024). Fiori applications are designed to respond to the available screen space, automatically adjusting the arrangement of interface elements (Valaboju, 2020; Sipayung & Yanuartha, 2024), thereby optimizing content presentation.

3.2. Task support

The SAP Fiori UI component known as *Process Flow* enables a visual representation of process steps, featuring zoom capabilities, popovers for additional details, highlighting, and interactive elements that guide users through each stage of an activity flow. A visual example of the process flow component is available on the SAP website (www.sap.com) (SAP, n.d.). SAP Fiori applications provide real-time access to data and significantly streamline workflows (Devarashetty, 2023). Its role-based design ensures that each individual sees only the details and features relevant to their professional function (Choli & Mudhol, 2024), making application and data access fully aligned with employees' specific tasks and responsibilities within the organization (Sirse, 2024). Users can automate repetitive tasks, create

shortcuts to frequently used functions, and integrate other business tools and processes resulting in a work environment with fewer interruptions and higher efficiency (Devarashetty, 2023).

There is some debate over whether SAP Fiori supports the natural flow of users' work. On one hand, Ilg (2020) argues that platform independence actually limits the desktop version of Fiori application display, leaving large areas of unused space and requiring unnecessary navigation. According to this view, Fiori tiles do not follow a user's natural workflow but instead serve isolated purposes, and navigating through the Fiori Launchpad often involves frequent transitions between tiles and the Launchpad itself. On the other hand, Sipayung and Yanuartha (2024) contend that information is presented intuitively, and tasks are simplified through flexible navigation within the Fiori interface, which supports the thought processes of knowledge workers, enabling them to move seamlessly from one task to another without losing focus. Much of the academic literature also supports claims of increased efficiency in work processes through the use of the Fiori interface (Suder & Gospodarek, 2022; Yuzgat & Bakir, 2025; Choli & Mudhol, 2024). Illustrative examples include Coca-Cola, which optimized its internal processes, improved productivity, and enhanced decision-making through SAP Fiori (Choli & Mudhol, 2024), and pharmaceutical company Boehringer Ingelheim, which simplified workflows and improved efficiency in data collection and analysis using SAP Fiori (Devarashetty, 2023).

Beselga and Alturas (2019) noted that SAP Fiori initially allowed users to perform only the most basic task (lacking many of the capabilities available in SAP GUI) and that code could not be modified in the event of a migration to the HANA database without editing it in the SAP GUI version. Grey literature shows that this situation has improved since 2019. Several enhancements have been introduced (Dart, 2020), including the SAP Fiori Custom Code Migration application, which enables the analysis and adjustment of ABAP code directly within Fiori, eliminating the need to rely exclusively on SAP GUI (SAP, 2019).

3.3. Privacy

Given the sensitive nature of the business data processed by Fiori applications, security is one of the core pillars of SAP's development approach. SAP has established best practices for implementing authentication, role-based authorization, and data encryption to protect information integrity and prevent unauthorized access (Devarashetty, 2023; SAP, n.d.). The security of Fiori applications is further reinforced through strict security standards and conventions designed to ensure the confidentiality, integrity, and availability of sensitive business information (Choli & Mudhol, 2024). SAP Fiori leverages the user and permission management mechanisms of the ABAP platform (SAP, n.d.) and controls access through security keys, granting permissions only to employees with authorized access, thereby reducing the risk of unauthorized breaches (Kulkarni et al., 2016). A key role in this context is played by SAPUI5, the development framework (Choli & Mudhol, 2024) that provides built-in protection against common security threats such as XSS attacks, as well as advanced safeguards against clickjacking and CSRF attacks—all enabled by default. Additionally, applications developed on the SAP HANA Cloud platform operate in a modular, lightweight containerized runtime environment, ensuring high scalability and secure execution (Rani & Priya, 2021).

3.4. Visibility of system status

SAP distinguishes between two types of feedback: system-generated feedback (e.g., activity and process status indicators such as the network activity indicator or loading indicator) and end-user–generated feedback (responses to user actions, such as a checkout indicator, progress or processing indicator, and toast messages) (SAP, n.d.). To provide users with a clear understanding of the workflow within an application, SAP Fiori employs various messaging patterns, including busy indicators, notifications, and error messages. These elements ensure that users remain informed about the application's status at all times, thereby increasing transparency and enhancing the user experience (Kumar, 2023). From a developer's perspective, issues with system status visibility may arise due to user authorization problems or incorrect system configurations, manifesting as missing elements or errors. Possible solutions have been outlined by Palus (2024).

3.5. Alignment between system and practical environment

One of the key advantages of SAP Fiori applications is their consistency in appearance and behavior. By applying a unified design language and coherence principles, all Fiori applications share the same visual identity and interaction patterns. This means that once users become familiar with one Fiori application, they can easily navigate others, as each new environment feels familiar and intuitive (Sipayung & Yanuartha, 2024). The SAP Fiori design team carefully considers cultural and intercultural factors when defining design concepts and application layouts. This includes accounting for differences in language, behaviors, practices, communication contexts, and the economic background of users. The goal is to create a design language that is not only universal but also flexible enough to adapt to real-world experiences across the globe. In line with this, SAP Fiori supports more than 30 languages, multiple calendar formats, the ability to change labels and sequencing, as well as UI adaptations for specific needs, including accessibility themes for visually impaired users (Geisel, 2018).

Through the use of clear and simple language, precise usage instructions, and consistent visual design, Fiori ensures clarity and accessibility, enabling users to interact with applications regardless of their background or technical expertise (Kumar, 2023). This same design language is employed by designers and developers to create applications that feel natural and functional across different contexts (Geisel, 2018). According to Sipayung and Yanuartha (2024), the training time required for new users to adopt the Fiori interface is minimal due to its simplicity and consistent design patterns across all applications, facilitating quick adoption. Conversely, Nissen et al. (2023), who evaluated the usability and user experience of four major ERP systems including SAP Fiori, among inexperienced users in a learning context, reported poor ratings. Due to the low hedonic value of these systems, perceived usability was low, and UX barriers were present even before first-time use. The researchers also noted the high complexity of training and proposed gamification as a potential solution.

3.6. Control and freedom of the user

Since SAP uses hash-based navigation, users can click "Back" to exit an unwanted state, at which point the system will display a pop-up window asking, *"Do you want to discard your changes?"* However, a user may remain stuck in Draft mode if they do not explicitly discard or save their changes (SAP, n.d.). In addition, if custom Fiori applications lack clearly defined navigation or do not use the Cross Application Navigation service, switching between tabs in Fiori may result in the loss of the previous state—such as applied filters, search options, or prior interactions. Members of the SAP Community have proposed solutions to these issues, based on their own experiences encountering and resolving them (John, 2017). SAP application developers can manage errors by examining logs, verifying service activation, ensuring proper authorization assignments, and implementing specific error-handling strategies within the UI5 code (SAP, n.d.).

3.7. Error prevention

Clear indicators such as visual cues, illustrations, or specific text formats enable users to easily identify where an error has occurred and how to correct it (Kumar, 2023). This approach not only streamlines the workflow but also reduces the number of errors during day-to-day system use. Studies have shown that the user experience provided by SAP Fiori leads to fewer errors (Suder & Gospodarek, 2022; Choli & Mudhol, 2024; Devarashetty, 2023; Mourya, 2025), improved user adoption, a reduced learning curve (Devarashetty, 2023), lower training costs, and higher satisfaction rates (Choli & Mudhol, 2024). The simplicity, intuitiveness, and well-structured nature of Fiori's interface play a key role in these positive outcomes. When a system is designed with real user needs in mind, the potential for errors decreases, and even new users can quickly find their way around. Role-based interfaces and guided workflows further help users stay focused and navigate applications without confusion. This not only speeds up data entry but also supports faster, more accurate business decision-making (Devarashetty, 2023). For developers, SAP Fiori elements (a UI development framework) apply Fiori standards automatically,

reducing the need for manual UI coding and, in turn, minimizing the likelihood of errors (Stapleton, 2025).

3.8. Recognition instead of recall

Users can leverage their prior knowledge when working with new applications, as they recognize familiar patterns that enable them to perform new tasks intuitively (Fritsche, 2017). SAP Fiori significantly reduces the need for memorizing codes and instead promotes recognition. Users can easily select applications via tiles and take advantage of intelligent input suggestions, all of which contribute to a more intuitive and productive workflow (Stepleton, 2025). Even the SAP UX guidelines emphasize the principle: *"Don't make me remember"* (Dart, 2016).

3.9. Flexibility and efficiency of use

In SAPUI5, the foundational UI development toolkit for building SAP Fiori applications, accessibility is emphasized as a key aspect. The controls in SAPUI5 are inherently designed to be accessible and usable by a broad range of users, including those with visual impairments, significantly expanding the reach of digital solutions (Choli & Mudhol, 2024). Accessibility is closely aligned with the design philosophy of SAP Fiori, which follows a design-driven development approach. This approach not only ensures visually appealing applications but also guarantees their functionality across different devices. Through thoughtfully implemented elements such as meaningful labels, contextual explanations, and clearly defined placeholders, users receive clear guidance while navigating the application, enhancing both efficiency and relevance (Kumar, 2023).

Research shows that using SAP Fiori can increase productivity by 64% when performing the same tasks compared to SAP GUI (Sipayung & Yanuartha, 2024), as well as improve both user and business performance (Sirse, 2024). In development-focused context, Banta & Cojocaru (2017) created a Fiori-based metrological software application for calibrating oil storage tanks, which enhanced mobility, centralized data, improved productivity and intuitiveness, and delivered a better user experience. Kongot & Pattanaik (2017) introduced the SAP Fiori Enterprise Design application suite for project managers, providing a unified view of all projects and key performance indicators in real time to improve project oversight. Kulkarni et al. (2016) developed a consumer basket analysis system as a SAP Fiori mobile application, which addressed the need for faster insights from available data, reduced costs, and preserved sales data privacy by building their own application. They also resolved the challenge of using the ECC database instead of the expensive HANA database by developing a custom data mining algorithm from scratch. Fritsche (2017) created a Fiori application to streamline capacity planning within production planning and control, which reduced data maintenance time, simplified workflows, facilitated operations, and minimized errors.

3.10. Aesthetic and minimalist design

Sirse (2024) notes that the SAP Fiori interface is clean, uncluttered, and features intuitive navigation patterns, allowing it to be used with minimal training. Its role-based design plays a key role in reducing cognitive load, enabling users to navigate the interface more easily and perform daily tasks more efficiently. Rather than being overwhelmed with unnecessary options, users can quickly access only the functions and information that are truly relevant to their work (Devarashetty, 2023).

3.11. Documentation and help

According to Choli and Mudhol (2024), SAP provides extensive documentation, regular updates, and a vibrant community that offers development guides, best practices, and API references. In addition, Fiori benefits from a network of designers, architects, and clients who contribute through meetups, blogs, and knowledge-sharing sessions. However, within the SAP community, developers working on SAP Fiori applications report challenges in finding relevant information for tasks not covered in the official documentation. They often resort to reverse-engineering standard applications, as documentation is frequently scattered across blogs, the Learning Hub, SAP Help, and other platforms (Rchudziak, 2022).

3.12. Help users recognize, diagnose, and recover from errors

SAP Fiori follows different guidelines for error handling. For end users, these include messages written in plain language that clearly describe the problem and suggest steps for resolving it (SAP, n.d.). For developers, the recommended approach is to rely on technical documentation and available support tools. According to Holics (2022), SAP offers a little-known plugin that performs checks for common issues in Fiori apps, such as authorization errors, Gateway failures, and OData-related problems.

Conclusion

The results of the content analysis of scientific papers and grey literature evaluating how well the SAP Fiori user interface meets the 12 customized heuristics for ERP systems proposed by Asif et al. (2022) are presented in Table 1. The responses indicate whether SAP Fiori meets the criteria of each heuristic ("yes"), partially meets them ("partly"), or does not meet them ("no").

Table 2. Heuristic evaluation

Users/Heuristic	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12
End users	yes	partly	yes	yes	partly	yes	yes	yes	yes	yes	yes	yes

Source: Author

The analysis showed that SAP Fiori largely meets all 12 customized heuristics for evaluating user interfaces. According to the reviewed literature, 10 heuristics are fully satisfied, while *Task Support* and *Alignment between System and Practical Environment* are only partially met, as examples indicate that the criteria are not entirely fulfilled. This suggests room for improvement in terms of more flexible adaptation of the application to user tasks and clearer guidance throughout task workflows. These findings confirm that SAP Fiori offers a high level of usability, intuitiveness, and alignment with end-user needs, with only minor areas for optimization. From a developer's perspective, however, the number of satisfied heuristics would be lower, as issues related to developing Fiori applications are more frequently reported in the SAP community than those concerning their usage.

Based on these results, it is recommended to improve task support and develop features that guide users more effectively through task flows, as well as to increase the hedonic value of the ERP system potentially through gamified training. Additionally, the experience of SAP Fiori developers should be enhanced by providing clearer documentation, more detailed guidelines, and improved tools for development and testing.

The main limitation of this study is that the heuristics were evaluated by a single researcher, although involving multiple evaluators is recommended. Furthermore, the assessment of how well the heuristics are met was based on previous research and identified issues from grey literature, making this a theoretical study. Future research will focus on empirically examining the design of the SAP Fiori user interface.

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Bankruptcy and its Role in Romania Compared to the European Union: A Comparative Study with Case Analyses

Bankrot i njegova uloga u Rumuniji u poređenju sa Evropskom unijom: Komparativna analiza sa studijom slučaja

Cristina Mihaela Nagy[1], Elena Doina Ghica[2]

[1]*"Tibiscus" University of Timișoara, Faculty of Economics Sciences, Timisoara, Romania, c.nagy@tibiscus.ro*
[2]*"Tibiscus" University of Timișoara, Faculty of Economics Sciences, Timisoara, Romania, elena.lepadat@yahoo.com*

Abstract: *This study explores the corporate bankruptcy landscape in Romania compared to broader European Union (EU) trends. Drawing on data from corporate annual reports, financial filings, and insolvency cases, the research highlights Romania's higher insolvency rates, slower legal proceedings, and elevated corporate debt. Through two case studies, Romania's Diverta and the Netherlands' Intertoys, the study examines the role of regulatory inefficiencies. The findings suggest that Romania must improve judicial efficiency and access to credit to align more closely with EU norms.*
Keywords: *Corporate bankruptcy, insolvency rates, legal efficiency, economic factors, debt-to-GDP ratio.*

Apstrakt: *Ova studija istražuje stanje korporativnog bankrotstva u Rumuniji u poređenju sa širim trendovima Evropske unije (EU). Koristeći podatke iz godišnjih izveštaja kompanija, finansijskih podnesaka i slučajeva insolvencije, istraživanje ističe veće stope insolventnosti u Rumuniji, sporije sudske postupke i povećan korporativni dug. Kroz dve studije slučaja, rumunske kompanije "Diverta" i holandske kompanije "Intertoys", studija ispituje ulogu regulatornih neefikasnosti. Rezultati ukazuju na to da Rumunija mora poboljšati efikasnost pravosuđa i pristup kreditima kako bi se bolje uskladila sa normama EU.*
Ključne reči: *Bankrotstvo preduzeća, stope nesolventnosti, pravna efikasnost, ekonomski faktori, odnos duga i BDP-a.*

Introduction

Corporate bankruptcy serves as an essential mechanism in market economies, providing a framework for financially distressed companies to either restructure or exit. However, Romania's post-communist economic transformation and EU integration have resulted in a legal and economic environment that has driven corporate bankruptcy rates higher than those in most EU countries (Adam, 2020). This paper examines these discrepancies, focusing on the underlying regulatory and economic factors. Through an analysis of corporate insolvencies in Romania and the EU, including case studies of major franchise bankruptcies, this research highlights the structural inefficiencies of Romania's bankruptcy system.

1. Methodology

This study draws on a combination of qualitative and quantitative data from corporate annual reports, financial databases (ECB, World Bank), and official insolvency registries from 2015 to 2023. The research compares corporate bankruptcy rates across Romania and EU member states, emphasizing differences in the duration of insolvency proceedings, recovery rates, and corporate debt levels. Two case studies—Diverta (Romania) and Intertoys (Netherlands)—provide practical insights into the consequences of different legal frameworks (Cernaianu, 2020).

2. Bankruptcy rates in Romania and the EU

Romania has consistently faced higher bankruptcy rates compared to the EU average, highlighting significant challenges within its corporate environment. This ongoing trend is indicative of deeper systemic issues that affect businesses operating in the region. According to data compiled between 2015 and 2022, one can observe fluctuations in the bankruptcy rates that reflect both economic cycles and the effectiveness of legal frameworks in place.

Table 1 illustrates these bankruptcy trends, revealing a notable increase during periods of economic downturns, particularly in response to external shocks such as the COVID-19 pandemic.

This crisis exacerbated existing vulnerabilities, leading to significant financial strain on many enterprises. In contrast, many EU countries managed to stabilize their bankruptcy rates or even reduce them through robust policy interventions and supportive financial ecosystems.

The disparities between Romania's bankruptcy rates and those of other EU nations can largely be attributed to a combination of factors, including the complexity and length of the bankruptcy process, access to financing for distressed companies, and the overall health of the Romanian economy. Additionally, cultural attitudes toward bankruptcy and the stigma associated with corporate failure can deter entrepreneurs from seeking the necessary financial restructuring during challenging times.

To address these persistent challenges, it is essential for Romania to explore and implement best practices from other EU member states. This could involve reforms aimed at improving the efficiency of bankruptcy proceedings, enhancing access to capital for businesses, and facilitating a more supportive environment for corporate recovery. By making these changes, Romania has the potential to align its bankruptcy performance more closely with that of its EU counterparts, ultimately fostering a healthier economic landscape and promoting long-term corporate sustainability.

Table 1. Bankruptcy rates in Romania and the EU (2015-2022)

Year	Romania (per 1,000 companies)	EU Average (per 1,000 companies)
2015	11.2	6.8
2016	10.5	6.9
2017	9.8	7.1
2018	10.2	7.0
2019	11.0	7.3
2020	12.1	8.1
2021	12.5	7.8
2022	12.3	7.6

Source: Romanian Trade Registry, 2023; European Justice Portal, 2023

3. Legal and procedural differences

Romania’s slow legal proceedings for corporate insolvency have significantly hindered recovery rates for businesses. As highlighted by Popescu (2021), the inefficiencies in the legal framework can lead to protracted and complicated processes that delay resolutions, ultimately affecting stakeholders, including creditors, employees, and the economy at large.

Table 2 presents a stark contrast in the average time required to complete insolvency proceedings between Romania and other EU countries. In Romania, it takes an average of 4.2 years to resolve insolvency cases, while the EU average stands at just 1.8 years. This disparity underscores the urgent need for reform in Romania’s legal system to enhance the speed and effectiveness of insolvency management. The extended duration of insolvency procedures in Romania not only creates uncertainty for businesses but also diminishes the likelihood of successful turnaround strategies. Delays can erode remaining assets, reduce the potential for recovery by creditors, and limit the opportunities for

companies to restructure and emerge from financial distress. As the proceedings drag on, the costs associated with maintaining operations and legal compliance accumulate, further complicating the recovery process.

Additionally, the slow pace of insolvency resolutions can dissuade new investments, as potential investors are often wary of the risks associated with uncertain legal outcomes. A more efficient legal framework would not only facilitate quicker recoveries for distressed companies but also enhance the overall business climate by instilling confidence among investors and creditors.

To improve these recovery rates, Romania must undertake comprehensive legal reforms aimed at streamlining the insolvency process. This could involve simplifying procedures, increasing the availability of information for all stakeholders, and adopting best practices from other countries with more efficient insolvency systems. Ultimately, such measures would contribute to a more robust economic environment that encourages entrepreneurship and fosters sustainable growth.

Table 2. Average time to resolve insolvency proceedings (Romania vs. EU)

Country	Average Duration (Years)	Average Recovery Rate (%)
Romania	4.2	23.5
EU Average	1.8	42.0
Germany	1.2	48.7
Netherlands	1.5	45.3

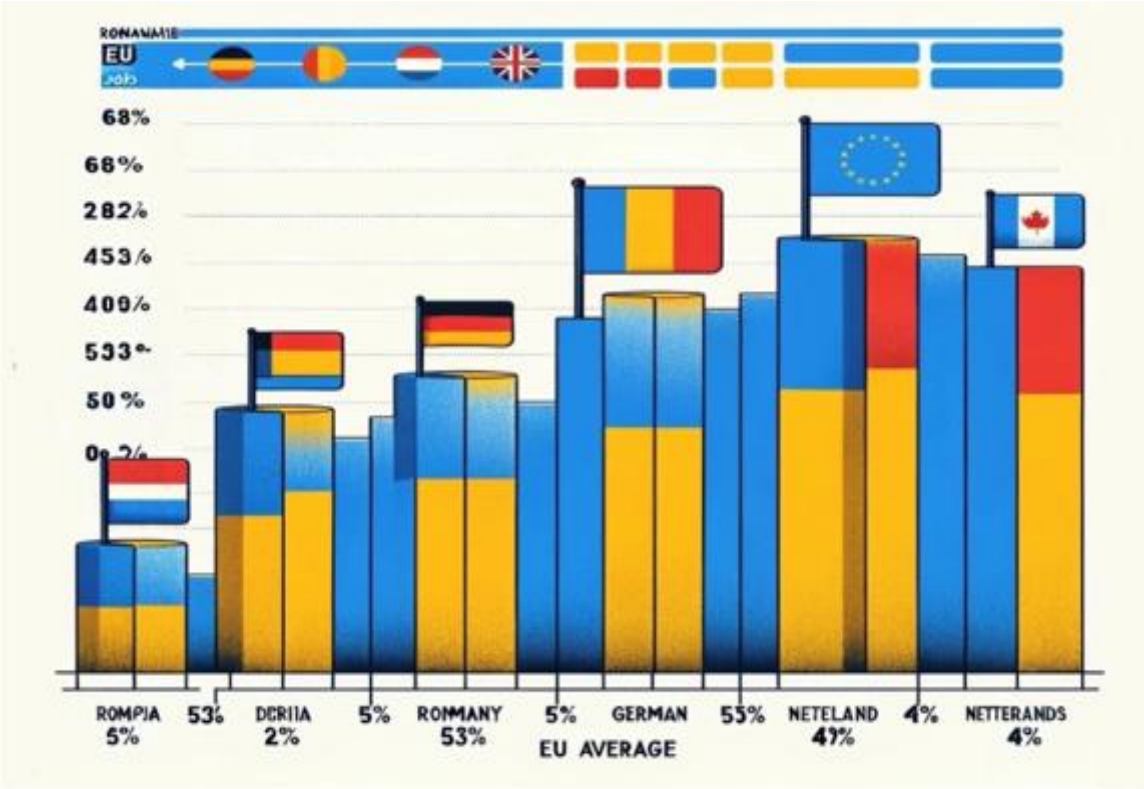
Source: ECB, 2022; World Bank, 2022

4. Economic factors

The high levels of corporate debt in Romania are a central factor contributing to the country's elevated bankruptcy rates. With a corporate debt-to-GDP ratio of 68%, significantly exceeding the EU average of 53%, Romania faces significant challenges that underscore its economic vulnerabilities. This disparity indicates a heavy reliance on borrowing, which can be detrimental to financial stability.

High corporate debt can severely limit a company's cash flow, as a substantial portion of revenue is allocated to servicing debt obligations. This situation restricts operational flexibility, hampers innovation, and curtails the ability to invest in growth opportunities. Moreover, during economic downturns, companies burdened with high debt levels are more prone to bankruptcy, as fixed liabilities do not decrease with falling revenues, leaving them vulnerable to insolvency. The implications of these high debt levels are compounded by the slow legal processes surrounding corporate insolvency in Romania. When businesses fail, they often face prolonged legal battles that delay recovery or liquidation, further increasing the likelihood of irreparable financial distress. The combination of excessive debt and inefficient insolvency proceedings creates a perilous environment for companies, discouraging investment and stifling economic growth.

In summary, addressing the challenges posed by high corporate debt in Romania is essential for reducing bankruptcy rates. Implementing measures to improve financial literacy, access to credit, and bankruptcy reform can help create a more sustainable economic landscape that encourages responsible borrowing and corporate resilience. Through strategic reforms, Romania can work to align its corporate debt levels more closely with those of its EU counterparts, fostering a healthier economic environment for businesses to thrive.



Graphic 1. Analysis of corporate debt-to-GDP ratios across different countries
Source: ECB, 2023; Romanian Trade Registry, 2023

5. Case study: Bankruptcy of franchise companies

5.1. Diverta (Romania)

Diverta, a leading Romanian bookstore and multimedia retailer, declared bankruptcy in 2019 due to mounting debt and reduced consumer spending. The company's insolvency process took over three years, reflecting Romania's slow legal procedures. Creditors recovered only 20.5% of claims, significantly below the EU average (Dobre, 2021).

Diverta's challenges stemmed from a combination of factors, including economic fluctuations, the rise of e-commerce, and changing consumer preferences. In the years leading up to its bankruptcy, the Romanian retail market faced stiff competition from online platforms, which offered lower prices and greater convenience. As consumers increasingly turned to digital shopping, Diverta struggled to adapt, failing to establish a robust online presence that could compete with established e-commerce giants.

Moreover, the overall economic environment in Romania presented additional hurdles. After a period of steady growth following EU accession, the economy began to slow, and inflation rates rose. This economic backdrop limited consumer spending power, directly impacting retailers like Diverta. As foot traffic in physical stores decreased, Diverta's revenues plummeted, leading to its eventual insolvency.

The lengthy insolvency process highlighted the inefficiencies of the Romanian legal system, which often hampers timely resolutions for distressed companies. Diverta's creditors faced significant losses, with only a fraction of their claims recovered. The experience served as a cautionary tale for other franchise businesses in Romania, emphasizing the need for proactive financial management and strategies to navigate economic shifts.

Table 3. Average time to resolve insolvency proceedings (Diverta end Intertoys)

Company	Country	Duration of Insolvency (Years)	Recovery Rate (%)
Diverta	Romania	3.2	20.5
Intertoys	Netherlands	0.8	50.0

Source: Romanian Trade Registry, 2023; Dutch Central Bank, 2020

5.2. Intertoys (Netherlands)

In contrast, the Dutch toy retailer Intertoys declared bankruptcy in the same year but underwent a rapid restructuring. Within 10 months, the company was acquired, and its operations were restored, with a recovery rate of 50% for creditors. The efficiency of Dutch insolvency law and better access to financing facilitated this outcome (Becker, 2021).

Intertoys faced its own set of challenges, including declining sales and increased competition from both online retailers and discount chains. However, the company benefited from a legal environment that favors restructuring over liquidation. The Dutch legal framework is designed to facilitate quicker recovery processes, allowing businesses to reorganize effectively. This proactive approach enabled Intertoys to negotiate with creditors, streamline operations, and enhance financial performance without the lengthy delays typical of many insolvency cases. Intertoys's swift recovery exemplifies the importance of a supportive legal framework and the ability to adapt to changing market conditions. The company managed to address its financial issues rapidly, ensuring minimal disruption to its operations. The recovery also underscored the critical role of investor confidence and strategic decision-making in revitalizing distressed businesses.

Conclusion

The results clearly illustrate a structural gap between Romania and the EU in terms of corporate bankruptcy management. Romania's longer insolvency processes and higher corporate debt contribute significantly to poorer outcomes for companies and creditors (Smith & Barroso, 2020). The case study of Diverta demonstrates the real-world consequences of these inefficiencies, with prolonged proceedings reducing creditor recovery rates. In contrast, Intertoys' swift resolution exemplifies how more efficient legal frameworks can mitigate the negative impacts of bankruptcy.

This study underscores the critical role that legal and economic frameworks play in determining the outcomes of corporate bankruptcy. In Romania, some persistent challenges contribute to elevated bankruptcy rates, including protracted legal processes and high levels of corporate debt. These issues not only hinder the efficiency of bankruptcy proceedings but also create an environment where businesses struggle to recover from financial distress.

One of the most pressing concerns is the slow pace of legal processes, which can lead to prolonged uncertainty for businesses facing bankruptcy. This delay in resolution often exacerbates financial difficulties, leading to a higher rate of failures among companies. Furthermore, the significant corporate debt levels in Romania point to structural vulnerabilities within the economy that could necessitate comprehensive legal reforms and policy initiatives.

To mitigate these challenges, Romania could benefit from adopting best practices in legal reforms and enhancing financial access, which have been successful in other EU member states. Implementing such reforms could streamline the bankruptcy process, making it more efficient and predictable, and thus bolster corporate solvency outcomes. By aligning with European Union standards and practices, Romania stands to reduce the disparity in bankruptcy outcomes with the rest of the EU, fostering a more stable economic environment.

Moreover, future research should delve into the long-term impacts of these legal and economic reforms on small and medium-sized enterprise (SME) bankruptcies in Romania. Analyzing the evolution of

bankruptcy rates among SMEs, post-reform, could provide valuable insights into the effectiveness of the implemented changes and guide further policy adjustments. Such research could also enhance our understanding of the interplay between legislative frameworks and economic resilience, which is vital for fostering a healthy corporate landscape in Romania.

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Green Fintech and Green Financial Instruments: The Contribution of Innovation to a Sustainable Economy

Zelena finansijska tehnologija i zeleni finansijski instrumenti: doprinos inovacija održivoj ekonomiji

Vesna Martin[1]

[1]*Economists Association of Belgrade, Belgrade, Serbia, martinv0803@hotmail.com*

Abstract: *Key innovations in the field of sustainable finance and the application of digital transformation are green financial technology and green financial instruments. Through the application of technologies such as digital platforms and artificial intelligence, green financial technologies enable more efficient management of environmental risks, monitoring of the investment impact and improving access to green finance. Green financial instruments, such as green bonds and green credits, carbon credits and climate derivatives, contribute to the redirection of financial resources towards projects that foster environmental sustainability and thereby reduce carbon dioxide emissions. This paper explores the role of innovations in the development of green financial infrastructure and their ability to ensure long-term economic stability, improve transparency and accelerate the green transition. By analyzing contemporary practices and examples from the region and the world, the paper provides insight into the opportunities and challenges of integrating innovations in order to build a sustainable financial system. This creates the foundations for reaching a sustainable economy, as it achieves greater transparency in the financing of environmental projects and contributes to strengthening the resilience of the financial system to climate risks.*

Keywords: *Green financial technology, green financial instruments, sustainable development, climate risks, green transition, environment.*

Apstrakt: *Ključne inovacije u domenu održivih finansija i primeni digitalne transformacije predstavljaju zelena finansijska tehnologija i zeleni finansijski instrumenti. Kroz primenu tehnologija poput digitalnih platformi i veštačke inteligencije zelene finansijske tehnologije omogućavaju efikasnije upravljanje ekološkim rizicima, praćenje uticaja ulaganja i poboljšanje pristupa zelenom finansiranju. Zeleni finansijski instrumenti, kao što su zelene obveznice i zeleni krediti, ugljenički krediti i klimatski derivati, doprinose preusmeravanju finansijskih sredstava ka projektima koji podstiču ekološku održivost i time smanjuju emisiju ugljen-dioksida. Ovaj rad istražuje ulogu inovacija u razvoju zelene finansijske infrastrukture i njihovu sposobnost da obezbede dugoročnu ekonomsku stabilnost, unaprede transparentnost i ubrzaju zelenu tranziciju. Analizom savremenih praksi i primera iz regiona i sveta, rad pruža uvid u mogućnosti i izazove integracije inovacija u cilju izgradnje održivog finansijskog sistema. Time se stvaraju osnove za postizanje održive ekonomije, jer se postiže veća transparentnost u finansiranju ekoloških projekata i doprinosi jačanju otpornosti finansijskog sistema na klimatske rizike.*

Ključne reči: *Zelena finansijska tehnologija, zeleni finansijski instrumenti, održiv razvoj, klimatski rizici, zelena tranzicija, životna sredina.*

Introduction

Today, more than ever, the modern world is facing a necessary transformation towards achieving a sustainable model of economic development, which is a consequence of the increasingly pronounced consequences of climate change, environmental pollution and excessive use of limited natural resources. A key role in this transition is played by the financial sector and technological innovations that enable the channeling of financial resources towards projects that have a positive impact on the environment.

Thus, the concept of sustainable finance is no longer a passing trend, but an increasingly important part of the strategic policies of states, international organizations, investors and regulatory bodies.

In this context, the field of green financial technologies (Green FinTech) is developing, which represents a combination of financial technologies (FinTech) and sustainable development goals. Green FinTech includes digital solutions that enable greater transparency, efficiency and accessibility in the use of green financial products. Through the application of technologies, such as blockchain, artificial intelligence, big data and digital platforms, FinTech helps in more accurate measurement of environmental impacts, monitoring ESG (Environmental, Social and Governance) performance and facilitates the entry of small investors and companies into the domain of green investments. In parallel with the development of Green FinTech, the use of green financial instruments such as climate derivatives, carbon credits, ESG funds and green bonds and green loans is increasing. These instruments not only mobilize financial resources for renewable energy, energy efficiency, circular economy and biodiversity protection projects, but also reduce systemic risks associated with climate change, thereby contributing to overall financial stability. The role of innovation in the development of Green FinTech and green financial instruments is not only technological, but also structural - they change the way capital markets, insurance, banking and risk management work. It is particularly important that innovations enable a more inclusive approach to green financing, thus strengthening the resilience of societies and accelerating the transition to a low-carbon and sustainable economy.

This paper aims to investigate how innovations in the field of financial technologies and green financial instruments contribute to sustainable economic development, through the analysis of global and regional examples of good practice, the institutional framework and the challenges that arise in the implementation of these solutions. The introduction is followed by a literature review, as well as a presentation of the theoretical framework of financial technologies and green financial instruments. The fourth part of the paper is devoted to the analysis of how Green FinTech contribute to sustainable development, followed by the presentation of good practices and global trends. In conclusion, the main findings of this paper is summarized.

1. Literature review

In the last decade, the growing challenges associated with climate change have put sustainability at the center of economic and financial policies around the world. In this context, more and more attention is being attracted by innovations that enable capital to be directed towards projects with a positive environmental and social impact. Particularly significant is the progress in the field of FinTech and the development of green financial instruments, which together form the basis for the development of Green FinTech.

In modern research, there is an increasingly pronounced interest in the role of innovations, especially FinTech, in improving sustainable development and strengthening green financial infrastructure. Numerous authors point out that technological progress has become a key driver of sustainable finance, especially through improving the accessibility and transparency of green instruments (Saeedi & Ashraf, 2024). Rahman, et al. (2024) in their systematic review emphasize the importance of FinTech in sustainable banking, especially in the context of digital transformation and the inclusion of marginalized groups in formal financial flows. Similarly, Qin et al. (2024) empirically confirm that FinTech contributes to the improvement of environmental quality, with green finance acting as an intermediary mechanism between technological innovation and environmental effects. Significant insight into the interdependence between FinTech and ESG performance is provided by the bibliometric analysis of Kumar Roy and Vasa (2025), which identifies key thematic areas and highlights the increasing role of digital tools in the implementation of ESG standards. The same line of analysis is represented by Li & Chen (2024), who show how FinTech enhances the effects of green loans, making them more profitable and more resistant to market shocks for commercial banks.

A separate segment of the literature deals with the analysis of green financial instruments and their connection with traditional asset classes. Ferrer et al. (2024) use advanced weather models to show how green instruments (such as green bond issuance) behave relative to conventional investments, which may have implications for investment portfolios and diversification strategies. Zeng et al. (2024) focus in particular on the management of carbon credits and the role of FinTech in shaping responsible emissions markets, offering an overview of current practices and challenges in algorithmic tracking of carbon flows. This topic is gaining importance given the need for standardization and digital monitoring of the carbon market. Analysis by Zaid et al. (2025) indicate how green finance positively affects sustainable performance in the banking sector, with an additional effect contributed by FinTech technology and digital transformation. Based on a survey conducted on a sample of 152 employees in Saudi banks and hierarchical regression analysis, the authors conclude that green finance directly improves sustainable performance, then that the application of FinTech enhances that effect, and finally that digital transformation acts as a secondary moderator, further enhancing the influence of FinTech on the link between green finance and sustainability.

At the methodological level, bibliometric and thematic reviews also contribute to the understanding of the development of this interdisciplinary field. Works such as Kwong et al. (2023) and Zournatzidou (2025), provide a map of the scientific discourse and highlight how Green FinTech has emerged as a separate research area within sustainable finance. The analysis of contemporary literature points to the increasingly prominent role of innovation in shaping sustainable financial flows, whereby FinTech and green financial instruments represent key mechanisms for supporting the green transition. Research consistently confirms that the application of digital technologies can improve the efficiency, transparency and accessibility of green financial solutions, especially through strengthening the ESG framework and capital mobilization towards sustainable projects.

2. Theoretical framework and conceptual demarcation

Green FinTech development is closely related to the accelerated process of digitization of the financial sector and the increasing need to respond to climate change and sustainable development goals. The first forms of digital solutions aimed at sustainable financing appear in the early 2010s, when FinTech solutions begin to improve access to investments, increase transparency and facilitate risk management. The connection between digital technology and environmental protection is becoming more pronounced after the adoption of global initiatives such as the Paris Climate Agreement from 2015 and the United Nations Agenda for Sustainable Development until 2030. Then there is a stronger direction of digital financial tools towards the goals of sustainable development. One of the important steps in the development of Green FinTech is the emergence of digital investment platforms that enable investment in environmental projects through innovative mechanisms such as blockchain and crowdfunding. Also, tools have been developed that allow users to monitor their own carbon footprint using mobile applications and online banking services.

In order to better understand Green FinTech, it is necessary to point out the meaning of green growth, which according to the analysis of Zhou et al. (2022), represents growth that enables economic growth and development, while simultaneously preventing environmental destruction, unsustainable use of natural resources, and loss of biodiversity. Thus, green growth indicates the necessity to achieve coordinated economic growth while preserving the environment, but also to improve human health and social protection. On the other hand, FinTech represents connection between finance and technology, whereby their effect on the economy is mostly related to the promotion of green growth - Figure 1. Piotrowska and Piotrowski (2025) define Green FinTech as an innovative non-banking financial institution that uses advanced digital technologies with the intention of having a positive impact on the environment. Today, Green FinTech encompasses various forms of application – from digital solutions for issuing green bonds and investing in projects that meet ESG criteria, to digital contracts and other solutions that facilitate access to sustainable financial products. Green FinTech nowadays includes a wide range of activities that include digital platforms for investing in green bonds,

then applications for tracking personal carbon footprints and blockchain solutions for verifying the sustainability of supply chains, as well as smart contracts for climate insurance products.

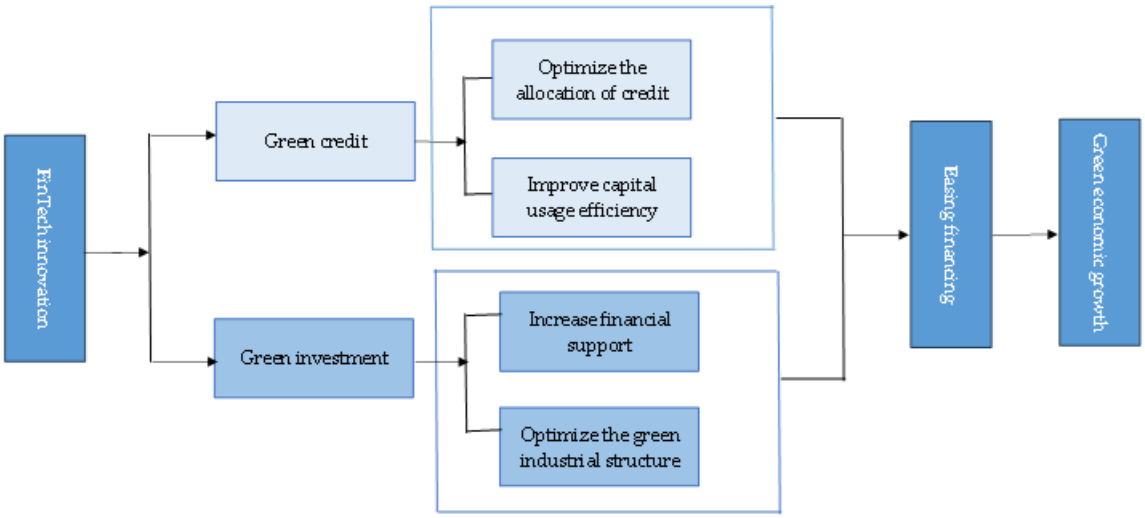


Figure 1. The impact mechanism of fintech innovation on green growth
Source: Zhou et al., 2022

Green FinTech and green financial instruments represent two interconnected segments of modern sustainable finance. While Green FinTech refers to the application of digital technologies in order to promote sustainable financing, green financial instruments are concrete products through which projects with a positive impact on the environment are financed. Their connection is reflected in the fact that FinTech solutions directly support, improve and digitize the entire green investment cycle - from issuance to monitoring of effects. Today, there is a continuous development of green financial instruments, within which green bonds and other green instruments are most often used. Historically speaking, the first green bond was issued by the European Investment Bank in July 2007 in the amount of 500 million euros, with maturity in May 2026. After that, the World Bank issued the first green bond in 2008, and in 2013, the International Financial Organization issued a global benchmark green bond in the amount of one billion dollars. The collected funds were used to finance climate needs. In addition to financial institutions, active participants in the market of green financial instruments are international corporations, such as Unilever, which in March 2014 issued the first green sustainability bond worth 250 million British pounds (Martin, 2023).

Climate Bonds Initiative in the report Sustainable Debt Global State of the Market 2024 indicates that the total amount of issued green, social, and sustainability (GSS) bonds and sustainability linked bonds (SLBs) as of December 31, 2024 is near 5.7 trillion US dollars - Table 1. The largest share of issued green financial instruments was recorded in Europe with a share of 45%, followed by the Asia-Pacific region (26%) and North America (16%). When it comes to the currency structure of issued green financial instruments, the euro (39%) and the dollar (30%) have the largest share.

Table 3. Green financial instruments scorecard on December 31, 2024

	Green	Social	Sustainability	Sustainability linked
Total size of market (cumulative)	USD 3.5 tn	USD 1.1 tn	USD 998 bn	USD 47.2 bn
Number of countries	98	53	75	25
Number of currencies	60	48	44	13

Source: Sustainable Debt Global State of the Market 2024

According to a market research report, published by Global Market Estimates, the global Green FinTech market is expected to grow at a Compound Annual Growth Rate (CAGR) of 22.4% from 2024 to 2029. This indicates a dynamic growth of this market segment and represents an orientation towards increased investment in sustainable projects.

3. Green FinTech: Innovation in the service of sustainable development

Contemporary challenges such as climate change, the depletion of natural resources and the rise of social inequalities indicate the need to direct the financial sector towards sustainable development. In this process, Green FinTech – a fusion of digital technologies and sustainable finance – is gaining increasing attention, enabling the development of products and services aligned with the goals of ESG (Zaid et al., 2025).

Digitization enables more efficient collection and processing of data that is important for making investment decisions in accordance with the principles of sustainability. For example, applications that allow users to track carbon emissions based on their spending habits are becoming increasingly available within digital banking (Migliorelli, 2021). Technological innovations, such as blockchain and big data processing, further strengthen the capacity of green finance (Saeedi & Ashraf, 2024).

Research by Lin and Xie (2025) shows that digital finance contributes to the energy transition by better channeling funds into green projects. This effect is more pronounced in more developed regions, which indicates the need for policies that encourage the even development of digital financial infrastructure. By using FinTech solutions, individuals and smaller businesses can more easily access financing without the need for intermediaries or large collateral.

Faruq and Huq (2024) emphasize the role of central banks in fostering sustainable finance through the inclusion of climate risks in regulatory policies. Central banks are using various mechanisms – from the development of green financial instruments to cooperation in international networks like the NGFS and Sustainable Banking and Finance Network (SBFN) – to encourage innovation that supports the green transition. According to Aslam and Ali (2024), technologies such as blockchain and smart contracts enable the automatic routing of funds only when pre-defined environmental goals have been achieved, thereby increasing accountability and efficiency in the use of funds.

Despite its many advantages, the development of Green FinTech faces challenges such as the lack of standardized rules for sustainability reporting, inconsistent regulatory frameworks and uneven quality of ESG data. In order to overcome these problems, a number of international initiatives (such as Task Force on Climate-related Financial Disclosures (TCFD) and the International Sustainability Standards Board (ISSB)) are working to develop guidelines that facilitate innovation in this domain. Based on the above, it can be concluded that Green FinTech represents an important mechanism for achieving the goals of sustainable development. Innovations in this sector contribute to the reshaping of the financial system, facilitate access to green investments, promote responsible investment and contribute to the development of an inclusive and resilient green economy.

4. Examples of good practice and global trends

As part of its efforts to ensure sustainable development and climate neutrality, the European Union has laid the foundations for a comprehensive economic transformation through the EU Green Deal. As one of the most ambitious global approaches to the green transition, this initiative relies heavily on innovation in the financial sector to channel capital towards activities that contribute to environmental protection, emission reduction and the advancement of the circular economy. In this context, new regulatory mechanisms – the EU Taxonomy and the Sustainable Finance Disclosure Regulation (SFDR) – have been developed to define and improve criteria for sustainable investments.

The taxonomy and SFDR are not only normative tools, but also act as drivers of innovation in the development of new green financial instruments, as well as financial technologies that enable transparency, efficiency and trust in "green" investments. Their implementation opens up space for the integration of digital solutions, such as Green FinTech platforms, advanced ESG analytics and automated reporting, thereby significantly improving the connection between regulatory frameworks and the real economy. This approach has the potential to improve resource allocation and foster sustainable growth, which is a key contribution of financial innovation to building a sustainable economy. Through the taxonomy and SFDR, the EU not only sets regulatory standards but also creates space for innovation in sustainable finance. These mechanisms represent the basis for market transformation, directing capital towards green goals and developing new technological solutions that support the green transition. Innovations stemming from these frameworks are crucial for the effective implementation of the EU Green Deal and for achieving a climate-neutral future.

Green FinTech, as a combination of financial technologies and sustainable finance, is gaining increasing importance on a global scale. Technological innovations enable the development of new digital platforms, applications and tools that help individuals, companies and institutions monitor and reduce their environmental impact, and invest in environmentally responsible projects. Solutions are being developed in different parts of the world, covering areas such as carbon management, green-focused mobile banking, crowdfunding for environmental initiatives and automated ESG reporting. Below are selected global examples of Green FinTech innovations that demonstrate how technology is becoming a key driver of a sustainable economy:

1) **Doconomy**: Founded in Sweden in 2018, Doconomy is the world's leading technology impact company, with a core mission to secure the future of life on the planet. Today, Doconomy has more than 100 clients and operates in more than 30 different markets with the goal of achieving sustainable lifestyles. Expanding its sphere of influence in 2023, Doconomy acquired Dreams Technology, a Stockholm-based financial wellbeing FinTech company, becoming the world's first holistic solution to drive significant climate and social impact in the financial services industry.

2) **Treecard:** Founded in 2020 in London, Treecard is one of the innovative examples of Green FinTech, with a focus on connecting financial transactions and climate-responsible actions. Treecard develops sustainable payment products, including a debit card made from responsibly sourced wood, as well as a mobile application that allows users to manage their finances and track their environmental impact. The basic business model is based on directing a portion of the revenue from each transaction to finance tree planting around the world, in partnership with Ecosia (Ecosia is a German company founded in 2009 and headquartered in Berlin, known for its eponymous Internet browser that finances tree planting). In this way, Treecard combines financial inclusion, environmental responsibility and digital innovation, creating a practical tool that allows consumers to directly contribute to the fight against climate change through the everyday use of financial services.

3) **Ant Forest**: Ant Forest is an innovative environmental initiative launched in 2016 by Ant Group, a subsidiary of Alibaba, as part of its flagship digital payment platform Alipay. The project uses digital technologies to motivate users to adopt sustainable habits and contribute to reducing carbon emissions. Alipay application users receive "green energy" for each activity (such as paying bills online, using public transportation, recycling) that reduces their carbon footprint. When a sufficient level of "green energy" is accumulated, it is converted into a virtual tree in the application, after which Ant Group plants real trees in areas prone to deforestation. By the end of 2022, more than 650 million users had participated in the project, planting over 26 million trees and reducing carbon emissions by more than 26 million tons.

4) **ESG Book**: ESG Book was founded in 2018 in Frankfurt and quickly established itself as one of the leading providers of ESG data and technology solutions for financial markets. This Green FinTech company covers data for more than 100,000 companies, including ESG and climate ratings, as well as portfolio analysis tools. Time ESG Book enables standardized and transparent publication of ESG

data, automated monitoring and reporting for compliance with SFDR and EU taxonomy, as well as integration of ESG metrics directly into financial products and processes of investment managers, which increases the quality and credibility of the green economy.

Examples of good practices and global trends show that Green FinTech is playing an increasingly important role in advancing sustainable finance around the world. Innovations such as digital platforms for green investment, carbon footprint measurement tools, and automated ESG reporting technologies contribute to greater transparency, efficiency, and inclusion. These examples confirm that the intersection of finance and technology is a key direction in the global green transition.

Conclusion

In the contemporary conditions of accelerated climate change, depletion of natural resources and growing social inequalities, the need to redefine the way the global economy functions is clearly emerging. This paper showed that Green FinTech - a combination of financial technologies and principles of sustainable development - represents one of the key mechanisms for achieving the goals of the green transition. Innovations in this sector enable more efficient data collection and use, improved ESG performance, reduced systemic risks and greater access to green finance for a wide range of actors, including small investors and businesses. Through the analysis of the theoretical framework, contemporary literature, institutional approaches and examples of good practice, it was determined that Green FinTech not only supports the financing of environmentally responsible projects, but also structurally changes the way the financial sector functions.

The adoption of the EU Taxonomy and the SFDR represents a milestone in the way sustainable finance policy is defined and implemented in Europe. These regulatory mechanisms not only set clear standards for "green" investments, but also create an institutional framework in which innovations in financial technologies are encouraged and put into practice. Green FinTech, as a combination of digitalization and sustainability, is becoming a key driver of this transformation – enabling transparency, impact tracking and the active participation of individuals and institutions in building a climate-resilient Examples such as Doconomy, Treecard, Ant Forest and ESG Book show how technological innovation can develop concrete solutions that contribute to reducing emissions, better managing resources and improving the environmental awareness of users. Their success confirms that Green FinTech has the potential not only to support the implementation of regulations, but also to be a driver of new business models that put sustainability at the heart of the financial system. In this sense, financial innovation is not only a technical tool, but also an essential element in building a fairer and more sustainable future.

Although it faces challenges, such as uneven reporting standards and regulatory desynchronization, Green FinTech is already contributing to the transformation of the global economy towards a more sustainable and inclusive model. It represents a platform for the development of a new generation of financial solutions that are aligned with the goals of environmental protection, social justice and long-term economic stability. Based on all aspects considered, it can be concluded that the further development of Green FinTech and green financial instruments is necessary to accelerate the transition to a low-carbon, resilient and sustainable economy.

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Theoretical Aspects regarding the Comparative Analysis of the Concept of Internal Audit and Internal Control

Teorijski aspekti u vezi sa uporednom analizom koncepta interne revizije i interne kontrole

Mladin Franca[1], Ulici Diana Sabina[2], Nagy Cristina Mihaela[3]

[1]*"Tibiscus" University of Timisoara, Faculty of Economics, Timișoara, Romania, frankamladin@yahoo.com*
[2]*Western University of Timisoara, Faculty of Economic Sciences, Timișoara, Romania, diana_branet@yahoo.com*
[3]*"Tibiscus" University of Timisoara, Faculty of Economics, Timisoara, Romania, c.nagy@tibiscus.ro*

Abstract: *The internal audit reports are "real business cards of the entity", which will be analysed and studied by the representatives of the European Commission, the Court of Accounts, international financial bodies and interested persons. For these reasons, the quality of internal audit reports is of particular importance and it depends on the competence and professionalism of internal auditors, on their relationship with general management, structural level management and executors. The role of internal audit will be achieved when it will be able to meet within the organization various insurance providers, respectively those responsible for organizing internal control, the person responsible for risk management and the levels of line management and provide the Board of Directors and the Audit Committee which represents a coordinated assurance for the evaluation of the effectiveness of the general management.*
Keywords: *Internal audit, internal control, management, public entity.*

Apstrakt: *Izveštaji interne revizije su „prave vizit karte subjekta", koje će analizirati i proučavati predstavnici Evropske komisije, Sud revizora, međunarodna finansijska tela i zainteresovana lica. Iz tih razloga, kvalitet izveštaja interne revizije je od posebnog značaja i zavisi od kompetentnosti i profesionalizma internih revizora, od njihovog odnosa sa opštim rukovodstvom, strukturnim nivoom rukovodstva i izvršiocima. Uloga interne revizije biće ostvarena se u okviru organizacije sastanu različiti pružaoci osiguranja, odnosno oni koji su odgovorni za organizovanje interne kontrole, lice odgovorno za upravljanje rizicima i nivoi linijskog rukovodstva i pruži Upravnom odboru i Odboru za reviziju koordinisanu garanciju za procenu efikasnosti opšteg rukovodstva.*
Ključne reči: *Interna revizija, interna kontrola, rukovodstvo, javni subjekt.*

Introduction

The qualitative preparation of audit reports holds major and significant importance, being contingent upon:

- the competence and professionalism of auditors;
- their relationship with general management;
- the interaction with structural management levels and operational staff.

The role of internal audit will be fulfilled when it succeeds in engaging, within the organization, with various assurance providers, namely:

- those responsible for organizing internal control;
- the individual responsible for risk management.

For these reasons, the quality of internal audit reports is of particular significance, depending not only on the competence and professionalism of internal auditors but also on their relationship with general management, structural management levels, and executants.

The role of internal audit will be fully achieved when it manages to bring together, within the organization, different assurance providers—specifically those responsible for organizing internal control, the risk management officer, and line management levels—and provide the Board of Directors and the Audit Committee with a coordinated assurance regarding the effectiveness of general management.

Over time, internal auditors will undoubtedly be rewarded by all management levels of the organization in terms of recognition and reputation.

1. Internal audit function vs. internal control function

Four decades ago, Anglo-Saxon accounting firms popularized the term audit on the European continent.

After 1990, out of the desire to align Romanian regulations with community regulations, this term began to be introduced in our country in different forms (quality audit, financial accounting audit, information flow audit, etc.).

The etymology of the word audit has its origin in the Latin "audire" - to listen and pass on (Dănescu & Prozan, 2020).

In general, nowadays, audit means the professional examination of information in order to express a responsible and independent opinion by comparing it to a criterion (standard, norm) of quality in order to satisfy some information users.

The persons who manage public funds or public patrimony have the obligation to achieve good financial management by ensuring legality, regularity, economy, effectiveness and efficiency in the use of public funds in the administration of public patrimony.

At the level of a public institution, this is done through the form of internal control specific to public institutions, internal public audit.

Internal public financial control – the entire internal control system in the public sector, consisting of the control systems of public entities, of other structures empowered by the Government and of a central unit that is responsible for harmonizing and implementing control and audit principles and standards.

In accordance with the legal provisions in force, Internal Control represents the set of forms of control exercised at the level of the public entity, including internal audit, established by management in accordance with its objectives and legal regulations, in order to ensure the administration of funds in an economic, efficient and effective manner which also includes organizational structures, methods and procedures (Order of the General Secretariat of the Government no. 600 of 07 May 2018 for the approval of the Code of Internal Managerial Control of Public Entities).

By studying the legislative framework we can define the internal public audit as a functionally independent and objective activity, which provides assurances and advice to the management for the good administration of public revenues and expenses, perfecting the activities of the public entity; helps the public entity to meet its objectives through a systematic approach, which evaluates and improves the efficiency and effectiveness of the management system based on risk management, control and administration processes (Law no. 672 of December 19, 2002).

Next, we will present the main differences between the internal audit function and the internal control function, through the lens of the following areas of reference.

1.1. The statute

Internal control: It is established within the organization in the form of a management and internal control system, which is also called Internal Managerial Control System-SCIM

Internal audit: It is part of the internal management and control system, but it is its evaluation component.

1.2. The beneficiaries

Internal control: Employees, line management and general management

Internal audit: General management

1.3. The objectives

Internal control: Established by the annual control plan approved by management with the aim of carrying out an assurance control (Order of the General Secretariat of the Government no. 600 of 07 May 2018 for the approval of the Code of Internal Managerial Control of Public Entities)

Internal audit: Established by the team of auditors and supervised by the head of the internal audit department

1.4. Scope

Internal control: In accordance with the annual control plan and management needs

Internal audit: All areas of the entity are auditable activities

1.5. Periodicity

Internal control: Periodic activity, depending on the evolution of risks

Internal audit: Permanent and planned activity, respectively all areas or activities are audited at least once every 3 years

1.6. The purpose of the action/mission

Internal control: Instruments an irregularity, deviation, dysfunction or even irregularity by verifying compliance with the normative and procedural framework in force

Internal audit: Reasonable assurance of the compliance of the audited activities and/or the effectiveness of their performance.

1.7. The approach

Internal control: The control activities are structured on the objectives of the action established by the management

Internal audit: It carries out an assessment of compliance with the objectives of the mission, based on the verification of samples of 2-5% of the total population, established statistically.

1.8. The way of organization

Internal control: Control activities are dissipated on the flow of processes

Internal audit: It is organized in the form of an internal audit department (Dănescu & Prozan, 2020) made up of at least 2-3 people to be functional.

1.9. Working method

Internal control: Control techniques and tools differ from one action to another depending on the particularities of the controlled activities

Internal audit: Specific standardized methodology common to all internal audit missions

1.10. Completion mode

Internal control: The controller establishes the dimensions of the detected deviations and even of the irregularities and the responsible persons, based on a control report

Internal audit: The findings and recommendations of the internal auditors are materialized in an Internal Audit Report, which is completed with an Action Plan, established according to the Calendar for the practical implementation of the recommendations.

1.11. The findings, recommendations and conclusions of the mission

Internal control: The findings and conclusions of the control, according to the law, must be accepted, if they are not disputed or, as the case may be, if they remain definitive

Internal audit: The recommendations and conclusions of internal auditors are optional for management, but good practice requires explanations for their non-implementation

1.12. Comparison with inspection

Internal control: Similar to inspection

Internal audit: Totally opposed to the inspection activity

1.13. Results

Internal control: Internal audit:

Internal audit: Provides reasonable assurance to general management on the functionality of managerial control systems

1.14. Staff

Internal control: The controller must have specialized higher education

Internal audit: The internal auditor has higher education and, in time, will also have to have a certification in the field

1.15. Perspective

Internal control: Activity that will evolve depending on the evolution of risks and the systematic updating of operational work procedures

Internal audit: The internal audit function must become increasingly stronger and provide general management with reasonable assurance for all auditable areas, which will represent added value for the organization

The internal control system of entities includes several controls, namely: self-control, mutual control, hierarchical control, partnership control, quality controls and preventive financial control, asset inventory, accounting control, financial control, inspections, etc.

These controls can be grouped as follows:

- ex-ante controls: self-control, mutual control, hierarchical control and preventive financial control.
- ex-post controls: self-control, mutual control, hierarchical control, asset inventory, cashier's control, accounting control, financial control, quality controls, inspection, etc. All these listed controls are not organized in independent compartments, but are found on the flow of operations between the phases of a procedural chain, exercised by each work station, at each level of responsibility or by delegation of competence, intrinsically attached to current activities.

Due to this organization, when the internal auditor establishes the non-existence of the procedures, their unadaptability or systematic non-updating, depending on the evolution of risks, non-implementation

of recommendations, etc., these represent major problems for management and for internal auditors. At the central level, an internal control harmonization unit can be established or there can be a single internal audit and internal control harmonization unit with separate departments for the two activities.

The organization of the internal control system in public entities in this way will make the internal audit activity more efficient, by ensuring the implementation of the auditors' recommendations, the accountability of managers and executors and the faster realization in practice of a clear differentiation between internal audit and internal control activities and the achievement, thus, of pre-accession objectives.

Of course, in order to respect good practice in the field and in Romania in the future, Audit Committees must be established in addition to the audit structures under the general manager, and which will take over part of the internal auditors' problems that are currently submitted to the Central Harmonization Union for Internal Public Audit.

In the absence of such a process, the internal auditor can help identify, evaluate and create a risk management and control system, which allows their management, without getting involved in the decision to implement the system.

In carrying out this mission, the auditor must formulate and express an opinion regarding: the application of the internal financial-accounting procedures established by the manager of the public entity in accordance with the legal provisions; the validity of the entries in the acts and documents that the public entity issued the entity, as well as the reality of the patrimony, the financial statements and the results entered in the centralizing and summary documents of the public entity.

In order to formulate a real and clear picture regarding the quality of management of patrimonial units, the auditor must analyze the reality and legality of the data and information entered in the financial documents (Dănescu & Prozan, 2020).

In formulating the findings, the auditor must also use the information resulting from the findings of the internal and external control bodies following the controls carried out at the level of public entities.

This information can provide the auditor with a solid support and a good basis in formulating the opinion in relation to the state of the patrimony of the audited units.

In order to be truly useful, the auditor's opinion must meet certain qualitative conditions like this (Ionescu & Nica 2021):

- to be real, i. e. the data and facts analysed have a direct and immediate connection with the authorities that were the subject of the audit;
- to be relevant (it refers to the audited attributions and in particular to their major risk situations);
- to be timely (to be presented in real time so that the efficiency is immediate).

In carrying out internal public audit missions, certain analytical procedures must be used; they consist in the analysis of indicators and significant trends as well as fluctuations and relationships that are not consistent with other relevant information or that deviate from the expected values.

These procedures require the auditor to compare an existing framework with a framework that he expects to find at the audited entity.

Analytical procedures use a variety of techniques to be able to determine relationships between data and test their veracity.

They include: the study of data from accounting reports for previous years, in order to make forecasts for the current year; comparing financial information with anticipated results, performing calculations to forecast some indicators, etc.

The case study consists of conducting an internal audit mission regarding the organization and implementation of the Internal Managerial Control System (hereinafter referred to as IMCS) within a public institution.

The purpose and objective of such an internal audit mission are to provide added value by assessing the manner in which the IMCS has been organized and implemented at the level of the entity.

Furthermore, through the recommendations it formulates, internal audit generates significant improvements in all processes and activities carried out within the municipality.

The objectives pursued, analyzed, and examined by the auditors—objectives that are included in all preparatory audit documents—are the following:

- The organization of the internal managerial control system;
- The implementation of the 16 Internal Managerial Control Standards;
- Semi-annual and annual reporting.

As an example, we refer to: Standard No. 2 – Duties, Roles, Tasks; Standard No. 3 – Competence, Performance; Standard No. 4 – Organizational Structure; and Standard No. 5 – Objectives.

Following the review of the documents provided to the internal auditors by the entity's management, the following irregularities in relation to legality were identified:

Standard No. 2 – Duties, roles, tasks

During the audit, Standard No. 2 concerning Duties, Roles, and Tasks was not presented in the required structured form, namely: description of the standard, general requirements, and main references.

The Mission Statement of the audited entity was not presented.

A nominal list of the municipality's staff who had acknowledged this Internal Regulation was presented.

The entity had not elaborated the Regulation on the organization and functioning of the specialized apparatus of the credit authorizing officer, which should have been correlated with job descriptions. It should be noted that some job descriptions included, in their annexes, duties related to the Internal Managerial Control System (IMCS).

In the absence of this Regulation on organization and functioning, the entity could not present a nominal list of municipal staff who had acknowledged it.

Furthermore, a list of sensitive functions, which should have existed, was not provided.

Recommendations:

- Elaborate the Mission Statement of the audited entity, approve the Internal Regulation through an official order, and prepare all necessary regulations regarding the organization and functioning of the entity;
- Ensure that this regulation is approved in a local council meeting and subsequently follow the publicity procedure, by posting, displaying, and publishing it on the entity's official website;
- Ensure that the regulation is acknowledged and signed by all employees;
- Prepare a list of sensitive functions and, in this respect, comply with the legal provisions requiring that, for sensitive functions, a staff rotation plan be developed within intervals of no more than five years.

Standard No. 3 – Competence and performance

Another finding of the audit was that Standard No. 3, concerning competence and performance, was not presented in the required structured form, namely: description of the standard, general requirements, and main references.

The analysis revealed the following: certain job descriptions were neither updated nor included, as annexes, the additional duties established through the Order of the entity's manager regarding the establishment of the Risk Management Team within the audited entity.

Additionally, evaluation reports were identified, specifying training programs recommended for future completion by the executive staff of the municipality.

Recommendations:

Update all job descriptions, prepare the Professional Development List for staff, and elaborate the Annual Professional Development Program.

Create and systematically update a database as an essential activity for the continuous completion of the list of key market factors, potential suppliers, quality levels of products or services, practiced prices, etc.

The database must be structured as an instrument for observing and monitoring market trends rather than as a tool for limiting competition in the field.

Standard No. 4 – Organizational structure

During the audit, Standard No. 4, referring to Organizational Structure, was also not presented, despite its requirement to be structured into three components:

- description of the standard;
- general requirements;
- main references.

In this case as well, no Nominal Delegation List, no official Delegation Order of competencies, nor the Register of Delegations of the department were presented.

Recommendations:

Remedy the shortcomings by issuing the necessary documents.

Standard No. 5 – Objectives

Following the verification, the following situation was observed: objectives, which should have been structured according to the three components—description of the standard, general requirements, and main references—were absent.

No document was provided to demonstrate the general and specific objectives for the Financial–Accounting Department.

Furthermore, no management plan was presented that would include general management-level objectives, specific departmental objectives, measures/actions, responsible persons, resources, performance indicators, deadlines, and monitoring.

Likewise, no report was presented regarding the reassessment of the relevance of the indicators.

Recommendations:

- Establish general objectives closely aligned with the mission and objectives of the audited entity, ensuring that these are communicated to employees.
- Prepare a list of assumptions and premises underlying the determination of objectives.

- Develop a departmental management plan, including the analysis of the current situation, specific objectives that comply with S.M.A.R.T. criteria, and the associated action plan.
- Elaborate a Report on the reassessment of the relevance of indicators.

The comparative analysis between internal audit and internal control highlights both their interdependence and their distinct roles within public institutions. Internal control remains a managerial function, embedded in daily processes, while internal audit serves as an independent evaluation mechanism that ensures efficiency, transparency, and accountability. By addressing irregularities, formulating recommendations, and monitoring their implementation, internal audit becomes a driver of organizational improvement and a safeguard for good governance.

Conclusion

The internal public audit is carried out on all activities carried out in a public entity, including the activities of subordinate entities, regarding the formation and use of public funds, as well as the administration of public patrimony.

Internal control is organized at the level of the public entity, falls under the attributions of their management and is defined as the set of forms of control exercised at the level of the public entity, including internal audit, established by the management in accordance with their objectives and legal regulations, in order to ensure the administration funds economically, efficiently and effectively, also includes organizational structures, methods and procedures. Internal control is based on the following characteristics: it represents a continuous integration, incorporation into the composition of operations; it is carried out by the entity's staff; provides reasonable assurance and not absolute assurance; the attitude towards the internal control environment.

Internal audit and internal control are complementary, not substitutes. Internal control provides continuous monitoring of compliance, while internal audit evaluates and validates its effectiveness.

Internal audit generates added value for public institutions by identifying risks, ensuring the proper use of resources, and supporting the achievement of institutional objectives.

The implementation of internal managerial control standards and the consolidation of audit practices ensure compliance with both national legislation and European requirements.

The effectiveness of internal audit depends largely on the competence and professionalism of auditors, the quality of collaboration with management, and the adoption of international best practices.

Strengthening audit committees and harmonization units enhances sustainability in governance, ensures better risk management, and contributes to the long-term credibility of public entities.

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Organizational Advancement through Economic Policy: Managing Interventions for Resilience

Promocija organizacija kroz ekonomsku politiku: upravljanje intervencijama za otpornost

Gordana P. Djukic [1], Biljana Ilic[2], Bojana Ostojic[3]

[1]*University of Belgrade, Faculty of Economics, Belgrade, Serbia, gordanadkc048@gmail.com*
[2]*Educons University, Faculty of Project and Innovation Management, Belgrade, Serbia, bilja0110@gmail.com*
[3]*Educons University, Faculty of Project and Innovation Management, Belgrade, Serbia, bojanaostojic85@gmail.com*

Abstract: *In the contemporary business environment, organizational advancement is pivotal for economic resilience. Economic resilience does not emerge solely at the macro level – within national economies; its foundation lies in micro-level resilience – at the organizational plane (enterprises, institutions, NGOs). These entities are affected by shocks such as financial crises, pandemics, and climate disasters, and their recovery capacity has a direct impact on national economic stability. This paper examines how economic policy can proactively foster organizational resilience, not merely through passive support, but through the strategic management of targeted interventions. The objective is to demonstrate that organizational advancement should not constitute more assistance, but rather a strategic investment in national security. The theoretical framework centers on advancement as an instrument of economic governance, defining promotion as systematic state activities where the state must serve as the primary actor in cultivating resilience. The second part of the study will be grounded in a specific case study of German organizational practices.*
Keywords: *Organization, advancement, economic policy, managing, interventions, resilience.*

Apstrakt: *U savremenom poslovnom okruženju, promocija organizacije je ključna za ekonomsku otpornost. Ekonomska otpornost ne nastaje samo na makro-nivou – na nivou države; njen temelj leži u otpornosti na mikro planu – na planu organizacije (preduzeća, institucija, NGO). Ove entitete pogađaju šokovi poput finansijskih kriza, pandemija, klimatskih katastrofa, a njihova sposobnost oporavka direktno utiče na stabilnost nacionalne ekonomije. Rad će istražiti kako ekonomska politika može aktivno promovisati organizacije da postanu otpornije, ne samo kroz pasivnu podršku, već kroz proaktivno upravljanje adekvatnim intervencijama. Cilj je istaknuti da promocija organizacija ne treba da bude samo pomoć, već strateška investicija u nacionalnu sigurnost. Teorijski okvir rada će se fokusirati na promociju kao alat ekonomskog upravljanja u okvirima koji definišu promociju - odnosno da promocija podrazumeva sistematske aktivnosti države koja mora biti glavni akter za sticanje otpornosti. Drugi deo rada će se bazirati na primeru iz prakse nemačkih organizacija.*
Ključne reči: *Organizacija, promocija, ekonomska politika, upravljanje, otpornost.*

Introduction

To advance organizations through economic policy, the state must serve as the primary driver of measures that encourage organizations to adopt resilient practices (OECD, 2021). This can be achieved (for instance) through diversification of supply chains (Ivanov, 2022). Additionally, organizations should be granted access to resources for the transformation and implementation of new technologies, which can be accomplished via subsidies for digitalization (Bauer et al., 2021). Organizations must become visible as models of best practice through successful promotion and the creation of a recognizable brand. Economic instruments – such as fiscal, monetary, and regulatory tools – must be designed to promote resilience rather than merely mitigate consequences. For example, tax incentives

for companies investing in renewable energy are considered sufficiently impactful promotional measures, as they highlight these organizations as resilient to energy shocks (REN21, 2022). The management of interventions by competent state institutions is essential to the process of promoting and cultivating specific forms of resilience against environmental shocks (Boin & Lodge, 2021). Without effective management, manifested through planning, implementation, and monitoring, state policies remain abstract. The key lies in coordination among ministries, agencies, and the private sector. Mechanisms for advancing organizations through economic policy operate across three key channels through which policy promotes organizational resilience (Kagermann et al., 2020): a) Financial incentives through targeted interventions; b) Regulatory frameworks, and c) Capacity building.

Interventions undertaken by the state as financial incentives include subsidies for technological modernization, credit guarantees for Small and Medium-sized Enterprises (SMEs), and funds for workforce training. The role of management here involves transparent resource allocation and alignment with national resilience strategies. Regulatory frameworks are expressed through laws mandating risk planning, sustainability standards, and state incentives for sectoral resilience. Management's role entails flexible adaptation to changes and the reduction of administrative barriers. However, challenges may arise here due to data gaps, as organizations may underreport risks (e.g., dependency on a single supplier), thereby impeding targeted promotion (Power, 2020). Capacity building is achieved through public-private partnerships for innovation and risk data-sharing platforms (Hodge & Greve, 2021). State-led mentoring for SMEs could significantly benefit organizational advancement (Liguori et al., 2021). In this context, management's role would focus on identifying organizational weaknesses and measuring progress. An example of these channels in practice can be found in Germany's "Industrie 4.0" program, which promotes organizational sector resilience through a combination of the described approaches (Kagermann et al., 2020).

1. Integration of terms: management, economics, policy, and organizational advancement

At the core of every organization's functioning—whether business, public, or non-profit—four key domains inevitably intertwine and mutually condition one another: management, economics, policy, and organizational advancement. Their explicit integration is not merely a theoretical concept but a pragmatic necessity for sustainability, efficiency, and goal attainment in today's complex environment. The Management process, as the most significant function of an organization, can be illustrated in Figure 1.

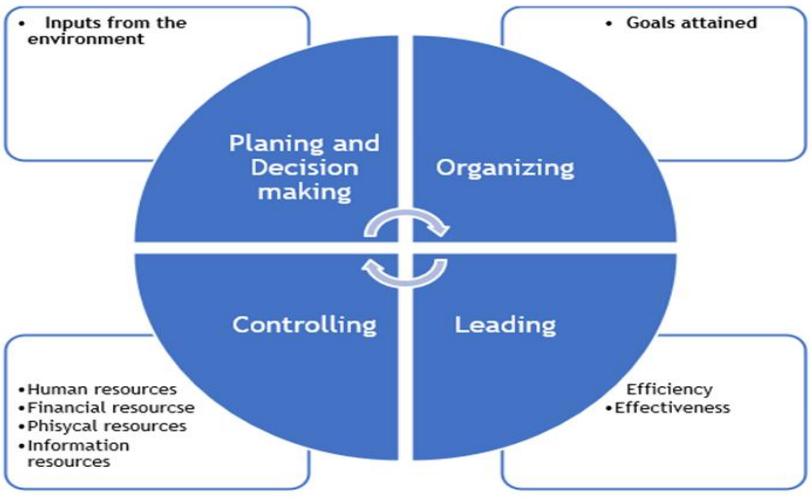


Figure 1. Management process
Source: Djukic et al., according to King et al., 2010.

Management represents the process of planning, organizing, leading (leadership), and controlling resources (human, financial, material, informational) within an organization to achieve precisely defined goals (Drucker, 1954). It is the function that ensures an organization operates efficiently and effectively, translating strategy into concrete actions and results. Management addresses the internal dynamics of the organization, coordinates activities, and motivates employees. Modern organizations cannot be reduced solely to economic entities or hierarchical structures; according to King and colleagues (2010), they are *social actors* who actively construct their role in the political and economic environment. This perspective unifies management (as a coordination process), economics (as a resource framework), policy (as a struggle for power), and advancement (as a tool for identity creation) into a single theoretical whole.

Economics: Economics is the social science that studies how societies, governments, businesses, and individuals make decisions about allocating scarce resources to satisfy their unlimited wants and needs (Samuelson & Nordhaus, 2010). In an organizational context, economics provides a framework for understanding market forces (supply and demand, competition), production costs, pricing, profitability, investment decisions, and the impact of macroeconomic factors (interest rates, inflation, GDP) on operations. The focus is on optimal resource use to maximize benefits (profit, social welfare).

Policy: Policy refers to the decision-making processes that shape the distribution of resources, power, and authority within society or, more specifically, within an organization and in its relationship with the external environment (Pfeffer, 1992). In an organizational context, policy encompasses:

- Internal politics: Struggles for influence, coalition formation, conflict management between individuals or groups, and defining rules and procedures.
- External politics: Interaction with state institutions (legislation, regulations), interest groups, media, local communities, and international actors. The goal is to secure support, influence policy decisions relevant to the organization, and manage risks from the political sphere.

Organizational Advancement: Organizational advancement (often synonymous with corporate communications, public relations, or institutional marketing) represents a strategically managed process of establishing and maintaining favorable relationships and images between an organization and its key publics (employees, customers, investors, media, government, local communities, the general public) (Kotler & Keller, 2016). It includes activities such as creating and nurturing image and reputation, media management, internal communication, investor relations, crisis communication, Corporate Social Responsibility (CSR), and increasingly, digital presence. The goal is to build trust, increase visibility, create positive perception, and generate support for the organization and its objectives.

These four terms are not isolated categories; they are deeply intertwined and interdependent, forming a dynamic system within and around the organization.

Management as the Coherent Force: Management is the central function that integrates the other three domains. Managers must apply economic principles (e.g., cost-benefit analysis, budget planning) when making resource allocation decisions. Simultaneously, they must navigate internal and external politics by building alliances, managing conflicts, and lobbying for favorable conditions. Ultimately, effective management includes strategic planning and implementation of advancement activities to support organizational goals and build reputation. Without efficient management, economic potential remains unrealized, political risks uncontrolled, and advancement becomes aimless and ineffective.

Economics as the Foundation and Framework: Economic principles and realities form the bedrock on which organizations function. Profitability (or financial sustainability for nonprofits) is often a key measure of management success. Economic conditions (recession, inflation) directly influence policy decisions (e.g., subsidies, tax incentives) and advancement (e.g., message adaptation during crises). An organization's policy (e.g., lobbying for lower taxes) is often motivated by economic interests. Organizational advancement must be economically justified—investments in communication should

yield measurable returns (e.g., increased sales, better capital access, stronger employee loyalty). Economics sets boundaries and provides motives for management, political action, and advancement.

Policy as the Environment and Dynamic: Political processes within and outside organizations profoundly impact all other aspects. Internal politics can hinder effective economic decisions or block advancement initiatives. External policy (laws, regulations, public opinion) can create new market opportunities or threats (e.g., bans on certain products, mandatory CSR reporting). Management must understand and actively participate in political processes to protect and advance organizational interests. Organizational advancement is often a key tool in political action—shaping public opinion and influencing decision-makers (e.g., campaigns for public project support). Policy defines the "rules of the game" and power currents within which organizations must operate, and which management and advancement must leverage or overcome.

Organizational Advancement as the Bridge and Shield: Advancement serves as a critical bridge between the organization and its environment (economic and political). Effective advancement builds trust and reputation, which constitute an economic asset (reducing capital costs, increasing customer loyalty, attracting talent) and political capital (generating public support, facilitating lobbying, mitigating regulatory risks). It communicates organizational economic results and political positions. Management relies on advancement to gain employee support for change, attract investors, or mitigate crisis fallout. In the information age, where public opinion is powerful, advancement is an essential tool for perception management and the protection of organizational value. Advancement transforms internal activities (management, economics, policy) into external support and legitimacy.

These four elements form a cyclical, mutually reinforcing system, as illustrated in Figure 2.



Figure 2. The four key elements for organizational resilience
Source: Authors

Management uses economic analysis and political skills to make resource allocation decisions. These decisions, along with organizational activities, generate economic outcomes and political reactions. Organizational advancement communicates these results and positions, striving to shape a positive economic environment (through customer/investor trust) and a favorable political climate (through public support and influence on decision-makers) (Djukic & Ilic, 2024). Feedback from the environment (economic trends, political pressures, public reactions) then feeds back into the management system, shaping new decisions. An effective organization is one that succeeds in harmoniously integrating and

managing these four dimensions, recognizing their interdependence and leveraging synergy to achieve strategic goals.

2. German "Industrie 4.0" program: an integrated system as a best practice example

In Germany, the "Industrie 4.0" program combined subsidies (financial incentives), digitization standards (regulatory framework), and knowledge networks (capacity building) to promote industry's resilience to global disruptions. Industry 4.0 was a strategic initiative of the German government, launched in 2011, with the aim of transforming production through digitization, the Internet of Things (IoT), and cyber-physical systems. Its main goal was to create "smart factories" in which machines communicate autonomously, optimize processes, and adapt to changes in real time. However, the program has evolved over the last decade into a comprehensive ecosystem that combines financial incentives (subsidies), regulatory frameworks (digitalization standards), and knowledge networks (capacity building) to build industry resilience to global disruptions – from the COVID-19 pandemic to geopolitical tensions and chain failures (Bauernhansl et al., 2021). The synthesis of these elements plays a key role in strengthening the competitiveness and adaptability of German industry.

2.1. Key pillars of the program and their integration

The subsidies were a financial incentive for digital transformation. The German government, through the Ministry of Economic Affairs and Climate (BMWK), has allocated significant funds to support enterprises, especially small and medium-sized enterprises (SMEs), in the implementation of Industry 4.0 technologies. The subsidies were focused on:

- Investments in IoT and AI: Support for the introduction of sensors, cloud solutions, and artificial intelligence in production lines.
- Digitization of supply chains: Funding platforms for tracking raw materials in real time, thus reducing the risk of disruption.
- Cyber security: Grants for the protection of industrial systems against hacker attacks (BMWK, 2021).

As a recent example of subsidies, the authors cite the "Digital Jetzt" program (2020–2023), which provides SMEs with grants of up to € 50,000 for digitization. Meanwhile, KfW banks offer favorable loans with interest subsidies for investments in "Industry 4.0-compatible" equipment. These financial incentives are key to overcoming the initial costs of transformation, which is especially important for SMEs, which make up 99% of German industry (Acatech, 2020). The introduction of digitization standards was a measure of the regulatory framework of organizations in Germany. Without harmonized standards, digitization would lead to system fragmentation and uncertainty. Germany has therefore developed technical standards that ensure interoperability, security and scalability: a) RAMI 4.0 (Reference Architectural Model for Industrie 4.0): A three-dimensional model that standardizes communication between devices, software and people (DIN SPEC 91345); b) IEC 62443: International standard for cyber security of industrial systems, mandatory for all subsidized projects; c) "Industrie 4.0" certification: Checking the compatibility of technologies with German and EU standards (Bauernhansl et al., 2021).

These regulatory frameworks have reduced the risk of "vendor lock-in" (dependence on one supplier) and enabled flexible integration of new solutions during crises. For example, during the pandemic, standardized platforms enabled a rapid shift of production to medical equipment without lengthy testing (Kagermann et al., 2020). Networks for Knowledge have led to the capacity building of German organizations. The program relied on horizontal and vertical cooperation between industry, science, and the state:

- Plattform Industrie 4.0: A national platform with over 300 members (Siemens, Bosch, Fraunhofer Institutes) that developed guidelines, organized workshops, and presented good practice cases.
- Mittelstand-Digital: A network of 25 centers for the digital transformation of SMEs, where experts provided free consultations.
- Academic initiatives: Universities such as RWTH Aachen and the Technical University of Munich have offered specialized courses and research within "Industrie 4.0" (Lasi et al., 2021).

These networks enabled the rapid diffusion of knowledge. For example, solutions for remote monitoring of production, developed during the lockdown, were shared with thousands of companies through the platform in just one week (Acatech, 2020). The synergy of the aforementioned pillars led to the building of the resistance of German organizations to global disruptions. The integration of the mentioned elements created an independent ecosystem of resilience. During the COVID-19 pandemic, subsidies enabled the rapid procurement of automation robots, standards ensured that new systems worked with existing infrastructure, and knowledge networks shared protocols for remote work. As a result, German industry reduced production decline by 5% in 2020 compared to an average of 11% in the EU (BMWK, 2021). Apart from Germany, the synergy of the mentioned elements contributed to Ukrainian organizations as well. During the war in Ukraine, supply chain shortages of steel and semiconductors were mitigated through subsidies for alternative suppliers (e.g., 3D printing of parts), standardized platforms for component interchange (RAMI 4.0), and through network consultation for rapid reconfiguration of production (Kagermann et al., 2020). Practice and shocks have influenced to try the long-term resilience of organizations through adequate programs. Thus, the new program was created to stimulate the development of "digital twins" – virtual replicas of physical systems. This allowed the simulation of crises (e.g., tsunamis, cyber attacks) and the testing of responses without the risk of real production (Lasi et al., 2021). Although the program for predicting future crisis situations achieved significant results, it was faced with various challenges, such as uneven adaptation (large corporations progress faster than SMEs), cyber threats (the growth of the number of connected devices increases the risk of attacks) (Acatech, 2020), geopolitical dependence (40% of many key components - for example semiconductors - are still imported from Asia) (Bauernhansl et al., 2021).

2.2. The future strategy for strengthening the resilience of organizations (2023-2027) focuses

The future strategy for strengthening the resilience of organizations (2023-2027) focuses on:

- Green digitalization: Integration of Industry 4.0 with climate neutrality goals (e.g., optimization of energy consumption using AI).
- Sovereignty in technologies: National initiatives for the production of semiconductors and batteries.
- Global leadership: Expansion of the RAMI 4.0 standard into ISO and IEC standards (BMWK, 2021).

The "Industrie 4.0" program transcended technological initiative – it became a model of holistic resilience policy linking financial incentives, regulatory frameworks, and capacity building. Its strength lies in synergy: subsidies accelerate adoption, standards ensure security, and knowledge networks enable collective learning. As global disruptions increase, the German approach offers a reliable path to building an industry that is not only efficient but also adaptable, secure, and sovereign. As Bauernhansl (2021) emphasizes: "Industrie 4.0 is not about technology – it is about transforming society through technology."

3. Overcoming challenges in managing interventions for organizational advancement

Beyond the exemplary practice of Germany's "Industrie 4.0" program, which has demonstrated remarkable success in strengthening organizational resilience against crisis shocks, it is essential to fundamentally examine approaches to overcoming challenges in managing interventions for organizational advancement. Key problems in this domain manifest through three complex categories. Policy fragmentation represents the primary obstacle, where measures are implemented in isolation – ministries of finance allocate subsidies without coordinating with the regulatory frameworks of economics ministries, leading to synergy deficits and diminished advancement effectiveness (Lee & Park, 2020). Short-term focus further complicates the situation, as governments often prioritize rapid, visible outcomes like emergency crisis assistance rather than long-term resilience-building strategies (Wilson & Davis, 2019). The third challenge is unequal resource access, where large corporations leverage their capacity and networks to more readily access support, while small and medium-sized enterprises (SMEs) remain marginalized despite constituting the backbone of industry (Johnson & Smith, 2021). Solutions to these challenges lie in establishing an integrated management system encompassing unified platforms for intervention application and coordination, alongside introducing resilience indicators such as supply chain diversification indices or digital maturity levels (Martinez & Thompson, 2022). Effective resilience advancement requires four key recommendations. First, creating a "resilience catalog" with clear criteria (financial reserves, digital readiness, cybersecurity) to guide policy measures. Second, establishing coordination bodies to facilitate dialogue between economic agencies and the private sector during intervention design. Third, measuring impact through indicators like the number of organizations adopting resilient practices, rather than merely tracking allocated funds (Martinez & Thompson, 2022). Fourth, promotion through success stories, such as narratives of companies surviving crises through state-supported digitalization, thereby creating a positive influence on others. Organizational advancement must be understood as a long-term strategy, as economic resilience is not a static state but a dynamic process requiring continuous investment (Wilson & Davis, 2019). Through coherent, targeted, and adaptable interventions, policy can transform organizations into pillars of stability – the crucial shift is from "damage control" to "immunity building" (Wilson & Davis, 2019).

Conclusion

In the concluding reflections, the authors emphasize that the paper provides an explicit connection among key terms—economics, organization, management, advancement, and policy—thereby establishing a comprehensive theoretical framework for understanding resilience. The practical orientation of the article is evident in its focus on the functional mechanisms of advancement rather than merely its necessity, making the text applicable to real organizational contexts. The logical structure of the paper guides the reader from theoretical foundations through concrete mechanisms to the identification of challenges and proposed solutions, while the German "Industrie 4.0" example serves as a practical synthesis of the concept. For all these reasons, this paper represents a solid foundation for comprehending the complexity of resilience and organizational advancement. The authors believe the article will be significantly beneficial to academics for further theoretical research, decision-makers for creating more effective policies, and managers of organizations for implementing resilience strategies in daily operations.

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The Impact of Corporate Environmental (CE) Reporting on the Financial Performance of Listed Companies: A Case Study of the Automotive Industry

Uticaj korporativnog izveštavanja o životnoj sredini (CE) na finansijske performanse kompanija koje kotiraju na berzi: Studija slučaja automobilske industrije

Andreea Weisner[1]

[1]*West University of Timisoara, Doctoral School of Economics, Romania, andrea_weisner@yahoo.de*

Abstract. *Growing global environmental concerns have transformed corporate environmental (CE) reporting from a voluntary practice into a strategic imperative, particularly for high-impact sectors such as the automotive industry. This study examines the financial benefits of CE reporting within the automotive sector, analyzing data from 50 publicly listed automotive companies over five years (2017-2022). The study identifies a robust positive correlation between comprehensive CE reporting and superior financial performance using a quantitative approach and financial metrics such as return on assets (ROA) and return on equity (ROE). Analysis of leading automotive companies (Tesla, BMW, and Toyota) reveals that enhanced environmental transparency contributes to profitability and investor confidence, especially in regions with stringent regulatory oversight. These findings highlight the strategic importance of CE reporting, suggesting that proactive environmental disclosure provides a competitive advantage. This study contributes to the existing literature on the link between sustainability and financial success, providing valuable insights for policymakers, investors, and industry leaders.*
Keywords: *Corporate environmental reporting, financial performance, automotive industry, sustainability, transparency.*

Apstrakt. *Rastuća globalna zabrinutost za životnu sredinu transformisala je korporativno izveštavanje o životnoj sredini (KE) od dobrovoljne prakse do strateškog imperativa, posebno za sektore sa velikim uticajem kao što je automobilska industrija. Ova studija ispituje finansijske koristi od izveštavanja KE u automobilskom sektoru, analizirajući podatke iz 50 javno kotiranih automobilskih kompanija tokom pet godina (2017-2022). Studija identifikuje snažnu pozitivnu korelaciju između sveobuhvatnog izveštavanja KE i superiornih finansijskih performansi koristeći kvantitativni pristup i finansijske metrike kao što su povraćaj na aktivu (ROA) i povraćaj na kapital (ROE). Analiza vodećih automobilskih kompanija (Tesla, BMW i Tojota) otkriva da poboljšana transparentnost u oblasti životne sredine doprinosi profitabilnosti i poverenju investitora, posebno u regionima sa strogim regulatornim nadzorom. Ovi nalazi ističu strateški značaj izveštavanja o KE, sugerišući da proaktivno objavljivanje informacija o životnoj sredini pruža konkurentsku prednost. Ova studija doprinosi postojećoj literaturi o vezi između održivosti i finansijskog uspeha, pružajući vredne uvide kreatorima politike, investitorima i liderima u industriji.*
Ključne reči: *Korporativno izveštavanje o životnoj sredini, finansijski rezultati, automobilska industrija, održivost, transparentnost.*

Introduction

The automotive industry faces escalating pressure to enhance environmental sustainability due to emissions, resource consumption, and climate change concerns. This pressure has driven increased corporate environmental (CE) reporting adoption, where companies disclose their environmental

impacts, policies, and initiatives. Growing demands for transparency from investors, governments, and consumers have accelerated the integration of CE reporting into broader corporate governance strategies (Jones & Stanton, 2021).

This study investigates the impact of CE reporting on the financial performance of automotive companies. This sector is particularly relevant given its high environmental impact and significant regulatory oversight. By examining critical financial metrics (ROA and ROE) in conjunction with CE reporting practices, this research aims to determine whether sustainability initiatives translate into improved financial performance.

1. Methodology

This study employs a quantitative approach to assess the relationship between CE reporting and financial performance. Financial data from 50 globally operating automotive companies were collected from 2017 to 2022, with a focus on companies known for their comprehensive CE reporting.

Data Collection : Annual financial data (ROA, ROE, net profit margin) were sourced from company reports and databases such as Bloomberg. CE reporting data were gathered from sustainability reports and scored using Global Reporting Initiative (GRI) standards.

Analytical Methods: Multivariate regression analysis was utilized to evaluate the influence of CE reporting scores on financial performance, controlling for factors such as market size, regional regulatory frameworks, and industry-wide environmental pressures.

2. Results: Case study of the automotive industry

2.1. Introduction to the case study

The automotive sector is among the most environmentally impactful industries globally, making it a prime candidate for the analysis of Corporate Environmental (CE) reporting. As environmental concerns intensify, the sector has faced rising regulatory pressure and shifting consumer demands toward sustainability (Clark et al., 2019). This section examines three leading automotive companies—Tesla, BMW, and Toyota—to investigate the relationship between CE reporting and financial performance from 2017 to 2023. Key financial metrics include Return on Assets (ROA), Return on Equity (ROE), and Net Profit Margins (NPM), exploring how transparent environmental disclosures influence these indicators (McWilliams et al., 2020).

2.2. Tesla: CE leadership and financial performance

Tesla has positioned itself as a global leader in sustainability through its focus on electric vehicles (EVs) and renewable energy. Its CE reporting has expanded significantly, with a CE score 88 in 2023. This reflects comprehensive disclosures on Tesla's carbon neutrality goals, renewable energy adoption, and supply chain sustainability (Tesla, 2024). Tesla's Gigafactory expansions and its integration of clean energy into manufacturing have bolstered its environmental credentials and financial outcomes (Eccles et al., 2020).

Table 1. Financial performance (2023)

Revenue	$121.7 billion (up from $81.5 billion in 2021)
ROA	4.3% (compared to 3.1% in 2021)
ROE	9.2% (compared to 5.6% in 2021)
Net Profit Margin	10.5% (compared to 8.3% in 2021) (Tesla, 2024)

Tesla's strong performance in 2023 can be attributed to a 47% year-over-year increase in EV deliveries, driven by increased demand for sustainable vehicles (Tesla, 2024). Moreover, Tesla raised $2 billion in green financing, demonstrating the financial benefits of comprehensive CE reporting. This has allowed

Tesla to expand production capacity while enhancing its reputation with environmentally conscious investors (Jones et al., 2022; Tesla, 2024).

2.3. BMW: Sustainability embedded in corporate strategy

BMW has long embedded sustainability into its corporate strategy, reflected in its high CE score of 90 in 2023. The company's CE reporting highlights substantial progress in reducing its carbon footprint, adopting renewable energy, and improving the sustainability of its supply chain (BMW Group, 2023). These initiatives have improved BMW's environmental performance and enhanced its market position and financial outcomes (Eccles et al., 2020).

Table 2. Financial performance (2023)

Revenue	€142.6 billion (from €129.2 billion in 2021)
ROA	7.5% (up from 6.9% in 2021)
ROE	13.4% (up from 12.1% in 2021)
Net Profit Margin	8.2% (up from 7.8% in 2021) (BMW Group, 2023)

BMW has also leveraged its CE reporting to access new sources of financing. In 2023, the company issued a €1 billion green bond, which helped finance its investment in low-emission vehicle production and battery technology research (BMW Group, 2023). The company's EV sales increased by 47% year-over-year, demonstrating the positive link between sustainability initiatives and financial performance (Jones et al., 2022).

2.4. Toyota: Balancing CE reporting with global operations

Toyota, the largest automaker by volume, has approached CE reporting focusing on hybrid technologies and carbon reduction. Its CE score improved to 89 in 2023, reflecting enhanced transparency on emissions, energy efficiency, and the use of renewable resources (Toyota Motor Corporation, 2023). Toyota's extensive global operations present challenges in standardizing sustainability practices, yet the company has made significant strides in reporting (Hahn & Kühnen, 2022).

Table 3. Financial performance (2023)

Revenue	¥39.0 trillion (up from ¥33.5 trillion in 2021)
ROA	5.6% (up from 5.1% in 2021)
ROE	10.1% (compared to 9.4% in 2021)
Net Profit Margin	7.4% (compared to 7.2% in 2021) (Toyota Motor Corporation, 2023)

Toyota's ¥1.5 trillion investment in hydrogen fuel cell development and zero-emission vehicles demonstrates its long-term commitment to sustainability, which has been well-received by both consumers and investors (Toyota Motor Corporation, 2023). The company's goal of carbon neutrality by 2050 aligns with its growing emphasis on CE reporting, contributing to its steady financial performance (Toyota Motor Corporation, 2023).

2.5. Comparative analysis

The financial data from Tesla, BMW, and Toyota illustrate a clear link between CE reporting and improved financial performance. Tesla's rapid revenue growth and profitability are closely tied to its sustainability-driven business model. At the same time, BMW's robust CE reporting has allowed it to enhance its market position and access to sustainability-focused capital (Clark et al., 2019). Toyota's consistent financial returns, supported by its hybrid technology leadership, further underscore the value of integrating CE reporting into corporate strategy (Hahn & Kühnen, 2022).

Table 4. Comparative analysis

Company	CE Score (2023)	Revenue (2023)	ROA (%)	ROE (%)	Net Profit Margin (%)
Tesla	88	$121.7 billion	4.3%	9.2%	10.5%
BMW	90	€142.6 billion	7.5%	13.4%	8.2%
Toyota	89	¥39.0 trillion	5.6%	10.1%	7.4%

2.6. Discussion: The financial impact of CE reporting

The correlation between CE scores and financial performance in the automotive industry is well-documented (Clark et al., 2019). Tesla's impressive financial gains are tied directly to its sustainability and clean energy leadership. At the same time, BMW's ability to raise €1 billion through green bonds illustrates how CE reporting can attract new sources of financing (BMW Group, 2023). Toyota's hybrid vehicle success and its long-term strategy for carbon neutrality further emphasize the financial advantages of proactive environmental disclosures (Toyota Motor Corporation, 2023).

While all three companies operate in different regulatory and market environments, the positive impact of CE reporting on financial performance is consistent. The strength of this relationship varies depending on the company's geographic location and the stringency of environmental regulations. For instance, European automakers like BMW have seen more robust financial returns from their CE efforts due to more stringent regulations and higher consumer demand for sustainability (Hahn & Kühnen, 2022; McWilliams et al., 2020).

2.7. Conclusion

The Tesla, BMW, and Toyota case studies provide clear evidence that comprehensive CE reporting enhances financial performance. Companies with vital environmental transparency, like Tesla and BMW, have reaped the benefits of increased revenue, profitability, and access to green financing (Jones & Stanton, 2021). Toyota's focus on hybrid technology and its commitment to sustainability goals have similarly contributed to steady financial returns. This analysis underscores the importance of integrating CE reporting into corporate strategy as a critical driver of financial success in the automotive industry (Eccles et al., 2020).

3. Discussion

This study's findings highlight the substantial positive correlation between comprehensive CE reporting and strong financial performance within the automotive industry. Leading companies with detailed environmental disclosures consistently outperform their peers financially. This aligns with the view that robust CE reporting improves financial outcomes through operational efficiency gains, enhanced investor confidence, and improved risk management (Eccles et al., 2020).

The automotive industry's sensitivity to environmental regulations and public perception makes CE reporting particularly impactful. Companies demonstrating accountability through comprehensive reporting often realize operational efficiencies and cost savings (López-Gamero et al., 2016). Furthermore, investor preferences for sustainable firms play a crucial role. The growing trend of socially responsible investing (Clark et al., 2019) signals increased demand for shares of environmentally conscious companies.

While the link between CE reporting and financial improvement is evident, the magnitude of this impact varies across all companies. Regulatory environments and the maturity of a firm's environmental reporting practices play significant roles. For instance, European automotive companies operating under stricter regulations tend to exhibit a stronger correlation between CE reporting and

financial performance (Hahn & Kühnen, 2022). Consumer preferences also influence this dynamic; companies communicating their commitment to sustainability may gain market share and loyalty.

Conclusion: The interplay of ce reporting, financial performance, and future research directions

This study's findings robustly demonstrate a significant positive correlation between comprehensive corporate environmental (CE) reporting and enhanced financial performance within the automotive industry. Analysis of leading companies—Tesla, BMW, and Toyota—reveals that organizations embracing transparent and robust environmental reporting practices experience substantial improvements in key financial metrics, including return on assets (ROA), return on equity (ROE), and net profit margins. This evidence suggests that CE reporting transcends mere regulatory compliance; it represents a strategic advantage that contributes significantly to financial success (Eccles et al., 2014). The observed financial benefits extend beyond immediate gains, indicating a potential for long-term value creation through enhanced operational efficiency, improved investor relations, and strengthened brand reputation.

However, this research also highlights crucial areas needing further investigation. The current body of knowledge needs to improve concerning the long-term financial implications of CE reporting across diverse sectors and geographical regions. Future research should address this deficiency by undertaking longitudinal studies that track the financial performance of companies with varying levels of CE reporting commitment over extended timeframes. This longitudinal approach will allow for a more nuanced understanding of the temporal dynamics between CE reporting and financial outcomes, providing crucial insights into the sustainability of these financial benefits.

Furthermore, the role of emerging markets in shaping the future of CE reporting and its impact on financial performance demands closer scrutiny. The regulatory landscape, investor expectations, and consumer preferences concerning environmental responsibility vary considerably across different global regions. Comparative studies examining the influence of CE reporting in both developed and emerging economies are needed to determine whether the observed correlation between CE reporting and financial performance is consistent across diverse economic and regulatory contexts (Sullivan & Mackenzie, 2017). Such research should account for factors such as the level of regulatory enforcement, the sophistication of capital markets, and the prevailing cultural norms regarding environmental sustainability.

In addition to cross-regional comparisons, future studies should explore the multifaceted relationship between CE reporting and financial performance. While this study indicates a positive correlation, it is crucial to delve deeper into the mediating and moderating factors that influence this relationship. For instance, the quality of CE reporting (i.e., comprehensiveness, reliability, and assurance), the specific environmental initiatives undertaken by companies, and the integration of sustainability into overall business strategy are likely to influence the strength and nature of this correlation. Further research should employ more sophisticated analytical techniques to disentangle these complex interactions and to ascertain the specific mechanisms through which CE reporting generates financial value.

In conclusion, while this research provides strong evidence supporting the link between comprehensive CE reporting and enhanced financial performance, it also underscores the need for more extensive, longitudinal, and cross-regional studies to understand this relationship's multifaceted nature fully. By investigating the long-term impacts of CE reporting, accounting for diverse regulatory and cultural contexts, and delving deeper into the mediating mechanisms, future research can provide a more holistic and nuanced understanding of the strategic significance of CE reporting for firms across various sectors and geographical regions. This enhanced understanding will be critical for informing corporate

strategy and investment decisions and developing effective environmental policies (Porter & Kramer, 2011).

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Perceptions and Awareness of Data Security in Artificial Intelligence Systems

Percepcije i svest o bezbednosti podataka u sistemima veštačke inteligencije

Marko Marković[1], Olja Krčadinac[2]

[1]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, marko.markovic@mef.edu.rs*

[2]*University "Union-Nikola Tesla", Faculty of Informatics and Computer science, Belgrade, Serbia, okrcadinac@unionnikolatesla.edu.rs*

Abstract: *This paper analyzes users' perception and awareness level of data security in artificial intelligence systems, with a particular focus on the challenges, risks, and preventive protection mechanisms. The research was conducted on a sample of 110 information technology students, which represents a relevant group considering their intensive use of these technologies. The results indicate that most respondents have partial knowledge of risks and protective measures, while the number of fully informed users is relatively low. Data availability, access control, and adherence to ethical principles were identified as the dominant challenges, while unethical use and data theft were the most significant risks. Respondents recognize encryption, regular system updates, and strengthening authentication mechanisms as key preventive measures. The report emphasizes the need for systematic user education, consistent application of legal frameworks, and alignment with international standards to ensure balanced use of artificial intelligence while preserving data integrity and privacy.*
Keywords: *Data security, artificial intelligence, security risks, protection mechanisms, user awareness.*

Apstrakt: *Ovaj rad analizira percepciju i nivo svesti korisnika o bezbednosti podataka u sistemima veštačke inteligencije, sa posebnim osvrtom na izazove, rizike i preventivne mehanizme zaštite. Istraživanje je sprovedeno na uzorku od 110 studenata informacionih tehnologija, što predstavlja relevantnu grupu imajući u vidu njihovu intenzivnu upotrebu ovih tehnologija. Rezultati ukazuju da većina ispitanika poseduje delimično znanje o rizicima i merama zaštite, dok je broj u potpunosti upoznatih korisnika relativno nizak. Kao dominantni izazovi identifikovani su dostupnost podataka, kontrola pristupa i poštovanje etičkih principa, dok su najznačajniji rizici neetička upotreba i krađa podataka. Ispitanici prepoznaju enkripciju, redovno ažuriranje sistema i jačanje mehanizama autentifikacije kao ključne mere prevencije. Rad ističe potrebu za sistematičnim obrazovanjem korisnika, doslednu primenu pravnih okvira i usklađivanje sa međunarodnim standardima, kako bi se obezbedilo uravnoteženo korišćenje veštačke inteligencije uz očuvanje integriteta i privatnosti podataka.*
Ključne reči: *Bezbednost podataka, veštačka inteligencija, bezbednosni rizici, mehanizmi zaštite, svest korisnika.*

Introduction

Information is the most valuable resource of the modern era, upon which all business processes, operations, and functions depend (Paracha et al., 2024). Information sources are diverse, often designed to manipulate facts and mislead end users during the decision-making process. Since every piece of information is critical to the organization, it must carefully and with complete integrity protect that information from external factors or independent actors (Alzoubi & Mishra, 2025). In addition, it is essential that the information be stored in secure data repositories, which are appropriately protected against unauthorized use or modification. Altered information that loses reliability can significantly impact social and economic processes, so businesses must focus on the accuracy of their information when using it in decision-making (Chen et al., 2025). In the current era of machine learning, it is essential

to be mindful of information security and its impact on machine learning algorithms. If we allow a system access to train on our information, which may be of strategic importance to our operations, it raises the question of whether a machine learning system could compromise the information.

Machine learning is not a concept that has only become known in the last few years, it dates back to the mid-18th century. To examine the functionality of the machines and their automation in the process, Turing created the "Imitation Game" algorithm. Turing wanted to demonstrate how the machine could react like a human and thus deceive the user in its response. The test was conducted by one user interacting with the machine, which could be software or a calculating machine. The evaluator itself, by asking questions, had to recognize which answer was provided by a human and which by the machine. Through an interface or other access, the evaluator communicates and attempts to determine who is providing the answer from the other side. Today, we can also observe this type of test with machine learning platforms, which, when providing answers, attempt to imitate human communication and thus provide the user with all the necessary information they are looking for. Due to their capabilities, efficiency, and communication methods, users find them useful because they increase their productivity. While the other segment of these platforms is seen as disappointing.

With the wider implementation of machine learning, complications are also arising in the security of users' information. Information security is the process by which all data possessed by an individual, platform, or organization is protected to prevent that information from leaving its original environment through any action or instrument that could exploit that information (Šušter et al., 2025). Deficiencies in information security result in security threats that can compromise and endanger the privacy of information. As researchers emphasize in their studies, the protection and encryption of information are the only things that can guarantee that the information remains secure (Upreti et al., 2024). Information that leaves the platforms often becomes the subject of commercial exchange. We must educate ourselves properly about the importance of protecting information and how to adequately protect ourselves, our information, and all of our digital assets.

Every piece of information is sensitive and can cause significant damage to the organization or the user. Besides commercial information, it's also important to be careful about private data, which is not advisable to enter into machine learning platforms (Yang et al., 2023). Most often, the terms of use for a specific application will specify how data is handled, but users skip these details and don't pay attention to how their data will be treated in that application. In the process of solving certain problems, these systems retain all entered information and perform analysis on it during the interaction, but what happens to that information after the session ends? The information remains as training material for such systems. Since they are capable of processing vast amounts of information, there is a likelihood that they will also exploit that same information. Morality also presents a central challenge, as it raises questions of value principles and programming. There are two approaches to moral standards in this context, and these systems most often rely on them. The "top-down" approach implements pre-established moral standards into the system itself, thus defining the framework, while the "bottom-up" approach does the opposite and aims to learn by observing the user and how they interact with the system in terms of morality and values. Both approaches have an identical problem, which is the very ideology that guides them in their value base and value judgment when interpreting human needs.

Contemporary research in privacy-preserving machine learning has introduced innovative approaches to address the fundamental tension between data utility and privacy protection (Achuthan et al., 2024). Federated learning has emerged as a promising paradigm that enables collaborative model training while keeping sensitive data decentralized, thereby reducing the risk of large-scale data breaches (Saha et al., 2024). However, recent studies have demonstrated that even federated learning systems are vulnerable to various attack vectors, including gradient inversion attacks and model poisoning (Tayyeh & Al-Jumaili, 2024). To mitigate these vulnerabilities, researchers have developed differential privacy mechanisms that add calibrated noise to the training process, ensuring mathematical guarantees of privacy while maintaining model performance (Halim et al., 2021). The integration of encryption with machine learning workflows represents another significant advancement, allowing computations to be

performed on encrypted data without revealing the underlying information (Chen et al., 2024). These technological developments suggest that the future of secure machine learning lies in the combination of multiple privacy-preserving techniques, creating layered defenses that can withstand sophisticated adversarial attacks while preserving the essential utility of machine learning systems.

1. Methodology

Artificial intelligence models have become commonplace, and it is unimaginable not to use them in daily business operations. However, minimal attention is given to the most important security factor, and in such models, we often allow access to all data. Before use, it is essential to thoroughly research the model and approach it in a way that guarantees the privacy of all entered data during communication. The model's privacy policy determines the model's compliance with data protection and ethical standards, so it is essential to study the model's documentation before using it. We live in a time when it is necessary to quickly obtain all the necessary information, therefore it is crucial to become familiar with a tool that will speed up the execution time. (Marković and Soleša, 2025).

This research aims to present us with the problems that users encounter in the use of these models, what are the dilemmas that are poorly discussed on the Internet. The internet has become a place where data is constantly shared and shared, but when it comes to the security of that data, there will be less people who want to work on it. The target group of this research were students of information technology who use such models the most. A sample of 110 respondents was selected. Respondents had the option to choose more than one option. In the next section, we will present the analyses and considerations that we can deduce from the diagrams in order to understand the current level of user awareness in the context of data security in artificial intelligence. The questions focused on the level of awareness of data security, risk perception, proposals for preventive measures and experiences with data misuse. The analysis covers the key parameters of this research and will also give us a better insight into the current situation.

2. Results

In the first step of the study, the aim is to explore the level of user awareness of the challenges of data security in artificial intelligence. The majority of respondents are partially acquainted, with 65 respondents confirming this. 27 respondents are insufficiently familiar with the challenges, which should be a clear sign that effort is needed to make this percentage of respondents aware of all the challenges. In the last place, 18 respondents are fully familiar with all the challenges. These figures indicate a worrying lack of comprehensive understanding and indicate an urgent need for educational programs.

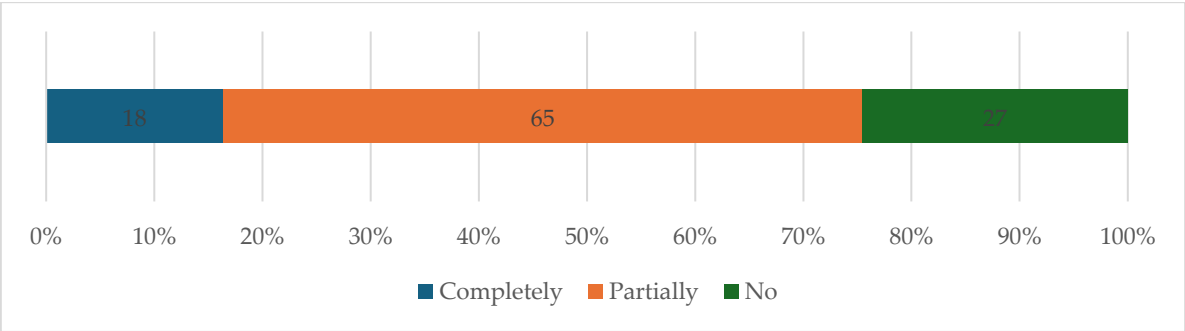


Figure 1. Awareness of the challenges of data security in Artificial Intelligence
Source: Authors

The following Figure 2 shows the biggest challenges that can be encountered when using artificial intelligence systems. We see that 48 of them have the most problems with the availability of their data, which indicates that they fear that their data will be compromised. The next item is control and access

to data, where 43 users believe that this is a problem of the privacy of the model itself. This information is important because data subjects do not want administrators or unwanted users to access their data. Next, the results of confidentiality and integrity of data are presented, which gives us a picture that 33 respondents take care of the data they receive from these models. In the last place, 21 respondents believe that ethical aspects are important.

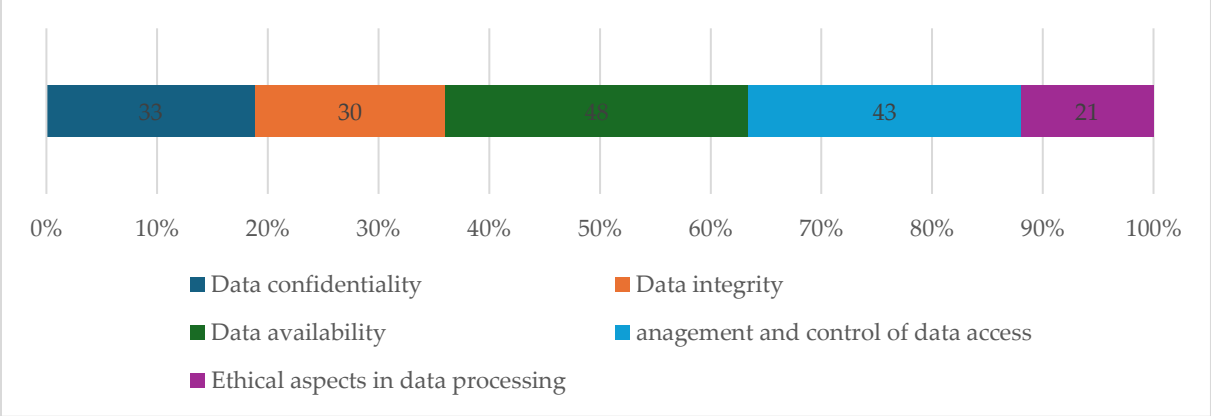


Figure 2. The most important challenges in data protection in Artificial Intelligence
Source: Authors

In Figure 3, we can see the risks of using artificial intelligence. In the first place, according to 52 respondents, is the unethical use of data, which again brings us to the ethics issues we mentioned. Ethics is an important aspect in data and it is necessary to process all the facts in an ethical way. In the next place is the theft or misuse of data, which is of concern to as many as 39 respondents. Stealing private data can lead to blackmail and manipulation. In the last place are the compromise of the system and the lack of privacy with a minimal difference in the respondents, due to the lack of privacy, and the compromise of the system occurs, because without privacy, it is very easy to compromise a system.

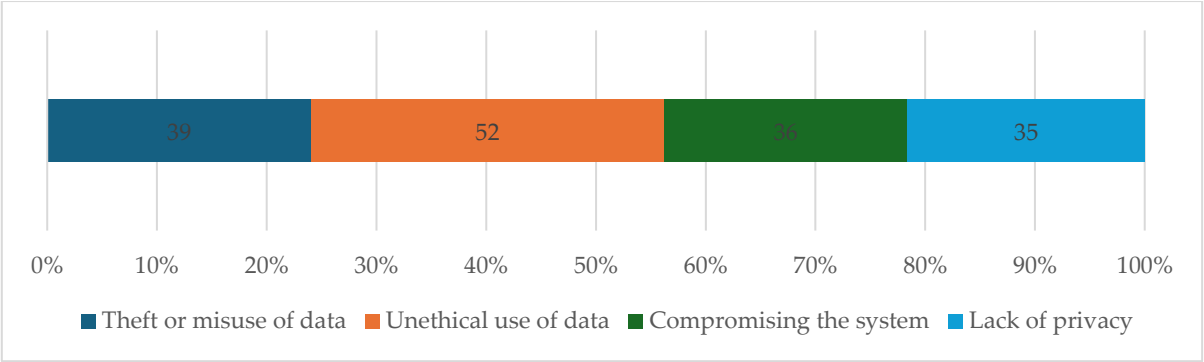


Figure 3. Risks in the use of data
Source: Authors

In addition to all the risks that can arise when using one of the artificial intelligence models, there is also the possibility that such systems can be improved and offer users safe and uninterrupted operation. In the first place is data encryption, which is recommended by 60 washers, in the second place is regular updating of the system, which can also improve all protection mechanisms. In the last place is the strengthening of authentication and access control, which is represented by 41 respondents. All three aspects of security can improve models and enable users to work transparently.

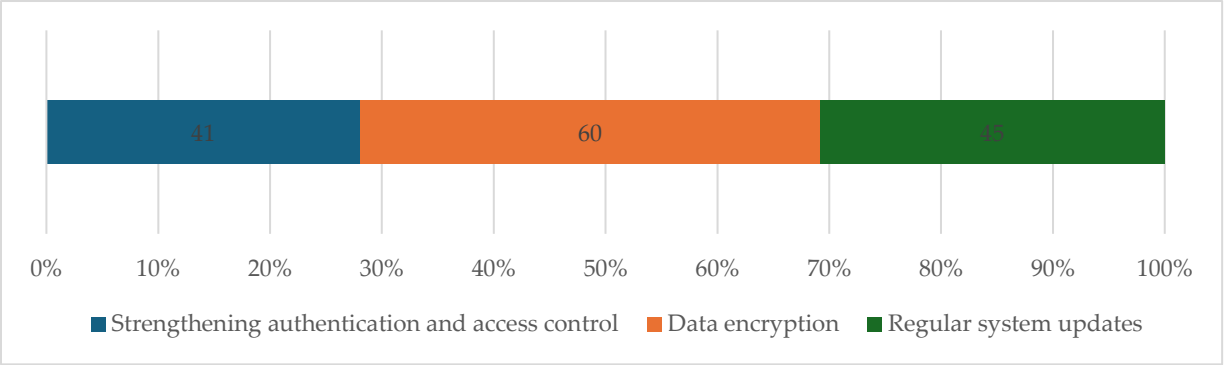


Figure 4. Preventive measures for data protection
Source: Authors

It is necessary to take into account the laws implemented by the state which relate to information security. This is an item that is a little less used by such models, which is why they are banned in some countries. Respondents agree that 57 of them need to comply with the General Data Protection Regulation, followed by the 46 respondents' opinions are the codes of ethics and principles that must be applied. Last but not least is the data privacy law, which 40 respondents consider important. Since artificial intelligence is a relatively new thing, there are not yet fully harmonized legal regulations for its use. The Ministry of Education, Science and Technological Development will report semi-annually to the Council for Artificial Intelligence on the implementation of the goals and strategic measures envisaged by this strategy, and the Council for Artificial Intelligence will report annually to the Government of the Republic of Serbia on the status of implementation, as well as on potential opportunities or risks for implementation.

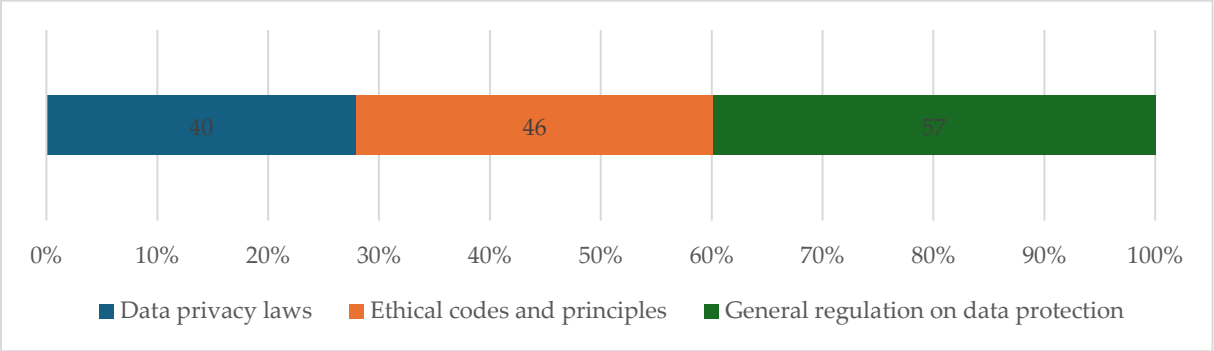


Figure 5. Legal aspects of Artificial Intelligence
Source: Authors

The sixth figure examines respondents' awareness of data privacy measures in artificial intelligence. In the first place, we see that 58 of the respondents are partially familiar with privacy measures, which leads us to the conclusion that it is necessary to introduce education of users about privacy measures. As many as 33 respondents have an insufficient level of knowledge of the measures, this can be a big problem, because the respondents can be misled and can be left without their data, without even being aware that someone can be held accountable for that act. In the last place, 30 respondents are fully aware of privacy measures, which is good data, because there are users who are aware of the risks that artificial intelligence can bring and means that there is a high probability that they will protect their data in an adequate way. On a global level, it is necessary to pay attention to data and its transfer, because data is a valuable capital, if we do not treat it adequately, problems can arise.

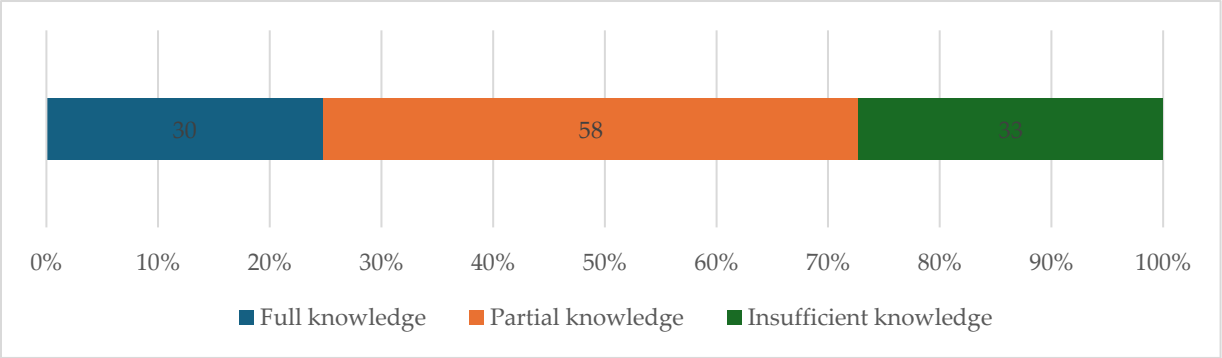


Figure 6. Knowledge of privacy measures in Artificial Intelligence
Source: Authors

The last question in the survey determined whether the respondents had problems with data theft. 49 of the respondents had a problem with the data and its security, which means that in some way all of their data was compromised. A larger number, 61 of them, had no experience in data theft. The fact that there are still a large number of users who have lost their data, leads to a problem that is not harmless at all. Data and identity theft is very common today and carries a great risk to the user. Cybercriminals steal data from users on a daily basis to achieve some of their goals. It happens that the data is locked with a monetary blackmail that it will be deleted. It is often threatened to share private content with other users. The misuse of data, in addition to all the downsides, can have social or political problems. It can contribute to major problems that can grow into a dangerous situation. No one is immune to such attacks, but it is necessary to take care and not rely on unreliable sources of electronic content. It is also necessary to have some anti-virus programs and risk detection systems in place to reduce the chance of data theft.

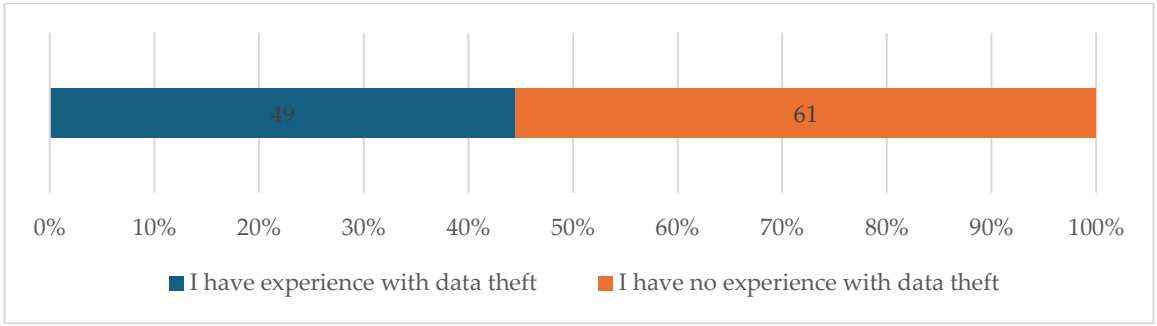


Figure 7. Data theft
Source: Authors

3. Discussion

With this research, we found that respondents are largely familiar with artificial intelligence, as well as the measures that need to be implemented to protect data in artificial intelligence. It is important that all information systems that use some form of artificial intelligence are fully protected. As basic measures, it is necessary to strengthen authentication and access control systems, use data encryption methods, regularly update and maintain the entire system, and create mechanisms for detecting risky and suspicious activities. There is also a need to strengthen ethical aspects and improve all protection systems. In addition to standard measures, it is necessary to pay attention to legal regulations and, if necessary, to adopt certain laws in the field of artificial intelligence. It is necessary to follow the methodology of the ISO 27001 standard related to information security. We can conclude that efforts are needed so that artificial intelligence can be controlled and applied in accordance with the norms that were set years ago, if we stay at the current level, we will have big problems with it and we will not be able to control it. If it is not treated appropriately, it is possible that it will train itself for greater things,

because if it has managed to optimize itself for all the world's languages, nothing prevents it from optimizing for other more dangerous actions.

Conclusion

Research has shown that user awareness of data security in artificial intelligence systems is still at an insufficient level, as most respondents only have partial knowledge of the challenges and protection measures. The research was conducted on a sample of 110 information technology students, which represents a relevant group considering their intensive use of these technologies. The biggest risks relate to unethical use and data theft, highlighting the need for a greater focus on ethical standards and responsible information management. Encryption, regular system updates, and strengthening authentication mechanisms were recognized as key preventive measures, confirming the importance of technical solutions in protecting digital resources. However, technical measures are not sufficient without raising the level of user awareness and knowledge, as the human factor remains the weakest link in the security system. Educational institutions and organizations must therefore prioritize comprehensive training programs that address both theoretical concepts and practical applications of data security. Furthermore, ongoing dialogue between developers, policymakers, and end-users is essential to bridge the knowledge gap and foster a culture of security consciousness. In addition, it is necessary to improve the legal framework and align it with international standards in order to ensure comprehensive data protection in the global digital environment. Only through a combination of technical, ethical, and legal mechanisms can the safe and responsible application of artificial intelligence be ensured, preserving data integrity and privacy and enabling its development for the benefit of society (De Almeida et al., 2021).

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The Significance of Economic Reforms on the Stability of Economic and European Systems

Značaj ekonomskih reformi za stabilnost ekonomskih i evropskih sistema

Boban Panovski[1], Jasmina Gligorijević[2], Aleksandar Stanković[3], Filip Cvetkovic[4], Nemanja Stankovic[5]

[1]*University "St. Kliment Ohridski-Bitola (UKLO)", Faculty of Technology and Technical Sciences (FTTS), Veles, North Macedonia, panovskib@gmail.com*

[2]*University of Business Academy in Novi Sad, Faculty of Applied Sciences, Niš, Serbia, jasmina.gligorijevic@fpn.rs*

[3]*University of Business Academy in Novi Sad, Faculty of Applied Sciences, Niš, Serbia, aleksandar.st.srb@gmail.com*

[4]*University of Business Academy in Novi Sad, Faculty of Applied Sciences, Niš, Serbia, cvetkovic.filip0@gmail.com*

[5]*University of Business Academy in Novi Sad, Faculty of Applied Sciences, Niš, Serbia, nemanja777stankovic@gmail.com*

Abstract: *Since its foundation, the European Community has undergone a long process of reforms, which have primarily come down to institutional reforms—meaning changes, redesigns, and the creation of new bodies within its institutions. The reform process is continuous, accompanied by certain difficulties, and the time frame for implementing ideas is long, as demonstrated by the example of the EU Constitution and the ongoing Lisbon Treaty process. It must be emphasized that the process of reforming the EU institutions does not come to an end. Economic reforms play a crucial role in ensuring the stability of economic and European systems. They aim to increase competitiveness, reduce structural deficiencies, and improve the institutional framework. In the context of the European economy, reforms carry specific weight because the functioning of the single market and the monetary union requires alignment and stability of the national economies. Reforms have positive effects on the stability, as they contribute to the stabilization of inflation, interest rates, and exchange rates, which is especially important for countries in the Eurozone. Reforms aid in improving competitiveness by increasing productivity and export potential, which is vital for maintaining economic balance. Reforms also promote social cohesion by reducing inequality and improving quality of life, which contributes to political and social stability. Economic reforms in the EU are part of a broader strategy to strengthen integration, stimulate economic growth and competition, and support sustainable and inclusive development solutions.*

Keywords: *European community, European systems, reforms, stability.*

Apstrakt: *Od svog osnivanja, Evropska zajednica prošla je kroz dug proces reformi, koje su se prvenstveno svodile na institucionalne reforme – što znači promene, redizajn i stvaranje novih tela u okviru njenih institucija. Proces reformi je kontinuiran, praćen određenim poteškoćama, a vremenski okvir za sprovođenje ideja je dug, što pokazuje primer Ustava EU i tekućeg procesa Lisabonskog ugovora. Mora se naglasiti da se proces reformisanja institucija EU ne završava. Ekonomske reforme igraju ključnu ulogu u obezbeđivanju stabilnosti ekonomskih i evropskih sistema. Cilj im je povećanje konkurentnosti, smanjenje strukturnih nedostataka i poboljšanje institucionalnog okvira. U kontekstu evropske ekonomije, reforme imaju posebnu težinu jer funkcionisanje jedinstvenog tržišta i monetarne unije zahteva usklađenost i stabilnost nacionalnih ekonomija. Reforme imaju pozitivne efekte na stabilnost, jer doprinose stabilizaciji inflacije, kamatnih stopa i deviznih kurseva, što je posebno važno za zemlje evrozone. Reforme pomažu u poboljšanju konkurentnosti povećanjem produktivnosti i izvoznog potencijala, što je od vitalnog značaja za održavanje ekonomske ravnoteže. Reforme takođe promovišu socijalnu koheziju smanjenjem*

nejednakosti i poboljšanjem kvaliteta života, što doprinosi političkoj i socijalnoj stabilnosti. Ekonomske reforme u EU su deo šire strategije za jačanje integracije, podsticanje ekonomskog rasta i konkurencije i podršku održivim i inkluzivnim razvojnim rešenjima.
Ključne reči: *Evropska zajednica, evropski sistemi, reforme, stabilnost.*

Introduction

The stability of economic systems in Europe is essential for maintaining economic growth, social cohesion, and the competitiveness of European countries. It depends on various factors, including monetary, fiscal, institutional, and geopolitical aspects. The stability of economic systems is closely linked to the implementation and success of economic reforms. Stability allows for the successful implementation of reforms, while reforms create a stronger and more resilient economic system that can withstand internal and external shocks. For successful synergy, a long-term vision, effective policy, and societal support are necessary. Reforms aim to create a more sustainable and resilient economic system, with stability serving as the foundation for their effective implementation. Thus, macroeconomic stability is a prerequisite for reforms. Reforms contribute to stabilizing inflation, interest rates, and exchange rates, which is especially important for countries in the Eurozone. A stable exchange rate and controlled inflation ensure a predictable economic environment, crucial for attracting investments and implementing reforms successfully.

Reforms enable the fiscal discipline by helping reduce budget deficits and public debt, creating room for funding structural reforms such as in education, infrastructure, or healthcare. Increasing financial inclusion and the stability of banks through regulatory reforms reduces the risk of financial crises. Reforms often include stimulating new industries and reducing dependence on a limited number of sectors, which also increases the stability of the economic systems.

Labor market reforms aim to reduce the level of unemployment and increase flexibility. This includes measures to improve workforce skills, promote mobility, and reduce employment barriers. Reforms that create a flexible labor market enhance the economy's ability to adapt to changes such as global economic crises or technological innovations. Increasing financial inclusion and the stability of banks through regulatory reforms reduces the risk of financial crises. Enhancing competitiveness through infrastructure modernization and encouraging innovations decreases the economy's vulnerability. Reforms help increase productivity and export potential, which is vital for maintaining economic balance.

Improving transparency, reducing corruption, and strengthening the rule of law are key to attracting investments and maintaining trust in economic systems. There are also social reforms aimed at improving social protection and reducing inequality, thereby preventing social unrest—which is also a prerequisite for economic stability.

Apart from the reforms currently taking place, there will undoubtedly be others, as changes in a country's political system are constant. Institutional reforms are the driving force of societal development, so it can be concluded that this process can never be considered complete, as societies are continuously evolving (Filipov, 2014).

1. Stability of economic and European systems

Economic and European systems are complex structures that regulate economic activity and political integration among countries. Understanding their interconnection, similarities, and differences is key to analyzing economic and political processes in Europe.

The economic system is an organized way through which societies produce, distribute, and utilize resources. The main types of economic systems include:

- Market economy – based on free markets, private ownership, and competition. Prices are determined by supply and demand. This system is common in the USA and some EU countries;
- Command economy – where the government controls production, distribution, and pricing. This system was typical of former socialist countries; and
- Mixed economy – a combination of market economy and government intervention to regulate the market and provide public services (as is the case in many European countries) (Zanalda, 2018).

The European economic system is a unique structure formed through the economic and political integration of EU member states. It is characterized by:

- a single market enabling free movement of goods, services, capital, and labor;
- the use of a common currency (the euro) in 20 out of 27 member countries (Eurozone);
- a unified trade policy with third countries; and
- investments in economically weaker regions to reduce inequalities.

Common components of the economic and European systems include:

Regulation of economic activity – Both systems focus on ensuring a balance between thefree market and social protection. Both the economic and European systems have developed regulatory mechanisms that ensure compliance with laws and policies. In the EU, this includes treaties and rules that govern trade, competition, product and service safety, and other aspects of the economy. The EU also develops and manages various funds, such as the European Regional Development Fund, the European Social Fund, and others, which provide financial assistance and investments to member states to support their economic development, similar to how national economic systems offer grants or subsidies for certain sectors.

Both the economic and European systems place significant focus on infrastructure projects, innovation, and technological development. In the European system, as well as in national economic systems, the labor market plays an important role, with the free movement of workers and employment opportunities within the EU. This mobility promotes competitiveness and growth in the European economy. Both economic and European systems impose policies and measures for environmental protection. The European Union is a leader in adopting strategies for green energy and sustainable development, which impact economic sectors such as industry, transportation, and agriculture (Jovanović, 2017).

Within the European Union, there are joint macroeconomic policies that regulate the economic stability of the member states, such as the Stability and Growth Pact, which aims to ensure that member states keep their budget deficits under controlled levels.

The economic and European systems are interconnected as a whole and share common components focused on economic growth, stability, competition, and sustainable development.

2. The importance of economic reforms in the institutions of the European Union (EU)

Widely accepted are the findings are that, the European Union is a community of nations or that it represents a *sui generis*—a unique form of society. This means that, in its political form, it has its central institutions, which, in terms of structure and competencies, are found in the political systems of almost all countries around the world, with different political systems (parliamentary, assembly-based, mixed, and presidential).

In the literature on EU institutions, a legal definition dominates, which outlines the basic structure, main competences, and functioning of the European institutions. As previously mentioned, EU institutions differ from all other institutions, because they reflect the principle of voluntary association of the member states. EU institutions must be closely linked with the institutions of the member states. In national institutions, their rights and obligations are defined by the Constitution. The EU treaties bind national institutions to adopt certain rights and obligations as their own. This is an important distinction between the institutions of the EU and the institutions of the member states (Gocevski, 2006).

The European Community has undergone a long process of reforms that have had great significance and impact on the development and stability of the entire European area. These reforms are implemented with the goal of achieving economic integration, competitiveness, and sustainable growth among EU member states, as well as ensuring the successful adaptation of institutions to new challenges in the global economy.

Economic reforms are a long-term process that requires strategy, political will, and support from citizens. In the context of European integration, successful reforms in individual countries strengthen the stability of the overall European system. In fact, the implementation of these reforms is carried out through the coordination of economic policies at both national and European levels, and through active and continuous adaptation to new economic and global challenges (Jovanović, 2017).

Economic reforms within EU institutions aim to improve economic integration, financial stability, and competitiveness. These have been adopted at different periods, depending on the need to adapt the economy and strengthen integration among member states. Below are some key historical economic reforms:

- In 1992 the Maastricht Treaty was signed and came into effect in 1993. It laid the foundation for the European Monetary Union and led to increased economic coordination through the monetary policy of the European Central Bank. In fact, this treaty established rules for economic and monetary integration, and also set the framework for the introduction of a common currency (euro).
- In 1999 began the use of the euro in cashless transactions in 11 member states.
- In 2002 the physical euro banknotes and coins were introduced.
- In 1997, the Stability and Growth Pact was adopted to ensure that member states adhered to the Maastricht Treaty's rules—specifically, aligning national budget policies with deficit and public debt criteria (deficit must not exceed 3% of GDP, and public debt must not exceed 60% of GDP).
- In 2007, the Lisbon Treaty was adopted and entered into force in 2009. It was agreed upon by the EU member states to improve the Union's functioning, particularly following enlargements that increased the number of member states. The treaty brought significant changes to the EU's institutional structure and modernized its policies.
- In 2010, the European Semester was introduced as a mechanism for coordinating economic policies within the EU. This process of coordinating economic polies allows member states to align their fiscal and economic policies based on recommendations from the European Commission in order to achieve economic growth and stability.
- In 2012, the European Council decided to establish a banking union in response to the global financial crisis. The Single Supervisory Mechanism was created under the European Central Bank to guarantee the stability of the banking sector.
- In 2014, the Single Resolution Mechanism for addressing problematic banks was established, marking the beginning of the functions of the Single Supervisory Mechanism and the initiation of stress tests for the banking sector in the EU. That same year, the financial regulation – the MiFID II directive – was introduced, which regulates financial markets with the aim of improving transparency and consumer protection.

- In 2019, strict supervision was imposed on EU financial institutions, including a revision of the Basel III regulations—which is part of the global banking regulation aimed at improving bank resilience.
- That same year, the European Commission published the European Green Deal, setting the EU's targets of achieving climate neutrality by 2050, with a focus on reforms that support the transition to a green and sustainable economy. These reforms include reducing harmful gas emissions, increasing energy efficiency, investing in renewable energy sources, and encouraging companies to invest in green technologies and innovations. This includes reforms in all sectors: energy, transport, industry, and agriculture. In 2020, the first legislative proposal was adopted to achieve climate neutrality by 2050.
- In 2020, the first legislative proposal for achieving climate neutrality by 2050 was introduced.

From 2016 to 2020, new trade agreements were adopted with countries such as Canada, Japan, and the United Kingdom post-Brexit. These agreements aim to boost EU trade and market competitiveness.

Also in 2020, the European Commission introduced regulations and adopted packages like the Digital Services Act (DSA) and Digital Markets Act (DMA), which regulate technological giants and digital platforms. These regulations set rules for the protection of personal data, consumer protection, and fair competition in digital markets (Hayes-Renshaw & Wallace, 2017).

These reforms are part of the broader EU strategy and aim to strengthen the economic integration of the EU, improve economic growth, ensure financial stability, and create more sustainable economic and environmental policies and sustainable development.

3. The importance of economic reforms for the development of the Republic of North Macedonia

The main goal of macroeconomic policy of our country Republic of North Macedonia is to create a stable environment as a prerequisite for completing the transition process and EU accession. On the other hand, the main goal of the microeconomic policy is focused on completing the transition process and initiating the process of shaping the economy in our country (enterprises and institutions) into a competitive participant in the EU's Internal Market. Macroeconomic reforms, although necessary, do not automatically ensure the required changes for a comprehensive transformation into a functioning market economy, as they do not address the structural weaknesses in a systematic way. To eliminate these weaknesses, clearly defined microeconomic policies and structural reforms are needed. These reforms will encourage the development of a healthy and competitively capable economy, ready to absorb shocks and thereby contribute to achieving macroeconomic goals. In general terms, the reforms have several objectives: creating favorable conditions for increasing investment activity, which is necessary for achieving sustainable economic development and employment growth; increasing international competitiveness in the business sector of the economy; and defining policy measures that will ensure the sustainability of the transition process from a social perspective and from an environmental protection standpoint. (National Strategy for the Integration of the Republic of Macedonia into the EU, 2004).

Economic reforms in our country play a vital role in development. These reforms are essential for stabilizing the economy, enhancing citizens' living standards, and achieving sustainable economic growth. The reforms mainly focus on attracting foreign investments, transforming the private sector, boosting economic competitiveness, advancing public finances, improving education and workforce skills, supporting a green economy, and promoting innovation and the digitalization of the economy.

Reforms in the areas of tax policy, legal certainty, and improving the business climate significantly contribute to attracting foreign investments. For developing countries like ours, these investments are crucial for creating new jobs, transferring new technologies, and improving production capacities.

Through these reforms, efforts are also made to privatize state-owned companies and support small and medium-sized enterprises. These reforms promote competition, increase efficiency, and encourage innovation. The private sector plays a key role in creating new jobs and stimulating economic growth. Economic reforms improve the overall business environment, reduce bureaucracy, and enhance transparency. This results in greater competitiveness of domestic companies in global markets. On the other hand, the development of infrastructure and the transportation system enables better connectivity with regional and international markets (Atanasov, 2013).

Reforms in public finances, such as the rationalization of public administration and control of public debt, are essential for achieving macroeconomic stability. These reforms improve the state's capacity to provide financial resources for infrastructure projects and other public investments.

Economic reforms often include changes to the education system, especially regarding vocational training and academic programs. These reforms aim to develop a workforce capable of meeting the demands of the modern economy and satisfying the labor market's needs.

Our country North Macedonia is striving for the development of sustainable economic policies and green transformation through reforms that encourage the use of renewable energy sources and ecological solutions in the industry. These reforms will enable companies to become competitive in global green markets.

One important aspect of the economic reforms is the digitalization of the public administration and support for the development of the digital sector. These reforms enable faster and more efficient operations for businesses and the administration, while simultaneously increasing access to new markets and improving productivity (Fiti, 2016).

In our country, there is an Economic Reform Programme (ERP), which is the most important strategic document in the economic dialogue with the European Commission and EU member states. This document is prepared annually and serves as preparation for participation in the process of economic and fiscal surveillance of EU member countries, as well as for involvement in the European Semester process for coordinating economic policies within the EU. The process, introduced with the Enlargement Strategy in 2013, aims to improve economic governance and coordination of economic policies to ensure long-term economic growth and competitiveness in accordance with the requirements of the Copenhagen criteria for EU membership.

The programme includes a medium-term framework for macroeconomic and fiscal policy and a detailed overview of structural reforms that are expected to contribute to increasing the competitiveness of the economy and creating jobs. In terms of structural reforms, the programme will serve as the basis for preparing the reform agenda for the country, in line with the Growth Plan for the Western Balkan countries announced by the EU, aimed at accelerating the integration of these countries into the EU's single market.

The preparation of this document at the government level is coordinated by the Ministry of Finance and is the result of intensive international cooperation. After its submission to the European Commission, the programme is reviewed with EU representatives during April and May, as part of the economic-financial dialogue within the Council of the EU. The dialogue concludes with the adoption of joint conclusions with recommendations for the country, which must be taken into account when preparing the next Economic Reform Programme.

The Economic Reform Programme 2024-2026 was adopted by the Government of the Republic of North Macedonia on January 16, 2024, and officially submitted to the European Commission on January 17, 2024 (Ministry of Finance, 2024).

Economic reforms in our country are fundamental for long-term economic development and prosperity. They have a significant impact on the stability of the economy, job creation, increased competitiveness,

and the improvement of citizens' living standards. Promoting foreign investment, privatization, and reforms in education and public finances are key to the country's future development.

Conclusion

Reforms determine the short-term and long-term outlook of any society. Deeper reforms strengthen the legitimacy of the system and increase political and social cohesion. They also affect interethnic relations, which are one of its main pillars of a stable society. Increased stability, tolerance, and mutual understanding are closely linked to the pace of reforms.

Economic reforms have a significant impact on societal development on multiple levels. These reforms, which can vary in nature, are aimed at improving economic stability, growth, and the development of all areas of social life. As we have seen, economic reforms have a positive impact and are focused on improving economic efficiency and the competitiveness of the national economy, reducing poverty, and enhancing social welfare. They also invest in education, improve the cultural and social aspects of society, stimulate innovation, and introduce new technologies, which are crucial for the competitiveness and progress of society. Support for research and development, as well as for new business models, can make the economy more efficient and competitive.

Economic reforms have a significant impact on the stability of European systems, which are complex and interconnected, including the economic, political, and social aspects. In the context of Europe, these reforms can be influenced by the internal needs of EU member states as well as by the global economic challenges (National Debate on the EU, 2017).

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Determining the Factors of Competitive Advantage in Manufacturing Enterprises Using the Picture Fuzzy Subjective Weighting Approach: The Case of Giresun Province

Određivanje faktora konkurentske prednosti u proizvodnim preduzećima korišćenjem subjektivnog težinskog picture fuzzy pristupa: slučaj provincije Giresun

Ahmet Aytekin[1], Selçuk Korucuk[2]

[1]*Samsun University, Faculty of Political Sciences, Depart Department of International Trade and Business, Samsun, Turkey, ahmet.aytekin@samsun.edu.tr*
[2]*Giresun University, Bulancak Kadir Karabas Vocational School, Department of Logistics Management, Giresun, Turkey, selcuk.korucuk@giresun.edu.tr*

Abstract: *Manufacturing companies today seek to use flexible structures and develop their business strategies with the goal of lowering costs and enhancing performance to gain a competitive advantage. Changing business processes and strategies emphasize the value of competitiveness, urging manufacturing organizations to become more flexible and enhance their organizational processes accordingly. Therefore, enterprises prioritize the factors that affect competitive advantage and assign them critical roles to achieve cost optimization and ensure long-term survival. In fact, one of the essential ways to manage business processes effectively and efficiently in manufacturing enterprises is through securing competitive advantage. In this context, the factors determining competitive advantage gain importance and become issues that need to be addressed with great care. Within the scope of this study, the factors determining competitive advantage in manufacturing enterprises were identified, and their weighting was aimed. For this purpose, the Picture Fuzzy Subjective Weighting Approach, was applied. According to the results of the analysis, among the factors determining competitive advantage in manufacturing enterprises, the most significant was identified as "Innovation", while the least significant criteria were found to be "Openness" and "Other Factors."*
Keywords: *Competition, competitive advantage, MCDM, picture fuzzy subjective weighting approach.*

Apstrakt: *Danas, proizvodna preduzeća teže da usvoje fleksibilne strukture i dizajniraju svoje poslovne strategije sa ciljem smanjenja troškova i povećanja performansi kako bi postigla konkurentsku prednost. Promenljivi poslovni procesi i strategije ističu važnost konkurentnosti, podstičući proizvodne firme da postanu agilnije i da u skladu sa tim poboljšaju svoje organizacione procese. Stoga, preduzeća daju prioritet faktorima koji utiču na konkurentsku prednost i dodeljuju im kritične uloge kako bi postigla optimizaciju troškova i osigurala dugoročni opstanak. Zaista, jedan od bitnih načina za efikasno i efikasno upravljanje poslovnim procesima u proizvodnim preduzećima jeste obezbeđivanje konkurentske prednosti. U ovom kontekstu, faktori koji određuju konkurentsku prednost dobijaju na značaju i postaju pitanja kojima se treba pozabaviti sa velikom pažnjom. U okviru ove studije, identifikovani su faktori koji određuju konkurentsku prednost u proizvodnim preduzećima i ciljano je njihovo ponderisanje. U tu svrhu primenjen je pristup subjektivnog ponderisanja slike (Picture Fuzzy Subjective Weighting Approach), jedna od metoda višekriterijumskog odlučivanja (MCDM). Prema rezultatima analize, među faktorima koji određuju konkurentsku prednost u proizvodnim preduzećima, najznačajniji je identifikovan kao „Inovacija", dok su najmanje značajni kriterijumi utvrđeni kao „Transparentnost" i „Ostali elementi".*
Ključne reči*: Konkurencija, konkurentska prednost, MCDM, picture fuzzy subjective weighting pristup.*

Introduction

Nowadays, the ability of businesses to sustain their existence and stand out among competitors depends not only on production but also on their performance-oriented behaviors in all organizational activities. One of the tools that enable firms to realize these behaviors is achieving competition and competitive advantage (Korucuk, 2018). In this context, one of the key concepts explaining the process and outcomes of competition among firms in the markets is competitive advantage. Competitive advantage has been defined as a resource or capability that allows firms to compete more effectively in the markets (Jap, 2001). In another definition, this concept is considered as a business having a competitive advantage by implementing a value-creation strategy not adopted by current or potential competitors. Business performance, on the other hand, is an indicator of how well a firm achieves its market-oriented and financial objectives (Yamin et al., 1999; Chahal & Bakshi, 2014). In other words, competitive advantage refers to the integration of various factors that allow businesses to differentiate themselves from competitors and achieve a unique and superior position in the market (Udriyah et al., 2019).

At the core of organizations' performance in competitive markets lies competitive advantage. In environments characterized by intensified competition and environmental uncertainty, sustainable competitive advantage can be achieved, and by maintaining these advantages as much as possible, positive outcomes can be realized in indicators of corporate performance (Burak & Deniz, 2021). Competitive advantage represents the strategic objectives that businesses aim to achieve while addressing environmental challenges. It emphasizes that business performance is central to gaining competitive advantage in the markets and highlights the importance of possessing rare, inimitable capabilities to obtain sustainable competitive advantage (Altarawneh, 2017).

Competitive advantage is a critical factor for organizations to survive and achieve sustainable success in the face of environmental pressures such as rising costs, changing customer expectations, and rapid technological developments. Improving service quality with the aim of enhancing customer satisfaction is important in attaining competitive advantage. This allows organizations to differentiate their services, stand out from competitors, and thereby gain a competitive edge. Competitive advantage is considered a fundamental element for businesses to withstand external pressures, such as increasing costs, changing customer expectations, and rapid technological advancements, while ensuring sustainable success (Açıkgöz & Biçer, 2025). At the same time, the importance of competitive advantage for a firm's survival has been comprehensively emphasized. With the significant increase in global competition, it has been highlighted that achieving competitive advantage and ensuring its sustainability are crucial for staying agile and ahead in the market (Mahdi et al., 2019). Moreover, a firm's competitive advantage stems from the strategy it pursues to leverage risks and opportunities in its external environment. In this context, the greater a firm's competitive advantage, the higher the probability of strategic success (Robinson & Minikin, 2012). On the other hand, it is widely believed that many businesses strive for competitive advantage because it provides them with superiority over their competitors.

Based on the issues mentioned above, identifying and ranking the factors that determine competitive advantage in manufacturing enterprises is considered an important indicator. Determining and prioritizing these relevant factors not only provides various added values to manufacturing firms but also contributes to addressing performance, efficiency, and cost requirements. Therefore, this study serves as a guide in addressing the existing gaps.

Finally, the decision-making framework proposed in this study to address the relevant decision problem contributes to filling the existing theoretical and methodological gaps in the literature, providing valuable insights for researchers in the field. In this regard, the proposed approach for evaluating the factors determining competitive advantage in manufacturing enterprises offers a solid and reliable theoretical framework for academic studies, research, and practical solutions. From this perspective, the study can serve as a critical reference point, particularly for researchers focused on solving decision-making problems in the relevant field. Within this scope, the study aims to identify the factors determining competitive advantage in manufacturing enterprises and proposes a solution using the

Picture Fuzzy Subjective Weighting Approach model. The study is structured in four sections. Section 2 provides a literature summary on competitive advantage in firms. Section 3 introduces the methods used in the study. The final section concludes the research by presenting policy recommendations, future research plans, and the limitations of the current study.

1. Literature

This section presents national and international studies on competitive advantage.

- Rose et al. (2010) examined the relationship between organizational resources, competitive advantage, and organizational performance, identifying the factors that influence this relationship.
- Omerzel & Gulev (2011) explored knowledge as a potential resource for competitive advantage and reviewed the literature on the assessment of knowledge assets.
- Rahimli (2012) conducted a detailed literature review to investigate the importance of knowledge management in terms of competitive advantage.
- Mihalič & Buhalis (2013) examined the business potential and productivity paradox of competitive advantage through the application of information and communication technologies in the hotel sector.
- Anatan (2014) investigated the effects of supply chain management practices on competitive advantage and supply chain performance.
- Stoilkovska et al. (2015) analyzed the competitive advantages of companies in Macedonia, as well as the possibilities and necessity of leveraging them for business expansion and development.
- Bakan & Şekkeli (2016) studied the relationship between logistics coordination capability, logistics innovation capability, customer relationship capability, and competitive advantage and logistics performance of firms operating in the logistics sector.
- Guimarães et al. (2017) examined the relationship between sustainable competitive advantage and organizational performance, aiming to measure the connection between environmental sustainability and social responsibility as characteristics of sustainable competitive advantage.
- Örgev & Şahinli (2018) evaluated the factors determining competitive power using the diamond model approach.
- Chiu & Yang (2019) measured the reciprocal causality between IT adoption and service innovation, determining their roles in competitive advantage and predicting the moderating effects of environmental factors.
- Andes et al. (2020) investigated the role of competitive advantage as a mediating variable in the effect of corporate governance and intellectual capital on firm value, reviewing previous studies.
- Garip et al. (2021) examined how independent variables such as supply chain integration, green marketing orientation, and supply chain resilience affect competitive advantage as the dependent variable.
- Cader et al. (2022) focused on corporate social responsibility as an important factor for competitive advantage in energy companies in Poland.
- Aksoy (2023) explored the potential of digital ecosystems to create value and provide competitive advantage for businesses and industries.

- Tran et al. (2024) investigated how organizational and contextual factors affect supply chain collaboration and, in turn, influence the competitive advantage of firms in the apparel industry.
- Atagül et al. (2024) examined dynamic planning and workflow management in achieving competitive advantage in businesses.
- Atmaja et al. (2025) analyzed the impact of organizational factors on quality performance, the effect of quality performance on competitive advantage, and the mediating role of quality performance between organizational factors and competitive advantage.

As a result of this comprehensive literature review, it has been observed that there is a limited number of studies addressing the factors affecting competitive advantage. This indicates a significant gap in the existing body of knowledge. In this context, the present study is expected to make meaningful contributions to the literature by providing new perspectives on the determinants of competitive advantage and developing a deeper understanding of the topic.

2. Picture fuzzy subjective weighting approach

Picture Fuzzy Sets (PFSs) are introduced by Cuong & Kreinovich (2013), an extension of Intuitionistic Fuzzy Sets. However, IFSs do not adequately represent the degree of irrelevance or abstain in decision-making problems. PFSs make it possible to handle this uncertainty.

Let X be the discourse universe. Then, a PFS A can be defined in Eq. (1), where $\mu_A(x), \eta_A(x), \nu_A(x) \in [0,1]$ (Cuong & Kreinovich, 2013; Görçün et al., 2024):

$$A = \{\langle x, \mu_A(x), \eta_A(x), \nu_A(x)\rangle | x \in X\}, \tag{1}$$

Here $\mu_A(x)$ is the degree of positive membership of x in A, $\eta_A(x)$ depicts the degree of neutral membership of x in A, and $\nu_A(x)$ is the degree of negative membership of x in A. The condition given in Eq. (2) is met (Cuong & Kreinovich, 2013; Görçün et al., 2024):

$$0 \leq \mu_A(x) + \eta_A(x) + \nu_A(x) \leq 1, \forall x \in X. \tag{2}$$

On the other hand, the degree of refusal membership of x in A is defined as $\pi_A(x) = 1 - (\mu_A(x) + \eta_A(x) + \nu_A(x))$. Assume that a, $a1$, and $a2$ are three PF numbers (PFNs), where $a = \langle \mu_a(x), \eta_a(x), \nu_a(x)\rangle$, $a_1 = \langle \mu_{a_1}(x), \eta_{a_1}(x), \nu_{a_1}(x)\rangle$, and $a_2 = \langle \mu_{a_2}(x), \eta_{a_2}(x), \nu_{a_2}(x)\rangle$. Then, the basic operations on PFNs are provided in Eq.s (3)-(7) (Cuong & Kreinovich, 2013; Görçün et al., 2024):

$$a_1 \oplus a_2 = \langle 1 - \left(1 - \mu_{a_1}\right)\left(1 - \mu_{a_2}\right), \eta_{a_1}\eta_{a_2}, \left(\eta_{a_1} + \nu_{a_1}\right)\left(\eta_{a_2} + \nu_{a_2}\right) - \eta_{a_1}\eta_{a_2}\rangle, \tag{3}$$

$$a_1 \otimes a_2 = \langle \left(\mu_{a_1} + \eta_{a_1}\right)\left(\mu_{a_2} + \eta_{a_2}\right) - \eta_{a_1}\eta_{a_2}, \eta_{a_1}\eta_{a_2}, 1 - \left(1 - \nu_{a_1}\right)\left(1 - \nu_{a_2}\right)\rangle, \tag{4}$$

$$a_1 \otimes a_2 = \langle \left(\mu_{a_1} + \eta_{a_1}\right)\left(\mu_{a_2} + \eta_{a_2}\right) - \eta_{a_1}\eta_{a_2}, \eta_{a_1}\eta_{a_2}, 1 - \left(1 - \nu_{a_1}\right)\left(1 - \nu_{a_2}\right)\rangle, \tag{5}$$

$$\lambda \cdot a = \langle 1 - (1 - \mu_a)^\lambda, (\eta_a)^\lambda, (\eta_a + \nu_a)^\lambda - (\eta_a)^\lambda\rangle, \tag{6}$$

$$a^\lambda = \langle (\mu_a + \eta_a)^\lambda - (\eta_a)^\lambda, (\eta_a)^\lambda, 1 - (1 - \nu_a)^\lambda\rangle. \tag{7}$$

Let a_j be the collection of PFNs, where $j = 1, \ldots, n$. Then, PF weighted arithmetic average (PFWAO) is computed by applying Eq. (8). Also, the PF weighted geometric average operator (PFWGO) is calculated via Eq. (9), where $\lambda_i = (\lambda_1, \lambda_2, \ldots, \lambda_n)^T$ is the weight vector (Cuong & Kreinovich, 2013; Görçün et al., 2024):

$$PFWAO_{\lambda}(a_1, \ldots, a_n) = \bigoplus_{j=1}^{n} (\lambda_j, a_j)$$
$$= \langle 1 - \prod_{j=1}^{n} \left(1 - \mu_{a_j}\right)^{\lambda_j}, \prod_{j=1}^{n} \left(\eta_{a_j}\right)^{\lambda_j}, \prod_{j=1}^{n} \left(\eta_{a_j} + \nu_{a_j}\right)^{\lambda_j} - \prod_{j=1}^{n} \left(\eta_{a_j}\right)^{\lambda_j} \rangle. \quad (8)$$

$$PFWGO_{\lambda}(a_1, \ldots, a_n) = \bigotimes_{j=1}^{n} (a_j)^{\lambda_j}$$
$$= \langle \prod_{j=1}^{n} \left(\mu_{a_j} + \eta_{a_j}\right)^{\lambda_j} - \prod_{j=1}^{n} \left(\eta_{a_j}\right)^{\lambda_j}, \prod_{j=1}^{n} \left(\eta_{a_j}\right)^{\lambda_j}, 1 - \prod_{j=1}^{n} \left(1 - \nu_{a_j}\right)^{\lambda_j} \rangle. \quad (9)$$

The defuzzification of a PFN is obtained by applying Eq. (10), where $\pi_a = 1 - (\mu_a + \eta_a + \nu_a)$.

$$s(a) = \mu_a + \frac{\eta_a}{2} + \frac{\pi_a(1 + \mu_a - \nu_a)}{2}, \quad (10)$$

The basic operations of PFSs are detailed in the previous part of this section. The weighting coefficients for the criterion in this study will be determined using the subjective weighting approach based on PFWAO. The steps required to implement this approach are as follows.

Step 1. The list of criteria and the experts are determined. In this context, $C = \{C_1, \ldots, C_n\}$ is the set of criteria, and $U = \{U_1, \ldots, U_z\}$ depicts the set of experts.

Step 2. Experts evaluate the importance levels of criteria using the linguistic terms provided in Table 1. $\iota_{jk} = \langle \mu_{jk}, \eta_{jk}, \nu_{jk} \rangle$ represents the PF importance of j-th criterion determined by k-th expert, where $j = 1, \ldots, n;\ k = 1, \ldots, z$.

Table 1. Linguistic terms for evaluating criteria

Notations	Linguistic terms	Picture fuzzy number		
		μ	η	ν
VH	Very High	0.90	0.05	0.05
H	High	0.80	0.10	0.10
M	Medium	0.50	0.20	0.20
L	Low	0.20	0.30	0.50
VL	Very Low	0.10	0.30	0.60

Step 3. The weight coefficient of each expert λ_k is determined, where $\sum_{k=1}^{z} \lambda_k = 1,\ 0 \leq \lambda_k \leq 1$.

Step 4. The integrated PF importance of j-th criterion ι_j is computed using Eq. (8). Here $\iota_j = \langle \mu_j, \eta_j, \nu_j \rangle$.

Step 5. The crisp importance value of j-th criterion $s(\iota_j)$ is calculated by appliyng Eq. (10).

Step 6. The weight coefficient of each criterion is determined using Eq. (11).

$$w_j = \frac{s(\iota_j)}{\sum_{j=1}^{n} s(\iota_j)} \quad (11)$$

3. Results

This study investigates the factors affecting the competitive advantage of businesses. To achieve this purpose, the Picture Fuzzy Subjective Weighting Approach method has been employed. The identified factors are presented in Table 2.

Table 2. The list of criteria

Codes	Criteria	Source(s)
C1	Management Quality	deWaal, (2013).
C2	Openness	Hossain,et., al., (2021).
C3	Action and Orientation	deWaal, (2013).
C4	Long-Term Orientation	deWaal, (2013).
C5	Innovation	Aytekin & Korucuk, (2024).
C6	Continuous Improvemen	Banmairuroy, et., al., (2022).
C7	Workforce Quality	Korucuk, (2018).
C8	Other Factors	deWaal, (2013) and Aytekin, et., al., (2023).

Five experts, who have very high knowledge and experience on the subject, are consulted about the solution of the problem. Table 3 presents the linguistic evaluations of experts on criteria.

Table 3. The linguistic evaluations of criteria

	C1	C2	C3	C4	C5	C6	C7	C8
U1	VH	M	M	H	H	M	H	M
U2	H	M	H	M	H	M	H	M
U3	M	M	H	M	H	H	M	M
U4	H	M	M	M	H	H	H	M
U5	H	M	H	M	H	H	H	M

Table 4 displays the results of PF- subjective weighting approach.

Table 4. The results of PF- subjective weighting approach

	C1			**C2**			**C3**			**C4**		
	μ_j	η_j	ν_j	μ_j	η_j	ν_j	μ_j	η_j	ν_j	μ_j	η_j	ν_j
ι_j	0.7909	0.1000	0.1000	0.5000	0.2000	0.2000	0.7115	0.1320	0.1320	0.5837	0.1741	0.1741
$s(\iota_j)$	0.8486			0.6650			0.7969			0.7187		
w_j	0.1376			0.1078			0.1292			0.1165		
Rank	2			7			4			6		
	C5			**C6**			**C7**			**C8**		
	μ_j	η_j	ν_j	μ_j	η_j	ν_j	μ_j	η_j	ν_j	μ_j	η_j	ν_j
ι_j	0.8000	0.1000	0.1000	0.7115	0.1320	0.1320	0.7598	0.1149	0.1149	0.5000	0.2000	0.2000
$s(\iota_j)$	0.8500			0.7969			0.8258			0.6650		
w_j	0.1378			0.1292			0.1339			0.1078		
Rank	1			4			3			7		

The findings, presented in Table 4, indicates that the most important criterion is "C5-Innovation." "C2-Management Quality" is the second most important criterion.

Conclusion

In manufacturing enterprises, identifying the factors that determine competitive advantage in alignment with business strategies is of great importance to achieve cost optimization and outperform competitors. Particularly in manufacturing firms, these factors enhance efficiency by providing various added values. Identifying these factors not only represents key variables in attaining competitive advantage but also constitutes fundamental components for improving cost efficiency, productivity,

and overall performance. Moreover, the factors determining competitive advantage positively influence business processes and contribute to long-term gains from policies and strategies. Therefore, these factors emerge as a critical area that managers in manufacturing enterprises should prioritize.

Within this framework, the study examined the factors determining competitive advantage in manufacturing enterprises with corporate identity in the province of Giresun. According to the findings, the most important factors determining competitive advantage in manufacturing enterprises were identified as **"**Innovation", "Management Quality", and "Workforce Quality". The least important factors were "Openness and "Other Factors".

This study should be evaluated with certain limitations in mind. First, the research was limited to manufacturing enterprises with corporate identity in Giresun; therefore, the generalizability of the findings to other provinces or different sectors may be restricted. Second, the study determined the importance levels of the factors based on specific measurement tools and criteria; different methodological approaches or data collection techniques may yield different results. Additionally, the study focused solely on presenting the current situation, and the changes or long-term effects of the factors were not comprehensively examined.

The findings of the study reveal the current state of factors determining competitive advantage in manufacturing enterprises and provide managers with various strategic recommendations. In this context, the results offer a roadmap for prioritizing these factors and guide in filling a significant gap in the field. Furthermore, in the future, this study can be evaluated more comprehensively using multi-criteria decision-making approaches or other parametric and non-parametric methods.

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Researching the Role of Shared Leadership on Employee Performance with the Mediating Effect of Self-Efficacy

Istraživanje uloge zajedničkog liderstva na učinak zaposlenih uz moderatorski efekat samoefikasnosti

Olgica Andrejić[1], Sandra Dramićanin[2], Mihajlo Đurović[3]

[1]*Toplica Academy of Applied Studies, Prokuplje, Serbia, olgica.andrejic@gmail.com*
[2]*Toplica Academy of Applied Studies, Department of Business Studies, Blace, Serbia, sandra.dramicanin@vpskp.edu.rs*
[3]*Toplica Academy of Applied Studies, Department of Business Studies, Blace, Serbia, mihajlo.djurovic@vpskp.edu.rs*

Abstract: *This study analyzes the relationship between shared leadership and employee performance, with self-efficacy acting as a mediating variable. The crucial question of this research is whether shared leadership has a positive impact on employee performance through self-efficacy. There is currently empirical evidence to explain how shared leadership can rally employee performance in the service sector in the Republic of Serbia. To confirm the set objective, a survey was conducted among 100 respondents (employee-supervisor pairs) in the service sector in the Republic of Serbia. The results show that shared leadership has a positive effect on employee performance. At the same time, the research results explain that self-efficacy mediates the relationship between shared leadership and employee performance. The general conclusion is that the results of this research provide an additional contribution, given the importance of shared leadership in shaping the employees' behavior in service organizations in the Republic of Serbia.*
Keywords: *Shared leadership, employee performance, self-efficacy, service sector, Republic of Serbia.*

Apstrakt: *Ovo istraživanje za cilj ima da analizira odnos zajedničkog (podeljenog) liderstva i učinka zaposlenih, gde se kao medijatorska varijabla javlja samoefikasnost. Glavno pitanje ovog istraživanja je da li zajedničko liderstvo pozitivno utiče na učinak zaposlenih posredstvom samoefikasnosti. Trenutno ne postoji dovoljno emirijskih dokaza koji objašnjavaju kako zajedničko liderstvo može poboljšati učinak zaposlenih, kada se govori o uslužnom sektoru u Republici Srbiji. Da bi se potvrdio postavljeni cilj, sprovedeno je istraživanje među 100 ispitanika (par zaposleni-rukovodilac) u uslužnom sektoru u Republici Srbiji. Rezultati pokazuju da zajedničko liderstvo pozitivno utiče na učinak zaposlenih. Ujedno rezultati istraživanja objašnjavaju da samoefikasnost posreduje u vezi između zajedničkog liderstva i učinka zaposlenih. Generalni zaključak je da rezultati ovog istraživanja daju dodatni doprinos, s obzirom na važnost zajedničkog liderstva u oblikovanju ponašanja zaposlenih u uslužnim organizacijama u Republici Srbiji.*
Ključne reči: *Zajedničko liderstvo, učinak zaposlenih, samoefikasnost, uslužni sektor, Republika Srbija.*

Introduction

In an environment of traditional leadership styles, a modern approach to leadership is necessary to make a difference in business among organizations. In today's business world, the importance of shared leadership, which varies from traditional leadership styles, is increasingly emphasized. Shared leadership, as a modern leadership style, represents a dynamic model of leadership that supports role division and influence among team members (Chen & Zhang, 2023). Previous research has shown that this type of leadership has a positive impact on individuals, teams, and entire organizations (Shane Wood & Fields, 2007; Pearce et al., 2009; Han et al., 2021; Castellano et al., 2021; Hofman et al., 2023). Shared leadership encourages employees to share leadership influence and take on responsibilities.

Recent research has exposed a significant impact of shared leadership on employee performance, in contrast to traditional leadership styles (Han et al., 2021; Lorinkova & Bartol, 2021; Fausett et al., 2024; Muller, 2024). Although shared leadership has been proven to have a positive impact on employee performance, there are no studies that have focused on the Serbian organizational concept. In particular, there is a lack of research connected to the role and importance of shared leadership in the service sector. This paper aimed to identify the shared leadership process that leads to employee performance. It is necessary to investigate the mediating role of self-efficacy. In situations of time pressure, self-efficacy plays a crucial role in empowering employees to quickly gather relevant information, make rational decisions, and respond appropriately (Maddux, 2016). Organizations with high levels of shared leadership have higher self-efficacy (Katitas, 2025) and rally employee performance (Castellano, 2021; Liu et al., 2022).

Unlike traditional leadership styles, modern approaches such as shared leadership demonstrate greater effectiveness in uncertain and dynamic environments. Shared leadership encourages organizational members to depend on one another by exchanging advice, sharing responsibilities, collaborating, and making decisions collectively. As a result, employees develop a stronger sense of belonging and participation in organizational processes, while taking greater responsibility for the future of the service organization.

1. Literature review

1.1. Shared leadership characteristic

Leadership is a dynamic, interactive process of influence among individuals in groups to achieve group or organizational goals (Pearce & Conger, 2003). Shared leadership is an approach in which leadership roles and responsibilities are distributed among team members, rather than being centralized in one person (such as a manager or formal leader) (Carson, 2007). Shared leadership implies a continuous process of recognizing leadership opportunities among employees and encouraging them to develop those capacities, so that they themselves occasionally find themselves in a managerial position (Eric Nielsen, 2015). Instead of relying on a single person for leadership, multiple people contribute leadership based on expertise, context, or task needs (Krier, 2022). Unlike the traditional theory of vertical leadership, which emphasizes the styles and behaviors of formally appointed leaders, the theory of shared leadership emphasizes the active and influential role of all team members in the leadership process (Pearce et al., 2008).

Shared leadership is characterized by several key features that distinguish it from traditional forms of leadership (Zhu et al., 2018). That approach is collaborative, with an emphasis on teamwork, mutual trust, and shared decision-making (Fletcher & Kaufer, 2003). Within this model, mutual influence is present, where each team member has the potential to influence others based on their abilities and knowledge (Sweeney et al., 2019). Also, there is high flexibility in roles, as leadership positions change according to expertise or the requirements of a specific task (Wang et al., 2014). Shared leadership is based on empowerment, as it encourages team members to take initiative and responsibility for their work and contribution (Goksoy, 2016).

This leadership style brings many benefits. One of the most important is better decision-making, which relies on diverse opinions, experiences, and knowledge of all team members (Edelman et al., 2020). Employee engagement is also higher because participation in decision-making encourages motivation and a sense of ownership of processes (Kocolowski, 2010). Teams become more agile and adaptable, as they can react to changes faster without the need for hierarchical approvals (Herbst & Rios-Collazo, 2019). Shared leadership encourages the development of leadership skills in all members, as leadership responsibilities are rotated (Kezar & Holcombe, 2017). Also, team cohesion is strengthened because this model fosters a culture of trust and open communication (Kang & Svensson, 2023). Shared leadership is particularly effective in knowledge-based environments such as research and development, the software industry, or consulting (Gichuhi, 2021). Such teams often include members with

complementary skills and expertise, allowing for a dynamic distribution of leadership roles. This model requires an organizational culture that supports autonomy, trust, and openness (Stojanović Aleksić, 2016).

1.2. Shared leadership and employee performance

The relationship between shared leadership and employee performance is a topic in contemporary theories of leadership and team management (Carvalho et al., 2022; van Knippenberg et al., 2025). Numerous studies have confirmed the positive effects of shared leadership on employee performance. This form of leadership leads to increased engagement and employee motivation because they feel valued and included when they have the right to vote and influence in the decision-making process (Ramzan et al., 2023). Better work performance has been directly affected by motivation (Chen & Zhang, 2023). Sharing power within the team encourages members to take initiative and responsibility for results more often. In addition, shared leadership enables faster decision-making and greater adaptability, as teams in which leadership roles rotate can respond more effectively (Mehta & Sharma, 2019; Ali et al., 2023). These leadership development skills stimulate members through direct experience, which contributes to both personal and team development (Lornikova & Bratol, 2021). One of the more significant outcomes of the impact of shared leadership on employee performance is the strengthening of team cohesion and trust, because enhanced communication and mutual support create a healthy basis for cooperation and shared success (Ben Sedrine et al., 2021; Han et al., 2024).

The impact of shared leadership on the employees' work performance is particularly prominent in activities that rely on knowledge, teamwork, and flexibility in decision-making (Mansoor et al., 2025). Such activities include, first of all, information technologies, where teams work on complex and dynamic projects that require an interdisciplinary approach and rotating leadership roles in accordance with professional expertise (Wang & Jin, 2023). Similarly, in the service sector, such as banking, hospitality, or customer support, shared leadership enables employees to respond more quickly to customer needs, take initiative, and thus contribute to a higher level of customer satisfaction and work efficiency (Ji et al., 2022). In healthcare facilities, where critical decisions are made in real time, the shared leadership model enables better coordination among team members, reduces the risk of errors, and increases trust (Mohammed & Al-Abrrow, 2023). This approach is also effective in research and development teams and creative industries, where the high complexity of tasks and the need for innovation require the collaboration of several experts (Castellano et al., 2021; Lornikova & Bartol, 2021; Wang & Peng, 2022; Wei & Tang, 2024). Conversely, in industries with clearly structured, routine tasks and rigid hierarchies, such as traditional manufacturing or military structures, the positive effects of shared leadership may be limited. Overall, the most effective results of shared leadership models are achieved in contexts where there is high trust, autonomy, and organizational support for collective decision-making (Fausing et al., 2013; Robert & You, 2018; Klasmeier & Rowold, 2020). From the above, the following hypothesis can be made:

H_1: Shared leadership has a positive impact on employee performance.

1.3. Shared leadership and self-efficacy

Self-efficacy refers to an individual's belief in their capacity to organize and execute the actions required to achieve specific goals in given situations (Bandura, 1997). It does not reflect actual abilities, but a subjective assessment of what he can do in a certain context (Maddux, 2016). The key characteristics of self-efficacy are reflected in its contextuality, motivational role, and flexibility (Schwarzer & Luszczynska, 2008). First of all, self-efficacy is not a universal trait; it depends on the specific task or situation in which the individual finds himself, which means that one person can have a high level of self-efficacy in one area and a low level in another (Eller et al., 2018). In addition, it has a strong motivational function; individual effort is amplified by self-efficacy, degree of perseverance when facing obstacles, and emotional responses in stressful situations (Margolis & McCabe, 2006). Self-efficacy is also flexible – it can develop and change over time through direct experiences, observing

others (modeling), verbal encouragement from other persons, as well as the ability to effectively regulate one's emotions across different contexts (Tao et al., 2024).

In the work environment, high self-efficacy is associated with several positive outcomes, such as better work performance, greater initiative, greater resistance to stress, and willingness to accept challenges (Lane et al., 2004; Cherian & Jacob, 2013; Haddad & Taleb, 2016; Kodden, 2020; Andrews et al., 2021). Employees with a high level of self-efficacy have confidence in their ability to complete tasks and actively contribute to achieving organizational goals, even under time pressure, uncertainty, or when faced with complex challenges (Hadi, 2023). Such individuals are more prone to proactive behavior - they efficiently find solutions, make rational decisions, and take appropriate steps at the right moment, which makes them a resource in modern work teams (Karimi et al., 2022).

Shared leadership, which is defined as a dynamic and interactive distribution of leadership roles within a team, has a significant impact on employee self-efficacy (Han et al., 2021). When employees actively participate in the decision-making process and take responsibility, they develop a sense of competence and confidence in their own abilities, which directly affects their self-efficacy (Chen & Zhang, 2023). Rather than relying solely on a single leader, team members are encouraged to leverage their skills and expertise, thereby strengthening their confidence in their ability to accomplish tasks (Wang et al., 2017). In such an environment, feedback and support shared among team members further enhance individual and collective self-efficacy (Shane Wood & Fields, 2007). Therefore, shared leadership not only enhances teamwork but also fosters individual capabilities, leading to improved performance and higher job satisfaction (Wu & Cormican, 2021). From the above, the following hypothesis can be made:

H_2: Shared leadership has a positive effect on self-efficacy.

1.4. Shared leadership, employee performance, and self-efficacy

There is a wealth of research demonstrating positive relationships between shared leadership and employee performance (Barnett & Weidenfeller, 2016; D'Innocenzo et al., 2016; Martin et al., 2018; Han et al., 2021; Porter et al., 2024; Tseng et al., 2024) as well as between self-efficacy and employee performance (Aziz et al., 2024; Ren & Shen, 2024; Huang et al., 2025). In many organizational models, self-efficacy plays as a moderator variable influencing the relationship between different forms of leadership and job performance (Hans & Gupta, 2018; Widianto, 2021; Castellano, 2021; Liu & Huang, 2022; Porter et al., 2024). For example, the effects of shared leadership on employee performance may be more intense for individuals with higher levels of self-efficacy because these employees are more willing to take initiative, cooperate with others, and act proactively (Wang, 2014; Jeon, 2022; Liu & Huang, 2022; Wang & Jin, 2023; Rohma & Khoirunnisa, 2024). Low self-efficacy can have opposite effects on the relationship between shared leadership and employee performance (Strows, 2024). Such effects are dependent on the perceived self-efficacy of others. From the above, the following hypothesis can be made:

H_3: The positive effect of shared leadership on employee performance is greater when employees are more self-efficacious.

Figure 1 presents the theoretical model.

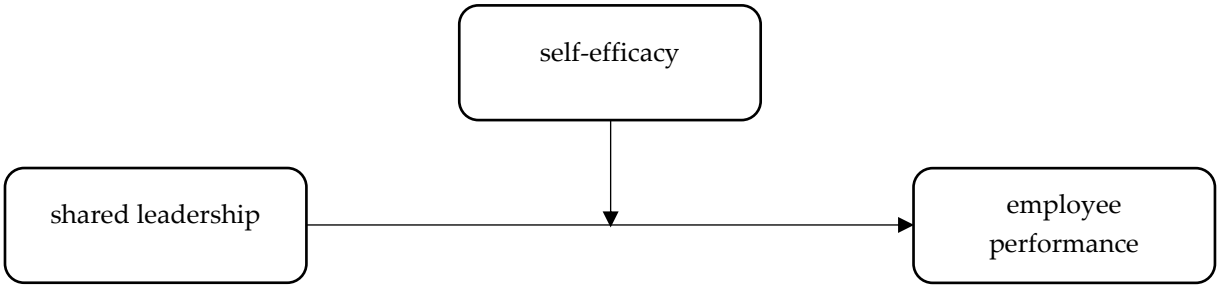


Figure 1. Theoretical model
Source: Authors

2. Methods and materials

2.1. Survey design

This research is a field study, in which respondents were encouraged to participate through personal contact or at their workplaces. All original questionnaires were in English, but due to the needs of this research, they were translated into Serbian. The questionnaire was filled out simultaneously by one employee and one manager. Before completing the questionnaire, participants were informed about the study's purpose and instructed on how to complete it. The research was conducted in 2025 on the territory of the Republic of Serbia. The respondents were over 18 years old, residing in the Republic of Serbia. The condition for participation in the research was that they worked in the service sector.

The questionnaire consisted of three parts: shared leadership, employee performance, and self-efficacy.

Shared leadership was measured using the scale developed by the author Hoch (2013) and contains 18 statements. The participants in the research evaluated each statement on a scale from 1 to 7 (1 - absolutely disagree, 7 - absolutely agree). The shared leadership scale demonstrated high reliability, with a Cronbach's alpha of 0.906. The reliability of this scale is excellent. A value above 0.90 indicates extremely high internal consistency, meaning that all questions in this scale measure the same construct in a highly reliable manner. Respondents' answers to questions about shared leadership are consistent. Employee performance was measured using a scale developed by Williams and Anderson (1991) and contains 21 statements. The participants in the research evaluated each statement on a scale from 1 to 7 (1 - absolutely disagree, 7 - absolutely agree). The employee performance scale showed excellent reliability, with a Cronbach's alpha of 0.899. A value close to 0.90 is an admirable indicator that the employee performance scale questions consistently measure performance. This demonstrates that the scale is reliable and suitable for research. Self-efficacy was measured using the scale developed by Riggot, Schyns & Mohr (2008) and contains 6 statements. The research participants evaluated each statement on a scale from 1 to 7 (1 - absolutely disagree, 7 - absolutely agree). The reliability of the employee performance scale is Cronbach's alpha = 0.932. The reliability of this scale is excellent. A value above 0.90 indicates extremely high internal consistency. The self-efficacy scale is highly reliable, and the questions consistently measure respondents' self-efficacy. All three scales used in the research show high reliability. This is crucial for the validity of the results, as it confirms that the instruments used to measure the concepts (shared leadership, employee performance, and self-efficacy) are well-designed and consistent. The total Cronbach's alpha for all three scales together is 0.957. This coefficient is exceptionally high, indicating excellent internal consistency across the entire questionnaire, comprising all 45 items. In other words, despite being divided into three separate scales, all the questions are consistent with one another and collectively measure a single, overarching construct.

2.2. Descriptive statistics

The final sample consisted of 100 respondents representing an employee-manager pair. Table 1 presents the mean values, standard deviation, and correlation.

Table 1. Mean values, standard deviation, and correlation

Variables	Mean	SD	Correlation Shared leadership	Correlation Self-efficacy
Shared leadership	3.72	1.48	-	-
Self-efficacy	3.94	1.46	0.613	-
Employee performance	3.83	1.46	0.697	0.706

Source: Authors

A strong, positive correlation between shared leadership and employee performance (r = 0.697), which means that as the level of shared leadership increases, so does employee performance. A strong, positive correlation between shared leadership and self-efficacy (r = 0.613) indicates that the more pronounced the shared leadership, the higher the employees' self-efficacy. A strong, positive correlation between self-efficacy and employee performance (r = 0.706) indicates that employees with higher self-efficacy

tend to achieve better performance. The correlation results are positive and statistically significant, indicating that all three variables are interconnected. These findings clearly demonstrate a strong relationship between shared leadership, self-efficacy, and employee performance.

2.3. Hypothesis testing

The impact of shared leadership on employee performance and self-efficacy, as well as the impact of self-efficacy on employee performance, were examined using linear regression. The results are shown in Tables 2 and 3.

Table 2. Linear regression of the influence of shared leadership and self-efficacy on employee performance

Independent variable	R^2	β	p
Shared leadership	0.486	0.697	0.000
Self-efficacy	0.499	0.706	0.000

Source: Authors

The R^2 value of 0.486 indicates that shared leadership accounts for 48.6% of the variance in employee performance. This is a relatively high and significant percentage, demonstrating that shared leadership is a strong predictor of performance. The positive β value of 0.697 further confirms a positive relationship between the variables. For every one-unit increase in shared leadership, employee performance increases by 0.697 units. The value of $p = 0.000$ is less than 0.05, which means that this result is statistically significant. It is safe to conclude that the link between shared leadership and employee performance is not accidental. Based on this analysis, shared leadership has an important and positive impact on employee performance.

The R^2 value of 0.499 indicates that self-efficacy explains 49.9% of the variability in employee performance. This is an extremely high percentage, showing that self-efficacy is a strong predictor of performance. The value of $\beta = 0.706$ is positive, further confirming a strong and positive relationship between the variables. For every one-unit increase in self-efficacy, employee performance increases by 0.706 units. The value of $p = 0.000$ is less than 0.05, which means that this result is statistically significant. It can be safely concluded that the relationship between self-efficacy and employee performance is not accidental. Based on this analysis, self-efficacy has an important and positive impact on employee performance.

Table 3. Linear regression of the influence of shared leadership on efficiency

Independent variable	R^2	β	p
Shared leadership	0.376	0.613	0.000

Source: Authors

The R^2 value of 0.376 indicates that shared leadership explains 37.6% of the variability in self-efficacy. This is a substantial percentage, demonstrating that shared leadership has a significant impact on employees' self-efficacy. The value 0.613 is positive, further confirming a positive relationship between the variables. For every one-unit increase in shared leadership, self-efficacy increases by 0.613 units. The value of $p = 0.000$ is less than 0.05, which means that this result is statistically significant. It can be safely concluded that the relationship between shared leadership and self-efficacy is not accidental. Based on this analysis, shared leadership has an important and positive impact on employee self-efficacy.

The simple regression analyses we conducted (shared leadership → performance, shared leadership → self-efficacy, and self-efficacy → performance) reveal strong and significant relationships.

H_1: Shared leadership has a positive impact on employee performance - ***confirmed.***

H_2: Shared leadership has a positive effect on self-efficacy - ***confirmed.***

This is an excellent prerequisite for testing a mediator model. To test the mediator model, multiple linear regression is used. Here, the influence of the independent variable (common leadership) and the

mediator variable (self-efficacy) on the dependent variable (employee performance) is simultaneously tested. Table 4 presents the regression analysis.

Table 4. Multiple linear regression

Variable	β	p
Shared leadership	0.222	0.015
Self-efficacy	0.613	0.000

Source: Authors

The regression coefficient for shared leadership (0.222) remains statistically significant ($p<0.05$), but it is smaller than in the first analysis (where it was 0.697). It indicates that there is mediation. The regression coefficient for self-efficacy (0.613) is statistically significant ($p<0.05$), confirming that self-efficacy has a unique effect on employee performance, even when controlling for the shared leadership effect. Since all conditions are met, it can be concluded that self-efficacy fully mediates the relationship between shared leadership and employee performance. This means that shared leadership has a positive effect on self-efficacy, and this increased self-efficacy, in turn, leads to better employee performance.

H3: The positive effect of shared leadership on employee performance is greater when employees are more self-efficacious - ***confirmed.***

3. Discussion

This paper aimed to investigate the impact of shared leadership on employee performance, with self-efficacy as a mediating factor. It was determined that all three hypotheses were confirmed, a positive impact of shared leadership on employee performance and self-efficacy. As self-efficacy was a mediating variable between shared leadership and employee performance, it was determined that the positive effect of shared leadership on employee performance is greater when employees are more self-efficacious.

The results of this research are in agreement with the results of the authors: Fausing et al., 2013; Robert & You, 2018; Klasmeier & Rowold, 2020; Castellano et al., 2021; Lornikova & Bartol, 2021; Wang & Peng, 2022; Ji et al., 2022; Wang & Jin, 2023; Mohammed & Al-Abrow, 2023; Wei & Tang, 2024; Mansoor et al., 2025.

Strows' (2024) research results show that shared leadership and self-efficacy are negative predictors of employee performance. However, the mediation hypothesis is supported, with a significant mediation relationship when self-efficacy is high, implying that when employees already practice shared leadership, the degree of self-efficacy can positively influence employee performance. Individually, the variables harm outcomes, but when combined, they have a positive effect.

The results of this research complement both domestic and foreign literature. Given the scarcity of studies examining the impact of shared leadership on employee performance through self-efficacy in the Republic of Serbia, particularly within the service sector, this research aims to fill the existing gap. Regarding international literature, the findings of this study align with the majority of existing research on the topic. However, it is important to note that self-efficacy is an internal construct based on individuals' perceptions of their abilities, and the results should be interpreted accordingly. A significant interaction at high levels of self-efficacy supports the proposed mediation hypothesis; however, due to the limited number of studies addressing this model, the interpretation of the results necessarily remains speculative.

The importance of this research is also reflected in the fact that the respondents were employee-manager couples, and the results enable a more comprehensive understanding of the employee-leader relationship in the service sector in the Republic of Serbia. The results of this research can benefit managers in service organizations, as well as owners, who become better acquainted with the possibilities of shared leadership and its impact on self-efficacy and employee performance. It can also

support employees in enhancing their self-efficacy and performance, both individually and through collaboration with colleagues and leaders within their organization.

Conclusion

Although this type of study has not yet been conducted in the Republic of Serbia, the results offer insights into previously unexplored aspects of shared leadership, self-efficacy, and employee performance. This research does have certain limitations. The first limitation is related to the sample size, as 100 respondents is too small a sample to draw meaningful conclusions and make generalizations. However, since the respondents were told that the questionnaire was anonymous, few of them wanted to participate. Another limitation is related to self-assessment, because the degree of sincerity of the respondents can be questionable (overestimation or underestimation occurs). Controlling this limitation can lead to more relevant results. The third limitation pertains to the fact that the research was conducted exclusively within the service sector. The theoretical part of the paper suggests that shared leadership is characteristic of the IT sector, creative industries, and healthcare. Further research in the mentioned sectors could provide additional insight and enable a comparative analysis with the results of this work.

Given the increasing focus of organizational research on leadership styles and team outcomes, it is significant to emphasize that team success depends on individual contributions. Therefore, understanding the influence of the individuals who make up the teams becomes a priority. This research contributes to that understanding, potentially for the first time in the service sector in the Republic of Serbia, by demonstrating that teams with shared leadership can increase employee self-efficacy levels. In addition, the degree of self-efficacy may mediate the relationship between shared leadership and employee performance. The results of this study fill a significant gap in the existing literature and serve as a foundation for further research.

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Evaluating Climate Challenges Readiness and Vulnerability in Central and Southeast Europe Using WENSLO–PIV Model

Ocena spremnosti i osetljivosti na klimatske izazove u zemljama Centralne i Jugoistočne Evrope primenom WENSLO–PIV modela

Aleksandra Fedajev[1], Danijela Pantović[2], Gabrijela Popović[3]

[1]*University of Belgrade, Technical Faculty in Bor, Serbia, afedajev@tfbor.bg.ac.rs*
[2]*University of Kragujevac, Faculty of Hotel Management and Tourism in Vrnjacka Banja, Serbia, danijela.durkalic@kg.ac.rs*
[3]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, gabrijela.popovic@mef.edu.rs*

Abstract: *This paper examines the readiness and vulnerability of Central and Southeast European countries to climate and related challenges using a hybrid multi-criteria model combining the WENSLO method, for calculating weights of criteria, and PIV method, for ranking 16 countries, including EU members and Western Balkan states. Data for 2023 from the Notre Dame Global Adaptation Initiative (used for calculation of ND-GAIN Index) provided scores for readiness and vulnerability as MCDM criteria. Results reveal notable disparities, with Baltic and Central European countries showing higher resilience and lower vulnerability than Southeast European states. The findings support the development of targeted policies to strengthen national and regional resilience.*
Keywords: *Climate change, readiness, vulnerability, WENSLO, PIV.*

Apstrakt: *Ovaj rad analizira spremnost i osetljivost zemalja Centralne i Jugoistočne Evrope na klimatske i srodne izazove primenom hibridnog višekriterijumskog modela koji kombinuje WENSLO metodu za izračunavanje težina kriterijuma i PIV metodu za rangiranje 16 zemalja, uključujući članice EU i države Zapadnog Balkana. Podaci za 2023. godinu iz Notre Dame Global Adaptation Initiative (korišćeni za izračunavanje ND-GAIN indeksa) korišćeni su za dobijanje skorova spremnosti i ranjivosti kao kriterijuma MCDM analize. Rezultati pokazuju značajne razlike, pri čemu baltičke i centralnoevropske zemlje imaju veću otpornost i manju ranjivost u odnosu na zemlje Jugoistočne Evrope. Nalazi istraživanja mogu poslužiti kao osnova za razvoj ciljanih politika radi jačanja otpornosti na nacionalnom i regionalnom nivou.*
Ključne reči: *Klimatske promene, spremnost, osetljivost, WENSLO, PIV.*

Introduction

Global warming can potentially trigger climate tipping points, with serious implications for natural and human systems and severe socioeconomic consequences worldwide (Anthoff et al., 2016; Defrance et al., 2017; Warren et al., 2018). Climate change represents one of the most complex and urgent challenges of our time, with far-reaching impacts on ecological systems, human health, and economic stability (Adedoyin et al., 2020). Projected temperature increases of up to 2.7°C by the end of the century, together with intensified climate-induced disasters, threaten to derail development progress, particularly in vulnerable economies (Jafino et al., 2020).

Addressing climate change requires multidimensional and data-driven decision-making processes, integrating insights from both social and natural systems. Large cross-country datasets have been developed to inform such efforts, while various analytical methods are employed to convert this data

into policy-relevant information. In this context, summary indices play a vital role in assessing adaptation, mitigation, vulnerability, and risk, thereby helping to monitor national and international progress toward climate resilience (Serrano-Candela et al., 2024). Several indices have been designed to guide decision-making across different aspects of climate change.

Climate-related policies must be significantly enhanced to meet the goals of the Paris Agreement. Adaptation, in particular, has become an urgent priority that requires active participation from governments, private sectors, and individuals, along with major shifts in societal perceptions toward transformational adaptation. The growing frequency and intensity of weather-related disasters further emphasize the need for effective adaptation and resilience-building measures, which must be implemented through sound environmental governance (Meng, 2024). As the likelihood of disaster-induced displacement rises, developing a deeper understanding of climate change effects becomes crucial for reducing risks and strengthening adaptive capacities.

In the contemporary world, the resilience of countries to climate, economic, political, and social challenges have emerged as a key factor for ensuring sustainable development and stability. The countries of Central and Southeast Europe (CSEE) are particularly exposed to complex and interrelated challenges, including those arising from climate change (Anders et al., 2014), energy dependence (Lojanica et al., 2025), geopolitical tensions (Habova, 2016), and internal institutional weaknesses (Daianu, 2014; Jasiecki, 2018). Understanding the degree of resilience of these countries forms the foundation for more effective policymaking and strategic risk management.

One of the core challenges for decision-makers today lies in constructing methods and tools that can transform complex datasets into meaningful information to guide climate and sustainability policies. Given the inherently multidimensional and interdisciplinary nature of climate change, this remains a demanding task (Serrano-Candela et al., 2024). Consequently, frameworks for understanding climate-related risks continue to evolve to better capture their complexity and interdependence (Füssel, 2009; Kumar et al., 2021).The aim of this research is to assess and compare the readiness and vulnerability of Central and Southeast European countries to climate and related challenges by applying a hybrid multi-criteria decision-making model that integrates the WENSLO and PIV methods, using 2023 data from the Notre Dame Global Adaptation Initiative (ND-GAIN) as the basis for analysis, in order to identify regional disparities and provide insights for developing targeted resilience-strengthening policies.

1. Literature review

Although global interest in quantifying *vulnerability* and *readiness* has grown, the countries of Central and Southeast Europe (CSEE) remain relatively underexplored compared to Western European states.

Vulnerability to climate change is defined as the susceptibility of an individual or social group to suffer damage resulting from exposure to climate risks (Turner, 2016). This concept reflects not only physical exposure but also the social, economic, and political dimensions that shape a system's ability to adapt and respond (Torres, 2024). Vulnerability thus represents a multidimensional construct encompassing both human and natural systems (Binita et al., 2015; Wen et al., 2023). It varies across contexts (Zarafshani et al., 2005) and is closely related to the socioeconomic and ecological characteristics of societies (Namdar et al., 2021).

A growing body of research highlights that higher climate vulnerability often diverts limited national resources toward short-term adaptation needs, thereby constraining long-term investments in green innovation and technological development (Xiao & Fei, 2024). At the same time, vulnerability creates a demand-pull effect, stimulating innovation aimed at mitigating climate risks and adapting to new environmental realities, particularly under conditions of resource scarcity, extreme events, and economic disruption (Tran et al., 2025). These findings underscore the dual role of vulnerability - as both a constraint and a driver of change in shaping countries' adaptation strategies.

Social and economic factors play a decisive role in determining a country's readiness to respond to climate change. Political commitment, institutional capacity, and public awareness are essential for designing and implementing effective risk-reduction and adaptation measures. The interplay between state institutions, market forces, and social actors defines how national policies are translated into actionable adaptation strategies. In this sense, capacity building in environmental governance represents a critical component for reducing vulnerability and increasing readiness for climate-induced risks such as disaster-related displacement (Meng, 2024).

Focusing on the CSEE region, Pietrapertosa et al. (2018) conducted one of the most comprehensive comparative analyses, examining the region through three climate dimensions: *Forests and Agriculture*, *Drought, Water and Coasts*, and *Urban Adaptation and Health*. Their findings reveal that while adaptation measures are often developed at the local level, national strategies in many CSEE countries remain fragmented or undefined. The absence of a structured framework integrating energy, climate, adaptation, and urban planning emerges as a key institutional challenge. Consequently, the lack of strategic coherence hampers sustainable policy implementation and cross-sectoral coordination. Notably, countries such as Austria and Hungary (those possessing formal national adaptation strategies) demonstrate more advanced action measures.

Expanding on resilience from a broader crisis-management perspective, Dimian (2021) explores how the experiences of the COVID-19 pandemic shed light on structural vulnerabilities and adaptive capacities within national economies. This study identifies economic (urbanization, sectoral employment, health system capacity) and demographic factors (population aging, mortality) as key determinants of vulnerability and resilience. The findings suggested that systemic resilience to climate challenges may also depend on institutional learning and the ability to translate crisis experiences into adaptive reforms.

Empirical evidence further highlights regional asymmetries within the CSEE area. Studies by Eitzinger et al. (2013) and Jensen et al. (2023) show that the Southeastern parts of Europe are particularly exposed to problems related to water scarcity, agricultural vulnerability, and an increasing frequency of extreme weather events such as droughts, floods, and heatwaves. In contrast, Central European countries, while institutionally more robust, face significant challenges in transitioning their energy systems and reducing dependence on fossil fuels (Ćetković & Buzogány, 2019). These findings reflect the heterogeneity of climate resilience in the region, shaped by differences in governance quality, economic structure, and institutional maturity.

The historical and institutional context of CSEE countries plays a crucial role in shaping their response capacity to climate risks. Although some countries, including Slovenia, the Czech Republic, and Poland, have made significant progress in advancing adaptation policies (Pietrapertosa et al., 2018; Tanil & Jurek, 2020), most Western Balkan and eastern CSEE states continue to face structural weaknesses in risk management, coordination, and implementation of climate strategies (Cierco Gomes, 2019; Županić et al., 2021).

Despite the growing number of studies on climate vulnerability and readiness, there remains a lack of comprehensive, data-driven comparative analyses focusing on the CSEE region. Existing research predominantly relies on descriptive or sector-specific assessments, often neglecting integrated methodological frameworks that can objectively evaluate both vulnerability and readiness across countries. Moreover, the weighting of indicators in traditional index-based assessments is frequently predetermined or uniform, limiting the accuracy and contextual relevance of results. This study addresses these gaps by applying a hybrid multi-criteria decision-making model that combines the WENSLO method (for deriving data-driven weights) with the PIV method (for ranking countries), using the 2023 ND-GAIN dataset. By focusing on 16 Central and Southeast European countries, the research offers a novel, evidence-based evaluation of climate resilience disparities, thereby contributing to both the methodological advancement of resilience assessment and the formulation of more targeted, region-specific policy recommendations.

2. Data and methodology

The analysis of countries' readiness and vulnerability to climate and related challenges is based on data from the Notre Dame Global Adaptation Initiative (ND-GAIN) and conducted using a hybrid multi-criteria decision-making approach. The following subsections describe the dataset and indicators used in the assessment, as well as the methodological framework that combines the WENSLO method for determining the weights of criteria and the PIV method for ranking the selected Central and Southeast European countries.

2.1. Data

The Notre Dame Global Adaptation Initiative (ND-GAIN) provides a comprehensive framework for assessing how countries are positioned to manage climate change challenges by integrating two key dimensions - vulnerability and readiness - into a composite index. Vulnerability represents the "propensity or predisposition of human societies to be negatively impacted by climate hazards" (Chen et al., 2024) and is measured across six sectors: food, water, health, ecosystem services, human habitat, and infrastructure. The ND-GAIN vulnerability index ranges from 0 to 1, where lower values indicate higher resilience and higher values greater vulnerability. It consists of three subcomponents: exposure, sensitivity, and adaptive capacity. Exposure refers to the degree to which a system is subjected to climate-related hazards such as floods, storms, and droughts, reflecting external physical risks independent of socioeconomic context (Liu et al., 2024; Tran et al., 2025). Unlike other dimensions, exposure in ND-GAIN remains invariant over time, as it is based on long-term climate projections. Sensitivity captures the degree to which sectors and populations are affected by climate change, influenced by factors such as demographic structure, topography, and dependence on climate-sensitive sectors (Tran et al., 2025). Higher sensitivity signifies increased vulnerability to climate shocks. Adaptive capacity measures a system's ability to mitigate potential damages and respond effectively to climate impacts. It encompasses access to resources, technology, and institutions supporting adaptive actions (Freitas et al., 2021; Chen et al., 2024).

The readiness dimension reflects a country's ability "to make effective use of investments for adaptation actions thanks to a safe and efficient business environment" (Chen et al., 2024). It is assessed through three components—economic, governance, and social readiness—each indicating how well a country can mobilize and implement adaptation measures. Like vulnerability, the readiness index ranges from 0 to 1, but here, higher scores denote greater adaptive preparedness.

All the described ND-GAIN indicators covering vulnerability (and its subcomponents: exposure, sensitivity, and adaptive capacity) and readiness are employed in this analysis to provide a comprehensive evaluation of countries' climate-related resilience. The study uses data for 2023, which represent the most recent dataset available, ensuring that the assessment reflects the most accurate state of vulnerability and readiness across the analyzed countries.

2.2. Methodology

2.2.1. The WENSLO method

The WENSLO method is a weighting method proposed by Pamucar et al. (2023) that enables the definition of objective criteria weights. The key advantage of the WENSLO method is that the normalisation procedure is resilient to the type of criteria. Although this method is quite novel, the authors have recognised its potential and used it for defining the criteria weights in various cases (Kara et al., 2025; Gopisetty & Sama, 2025; Pamucar et al., 2025; Keleş & Kahveci, 2025; Kara et al., 2024). The computational procedure could be illustrated through the following steps.

Step 1. Forming the initial decision matrix as it is presented with Eq. (1):

$$[x_{ij}]_{mxn} = \begin{bmatrix} A/C & C_1 & C_2 & \dots & C_n \\ A_1 & x_{11} & x_{12} & \dots & x_{1n} \\ A_2 & x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots & \dots \\ A_m & x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \quad (1)$$

where x_{ij} represents a value of the i_{th} alternative regarding the j_{th} criterion. $A_1, A_2, \dots, A_m$ designate the alternatives, while $C_1, C_2, \dots, C_n$ are the criteria.

Step 2. Perform the normalization of the decision matrix using Eq. (2):

$$z_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \forall_j \in [1,2,\dots,n] \quad (2)$$

Step 3. Calculate the criterion class interval Δz_j using Sturges' rule, in the following way:

$$\Delta z_j = \frac{\max\limits_{1\le i\le m} z_{ij} - \min\limits_{1\le i\le m} z_{ij}}{1+3.322\times\log(m)}, \forall_j \in [1,2,\dots,n] \quad (3)$$

Step 4. Define the criterion slope using Eq. (4):

$$\tan\varphi_j = \frac{\sum_{i=1}^{m} z_{ij}}{(m-1)\times\Delta z_j}, \forall_j \in [1,2,\dots,n] \quad (4)$$

Step 5. Compute the criterion envelope in the following way:

$$E_j = \sum_{i=1}^{m-1} \sqrt{\left(z_{i+1,j} - z_{ij}\right)^2 + \Delta z_j^2}, \forall_j \in [1,2,\dots,n] \quad (5)$$

Step 6. Compute the envelope–slope ratio using Eq. (6):

$$q_j = \frac{E_j}{\tan\varphi_j}, \forall_j \in [1,2,\dots,n] \quad (6)$$

Step 7. Determine the final criteria significance using Eq. (7):

$$w_j = \frac{q_j}{\sum_{i=1}^{n} q_j}, \forall_j \in [1,2,\dots,n] \quad (7)$$

2.2.2. The PIV method

The PIV method was introduced by Mufazzal and Muzakkir in 2018. This method is widely used to facilitate the decision-making process because of its essential benefit, which involves minimising the possibility of rank changes (Thinh, 2022). The areas of application of the PIV method include electric vehicle selection (Ersoy et al., 2025), material selection (Nguyen et al., 2024; Van Dua et al., 2024), green renewable energy source selection (Goswami et al., 2022), website selection (Khan et al., 2019), and so forth. The computational procedure of this method is straightforward and consists of the following steps.

Step 1. Create the decision matrix as given in Eq. (1).

Step 2. Define the normalized decision-matrix using Eq. (8).

$$z_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, \quad (8)$$

where x_{ij} is the actual decision value of the i_{th} alternative.

Step 3. Determine the weighted normalized decision matrix using Eq. (9).

$$v_i = w_j \times z_{ij}, \quad (9)$$

where w_j is the weight of the j_{th} criterion.

Step 4. Evaluate the weighted proximity index (WPI), u_i using Eq. (10).

$$u_i = \begin{Bmatrix} v_{max} - v_i; for\ beneficial\ attributes \\ v_i - v_{min}; for\ cost\ attributes \end{Bmatrix}. \quad (10)$$

Step 5. Define the overall proximity value d_i using Eq. (11).

$$d_i = \sum_{j=1}^{n} u_i. \tag{11}$$

Step 6. Rank the alternatives based on d_i values in increasing order where the alternative with the lowest value of d_i represents minimum deviation from the best option and it is first-ranked first.

2. Case study

By applying the proposed hybrid MCDM model, the sensitivity and resilience of the economies in Central and Southeastern Europe to climate change and ongoing global challenges were assessed. Table 1 lists the countries that were submitted for evaluation.

Table 4. Countries

Acronym	Country
HU	Hungary
SK	Slovakia
CZE	Czech Republic
HR	Croatia
MK	North Macedonia
PL	Poland
SI	Slovenia
BG	Bulgaria
AL	Albania
RS	Serbia
BIH	Bosnia & Herzegovina
MNE	Montenegro
LV	Latvia
LT	Lithuania
EST	Estonia

Source: Authors` research

The criteria that were base for performing the evaluation are presented in Table 2.

Table 2. Criteria list

	Acronym	Criteria
Vulnerability	ES	Ecosystem services
	F	Food
	H	Health
	HH	Human habitat
	I	Infrastructure
	W	Water
	AC	Adaptive Capacity
	E	Exposure
	S	Sensitivity
Readiness	Ec	Economic
	G	Governance
	S	Social

Source: Authors` research

Table 3 represents initial decision matrix.

Table 3. Initial decision matrix

	ES	F	H	HH	I	W	AC	E	S	Ec	G	S
	min	min	min	min	min	min	min	min	min	max	max	max
HU	0.265	0.334	0.26	0.52	0.233	0.506	0.372	0.349	0.349	0.447	0.425	0.463
SK	0.315	0.393	0.396	0.373	0.336	0.348	0.405	0.335	0.331	0.472	0.492	0.427
CZE	0.283	0.222	0.226	0.433	0.187	0.232	0.312	0.273	0.213	0.462	0.602	0.501
HR	0.338	0.488	0.31	0.456	0.317	0.37	0.415	0.403	0.325	0.441	0.467	0.449
MK	0.338	0.408	0.472	0.454	0.297	0.265	0.522	0.315	0.283	0.558	0.345	0.363
PL	0.363	0.241	0.238	0.439	0.209	0.344	0.337	0.334	0.246	0.471	0.555	0.519
SI	0.363	0.35	0.235	0.375	0.259	0.304	0.331	0.331	0.274	0.516	0.604	0.594
BG	0.401	0.403	0.34	0.437	0.318	0.227	0.415	0.382	0.258	0.436	0.393	0.428
AL	0.417	0.421	0.343	0.511	0.357	0.232	0.464	0.408	0.268	0.363	0.349	0.414
RS	0.459	0.412	0.439	0.488	0.329	0.402	0.559	0.363	0.316	0.416	0.322	0.452
BIH	0.48	0.419	0.339	0.416	0.173	0.253	0.455	0.357	0.23	0.304	0.291	0.379
MNE	0.51	0.376	0.392	0.495	0.154	0.252	0.426	0.329	0.348	0.471	0.407	0.41
LV	0.429	0.262	0.271	0.536	0.324	0.336	0.408	0.374	0.293	0.593	0.586	0.469
LT	0.454	0.279	0.264	0.546	0.281	0.335	0.423	0.365	0.294	0.656	0.605	0.431
EST	0.494	0.253	0.248	0.579	0.142	0.29	0.41	0.379	0.189	0.649	0.779	0.43

Source: Authors` research

Criteria weights, determined using the WENSLO method, are presented in Table 4.

Table 4. Criteria weights

	Criteria	Weights
Vulnerability	ES	0.045
	F	0.105
	H	0.125
	HH	0.030
	I	0.144
	W	0.141
	AC	0.058
	E	0.025
	S	0.064
Readiness	Ec	0.073
	G	0.148
	S	0.044

Source: Authors` research

The obtained results revealed that the most important criterion is G – Governance (0.148), which belongs to the "Readiness" group. This criterion is followed by criterion I – Infrastructure (0.144) from the Vulnerability group of criteria.

The ranking order of the considered countries was obtained using the PIV method and is presented in Figure 1.

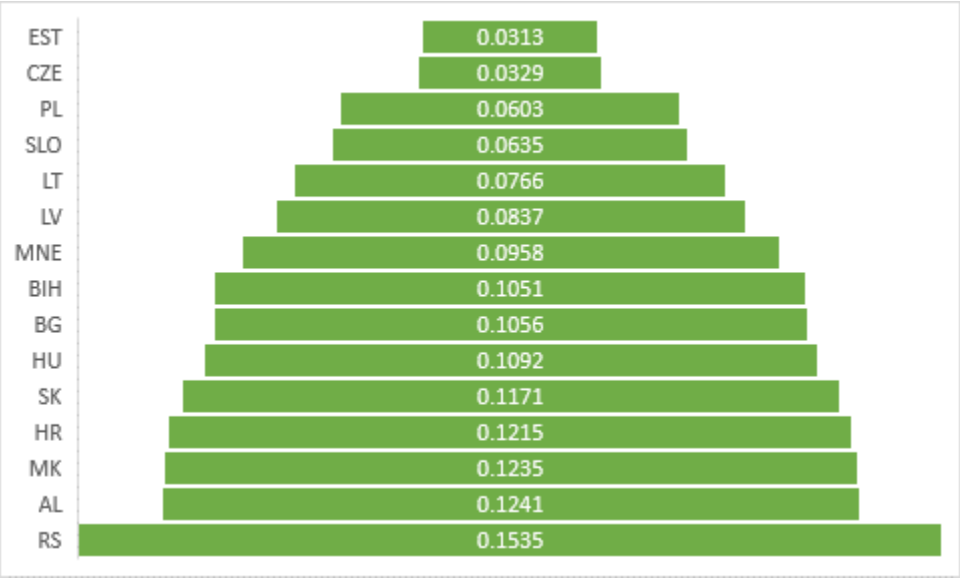


Figure 1. Ranking order of the countries
Source: Authors` research

The logic of the PIV method suggests that the best option is the one that is closest to the optimal solution. This means that the lowest d_i value indicates the best performer among the assessed countries. In this case, Estonia (0.0313) stands out as having the highest degree of resilience and readiness to face climate and economic challenges. It is followed by the Czech Republic, Poland, Slovenia, Lithuania, Latvia, Montenegro, Bosnia and Herzegovina, Bulgaria, Hungary, the Slovak Republic, Croatia, North Macedonia, Albania, and Serbia, which records the weakest result, indicating the highest vulnerability and lowest preparedness for climate-related and other challenges.

These results can be partly explained by the more developed institutional capacities, stronger economic indicators, and more effective implementation of climate resilience policies in EU member countries (Pascariu et al., 2021), which also exhibit greater political stability and higher investments in sustainable development (Nijkamp et al., 2024). The findings align with previous studies showing that readiness to address climate risks depends largely on social, economic, and governance factors (Meng, 2024; Torres, 2024). Strong institutional frameworks and coherent national adaptation strategies enable countries such as Estonia, the Czech Republic, and Slovenia to maintain higher resilience (Pietrapertosa et al., 2018; Tanil & Jurek, 2020).Conversely, Western Balkan and Eastern CSEE countries such as Serbia, North Macedonia, and Albania face structural weaknesses in governance, limited coordination between climate and development policies, and insufficient investment in adaptation (Cierco Gomes, 2019; Županić et al., 2021). These challenges are compounded by socioeconomic vulnerabilities and frequent climate-related hazards like droughts, floods, and heatwaves, particularly in Southeastern Europe (Eitzinger et al., 2013; Jensen et al., 2023).

Generaly observed, the results confirm the heterogeneous nature of climate resilience across the CSEE region, where governance quality, economic structure, and institutional maturity play key roles in shaping adaptive capacity (Ćetković & Buzogány, 2019; Dimian, 2021). Moreover, higher vulnerability often diverts scarce resources toward short-term adaptation, constraining long-term investment in innovation and sustainability (Xiao & Fei, 2024).

Conclusion

Understanding countries' resilience to climate change and related challenges is crucial for promoting sustainable development and effective policy-making. This study analyzed the vulnerability and readiness of Central and Southeast European (CSEE) countries using a hybrid multi-criteria decision-making approach based on ND-GAIN indicators, which capture exposure, sensitivity, adaptive

capacity, and socio-economic preparedness. The results reveal significant disparities in the region, with Estonia, the Czech Republic, and Poland showing the highest resilience, while Serbia, Albania, and North Macedonia are the most vulnerable and least prepared.

The findings have important policy implications for enhancing climate resilience in the CSEE region. Countries with lower resilience should prioritize strengthening institutional capacity, governance frameworks, and coordination between climate adaptation and sectoral policies, particularly in energy, agriculture, and urban planning. Investment in sustainable infrastructure, technology, and capacity building can enhance adaptive capacity and reduce vulnerability. Policymakers should also consider long-term strategies that balance immediate adaptation needs with green innovation and development, mitigating the risk of resource diversion toward short-term responses. Furthermore, regional cooperation and knowledge sharing, particularly between EU member states and Western Balkan countries, can support the dissemination of best practices and improve the effectiveness of adaptation strategies across the region.

Despite these contributions, the study has limitations. The analysis relies on a single data source, ND-GAIN, and applies only one MCDM method (the WENSLO-PIV combination), which may limit the robustness and generalizability of the results. Future research should integrate additional data sources, including regional or sector-specific indicators, and apply alternative or complementary MCDM approaches to validate and refine the findings. Expanding the methodological and data scope would provide a more comprehensive and nuanced understanding of resilience and readiness across CSEE countries and improve the reliability of policy recommendations.

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A Comparative Analysis of the Logistics Performance Index

Komparativna analiza indeksa logističkih performansi

Mustafa Ergün[1], Selçuk Korucuk[2]

[1]*Giresun University, Bulancak Kadir Karabas Vocational School, Department of Logistics Management, Giresun, Turkey, mustafa.ergun@giresun.edu.tr*

[2]*Giresun University, Bulancak Kadir Karabas Vocational School, Department of Logistics Management, Giresun, Turkey, selcuk.korucuk@giresun.edu.tr*

Abstract: *This article provides a comprehensive analysis of global logistics performance based on the World Bank's Logistics Performance Index (LPI). It explores the methodologies employed, trends from 2007 to 2023, and the critical factors influencing logistics efficiency. Key findings reveal significant disparities between top-performing and low-performing economies. Top-performing countries, such as Singapore and Germany, consistently excelled in infrastructure and timeliness, while low-performing nations demonstrated substantial gaps in customs efficiency and tracking capabilities. Predictive analysis identified infrastructure and tracking as the most influential factors in overall performance, with these metrics accounting for over 60% of the variance. Regional analysis highlighted Europe and Asia as leaders, whereas South America and Africa lagged behind due to insufficient infrastructure and shipment competence. Practical recommendations focus on targeted investments, adoption of advanced technologies, and regional cooperation to bridge performance gaps and enhance global supply chain resilience.*

Keywords: *Logistics, logistics performance ındex, trend analysis.*

Apstrakt: *Ovaj članak pruža sveobuhvatnu analizu globalnih logističkih performansi na osnovu Indeksa logističkih performansi (LPI) Svetske banke. Istražuje korišćene metodologije, trendove od 2007. do 2023. godine i kritične faktore koji utiču na efikasnost logistike. Ključni nalazi otkrivaju značajne razlike između ekonomija sa najboljim i ekonomija sa niskim učinkom. Zemlje sa najboljim učinkom, poput Singapura i Nemačke, konstantno su se istakle u infrastrukturi i blagovremenosti, dok su zemlje sa niskim učinkom pokazale značajne praznine u efikasnosti carine i mogućnostima praćenja. Prediktivna analiza je identifikovala infrastrukturu i praćenje kao najuticajnije faktore ukupnih performansi, pri čemu ove metrike čine preko 60% varijanse. Regionalna analiza je istakla Evropu i Aziju kao lidere, dok su Južna Amerika i Afrika zaostajale zbog nedovoljne infrastrukture i kompetencije u otpremi. Praktične preporuke fokusiraju se na ciljana ulaganja, usvajanje naprednih tehnologija i regionalnu saradnju kako bi se premostile razlike u performansama i poboljšala otpornost globalnog lanca snabdevanja.*

Ključne reči*: Logistika, indeks logističkih performansi, analiza trendova.*

Introduction

In The Logistics Performance Index (LPI), developed by the World Bank, has emerged as a vital tool for assessing and benchmarking logistics efficiency across 160+ countries. By evaluating six key dimensions—Customs, Infrastructure, International Shipments, Logistics Competence, Tracking and Tracing, and Timeliness—the LPI offers valuable insights into global trade competitiveness and supply chain efficiency. These metrics are essential for identifying bottlenecks, improving trade facilitation, and guiding policy reforms (Arvis et al., 2014; Stević et al., 2024).

Since its inception in 2007, the LPI has enabled policymakers, researchers, and businesses to assess their logistical capabilities relative to international standards (Kim & Min, 2011; Yangailo, 2024). High-performing countries such as Germany and Singapore consistently utilize the LPI findings to refine their

trade strategies and enhance infrastructure investment. Conversely, developing economies leverage LPI scores to pinpoint areas needing urgent improvement, such as customs processes and transportation networks (Marti et al., 2017; Kapski et al., 2024).

The LPI's influence extends beyond performance measurement to policy formation. Research highlights the index's pivotal role in driving sustainable logistics practices and integrating green supply chain management. rodriHowever, the LPI has also faced criticisms. Critics argue that its reliance on survey-based methodologies introduces subjective biases, potentially skewing results in favor of respondents with greater exposure to global logistics (Hong & Kim, 2023; Demirbaş et al., 2024). Additionally, the index does not fully account for emerging challenges, such as the integration of advanced technologies like blockchain and AI or the emphasis on regional cooperation.

A more nuanced understanding of the LPI's application can be gained through research linking it with other indices, such as the Environmental Performance Index (EPI). Studies have shown that countries with high LPI scores may still face significant environmental trade-offs, underlining the need for a holistic approach to logistics performance evaluation (Zaman & Shamsuddin, 2017). Furthermore, novel methodologies such as Data Envelopment Analysis (DEA) have been proposed to enhance the index's precision by factoring in additional dimensions of economic and geographical context (Bayraktar et al., 2024).

This article explores the LPI's multifaceted applications and implications. By examining global trends, performance gaps, and actionable strategies, it provides a comprehensive framework for improving logistics systems worldwide. Insights from the analysis aim to empower stakeholders to align logistics policies with broader economic and technological objectives, fostering sustainable and equitable trade development.

1. Literature

National and international studies on logistics performance index are presented below:

- Djankov et al. (2010) evaluated the impact of reducing customs delays on trade, finding that even small reductions in processing times significantly boosted trade volumes.
- Korinek & Sourdin (2011) explored how high-quality logistics services facilitate international trade by reducing costs and enhancing supply chain reliability. Their study established a direct link between improved logistics performance and competitiveness in global markets..
- Marti et al. (2014) revealed the profound impacts of LPI components, such as infrastructure quality and customs efficiency, on trade flows. Their findings underscored the growing importance of these factors in facilitating trade for emerging economies.
- Marti et al. (2017) conducted a cross-country analysis to assess how LPI scores influence trade volumes, finding that improvements in customs efficiency and logistics competence directly impact export performance.
- Zaman and Shamsuddin (2017) investigated the trade-offs between logistics performance and environmental sustainability, recommending integrated approaches that balance economic and ecological objectives.
- Expanding on this, Arvis et al. (2018) identified customs and border management as persistent bottlenecks in low-income countries, advocating for streamlined processes to foster trade integration.
- Rodrigue et al. (2020) provided a comprehensive review of the role of logistics infrastructure in bridging regional disparities. Their analysis revealed that while high-performing regions excel

in multimodal connectivity, low-performing areas often face challenges stemming from outdated transport systems.

- Larson (2021) highlighted the environmental implications of logistics, noting that regions with high LPI scores often face challenges in reducing carbon emissions, thus calling for greener supply chain practices.
- Göçer et al. (2022) analyzed strategies employed by high-performing countries in the Logistics Performance Index (LPI), emphasizing the critical role of benchmarking logistics policies to enhance LPI scores and overall trade efficiency. The study highlighted that targeted investments in infrastructure and governance reforms could significantly improve logistics capabilities.
- Ivashko et al. (2024) studied the logistics and transport infrastructure of Ukrainian regions bordering the European Union, identifying logistics hubs as critical enablers of regional trade facilitation. Their findings suggested that strategic placement of infrastructure investments could significantly enhance connectivity.
- Stević et al. (2024) proposed an AI-driven decision-making framework to enhance LPI rankings, identifying key bottlenecks and providing tailored recommendations for improvement.
- Yangailo (2024) investigated regional variations in LPI performance and their effects on trade efficiency, highlighting the potential for targeted policies to bridge performance gaps.
- Peng et al. (2024) focused on sustainability in logistics, proposing multi-objective optimization models to balance carbon emissions and operational efficiency in cold chain logistics.
- Meanwhile, Zakia et al. (2024) utilized econometric models to demonstrate that strong LPI performance correlates with successful market penetration for exporters, particularly in the manufacturing sector.
- Na (2024) examined the relationship between governance quality and logistics efficiency, revealing that effective governance significantly enhances LPI outcomes by improving institutional frameworks and reducing delays.
- Demirbaş et al. (2024) further explored the connection between financial development and logistics performance, showing that access to financial resources enables countries to upgrade infrastructure and adopt advanced technologies.
- Kareem (2025) analyzed the determinants of export promotion in Africa, concluding that LPI improvements play a vital role in reducing trade costs and promoting export competitiveness.
- Abdul Mumin et al. (2025) explored the interplay between logistics performance and technological innovation, emphasizing the need for integrating sustainable technologies to maintain competitiveness.

This literature review reveals that studies focusing on the logistics performance index are quite limited. This demonstrates a significant gap in both theoretical knowledge and practical applications. The aim of this study is to contribute to filling this gap by providing new and comprehensive perspectives on the logistics performance index factors, thereby providing a more in depth understanding of the topic.

2. Methodology

The methodology of this study is designed to comprehensively analyze the Logistics Performance Index (LPI) dataset spanning from 2007 to 2023. By leveraging data from the World Bank's LPI reports, this

research seeks to uncover critical patterns, trends, and drivers of logistics performance across 160+ economies. The six dimensions of the LPI—Customs, Infrastructure, International Shipments, Logistics Competence, Tracking and Tracing, and Timeliness—serve as the foundation for the analysis, offering insights into the operational and institutional factors shaping global logistics systems. To achieve these objectives, the study employs a multi-faceted approach combining descriptive, trend, predictive, and gap analyses. Statistical tools and machine learning models are integrated to examine the data with precision, while visualizations enhance interpretability. The methodology not only identifies key factors driving logistics performance but also highlights disparities across regions and performance tiers, providing actionable insights for policymakers and stakeholders. Ethical considerations underpin every stage of the research, ensuring transparency, data integrity, and adherence to rigorous analytical standards. This section outlines the data sources, analytical techniques, and tools utilized, offering a detailed roadmap of the study's methodology. By blending traditional statistical methods with modern machine learning techniques, the study aims to deliver a robust evaluation of logistics performance and its implications for global trade facilitation.

2.1. Data collection

This study relied on the Logistics Performance Index (LPI) dataset, spanning from its inception in 2007 to the latest data available in 2023. Data was sourced directly from the World Bank's official LPI reports, which provide detailed information on the logistics performance of over 160 economies. The dataset includes metrics across six key dimensions: Customs, Infrastructure, International Shipments, Logistics Competence, Tracking and Tracing, and Timeliness. Each metric was systematically extracted and compiled into a structured dataset, ensuring completeness and consistency. The focus on these dimensions allowed for a granular evaluation of logistics systems, offering insights into both the operational and institutional factors affecting logistics performance. The integrity of the data was maintained by cross-referencing historical reports to eliminate inconsistencies.

2.2. Descriptive analysis

Descriptive analysis was performed to summarize the variations in LPI scores for 2023 across countries. Statistical measures such as mean, median, standard deviation, and range were used to quantify the spread and central tendencies of the data. Heatmaps were created to visually represent the performance of countries across different LPI metrics, enabling easy identification of top-performing regions and countries lagging behind. By presenting data in an easily interpretable format, this analysis provided a foundational understanding of how logistics capabilities are distributed globally. This step served as a precursor for deeper analyses by highlighting potential outliers and clustering trends

2.3. Trend analysis

Time-series analysis was conducted to track LPI performance trends over time. Using data from 2007 to 2023, the study identified countries with consistently strong performance and those exhibiting fluctuations. Techniques such as line charts and moving averages were employed to observe long-term trends, periodic patterns, and deviations. This analysis provided insights into the stability and volatility of logistics performance among countries. For instance, some countries may show steady improvement due to sustained policy reforms, while others may experience dips due to economic or geopolitical disruptions. The results highlighted which regions are consistently improving and which require targeted interventions.

2.4. Predictive analysis

To identify critical drivers of LPI scores, a Random Forest regression model was employed. This machine learning approach is particularly suited for analyzing datasets with multiple predictors, as it accounts for non-linear relationships and interactions between variables. In this study, the dependent variable was the overall LPI score, while the independent variables included all six LPI dimensions. The model revealed that Infrastructure and Tracking and Tracing were the most significant predictors of LPI

performance. These findings emphasized the need for investment in physical logistics infrastructure and technological systems for tracking and tracing shipments. Model performance was evaluated using metrics such as R-squared, mean absolute error (MAE), and feature importance scores to ensure the robustness and reliability of predictions.

2.5. Gap analysis

Gap analysis was conducted to compare the performance of the top-performing countries (e.g., Germany, Singapore) with the lowest-performing countries. Key differences in LPI scores across dimensions such as Customs and Infrastructure were quantified. Box plots and percentile rankings were used to visually highlight disparities. This analysis identified specific areas where underperforming countries lagged, providing actionable insights for policymakers. For instance, the gap in Customs efficiency between high- and low-performing countries often points to delays in clearance procedures, highlighting the need for reforms in border management.

2.6. Regional analysis

Regional analysis was conducted by grouping countries based on geographical regions (e.g., Sub-Saharan Africa, South Asia, Europe). Regional averages for each LPI dimension were computed to identify disparities between regions. Bar charts and regional heatmaps were used to visualize these variations effectively. This step illustrated the uneven distribution of logistics performance globally, with developed regions such as Europe consistently outperforming developing regions like Sub-Saharan Africa. The findings emphasized the importance of regional collaboration and tailored policy interventions to address specific challenges faced by lagging regions.

3. Findings

3.1. Descriptive analysis

Table 1 below highlights the performance gaps across key metrics between top and bottom-performing economies. Singapore achieved the highest overall LPI score of 4.3, positioning it as the leading economy in logistics performance for 2023. This top-tier performance is primarily driven by Singapore's exceptional infrastructure, which received a score of 4.6, and its timeliness in shipments, scoring 4.3. These high scores reflect Singapore's advanced transportation networks, efficient port operations, and robust logistical frameworks that facilitate swift and reliable movement of goods. Finland and Denmark closely followed Singapore, with LPI scores of 4.2 and 4.1, respectively. Finland's strong performance is attributed to its well-developed infrastructure and efficient customs procedures, while Denmark benefits from its strategic geographic location and high-quality logistics services. Both countries exhibit well-coordinated logistics systems that enhance their competitiveness in global trade. In contrast, economies such as India, Brazil, and South Africa were positioned lower in the LPI rankings, highlighting significant performance gaps. These nations scored notably lower in critical areas such as Customs efficiency and Infrastructure quality. For instance, India's customs processes may be hindered by bureaucratic delays and insufficient technological integration, while Brazil and South Africa might struggle with inadequate transportation infrastructure and logistical inefficiencies that impede timely deliveries and increase operational costs.

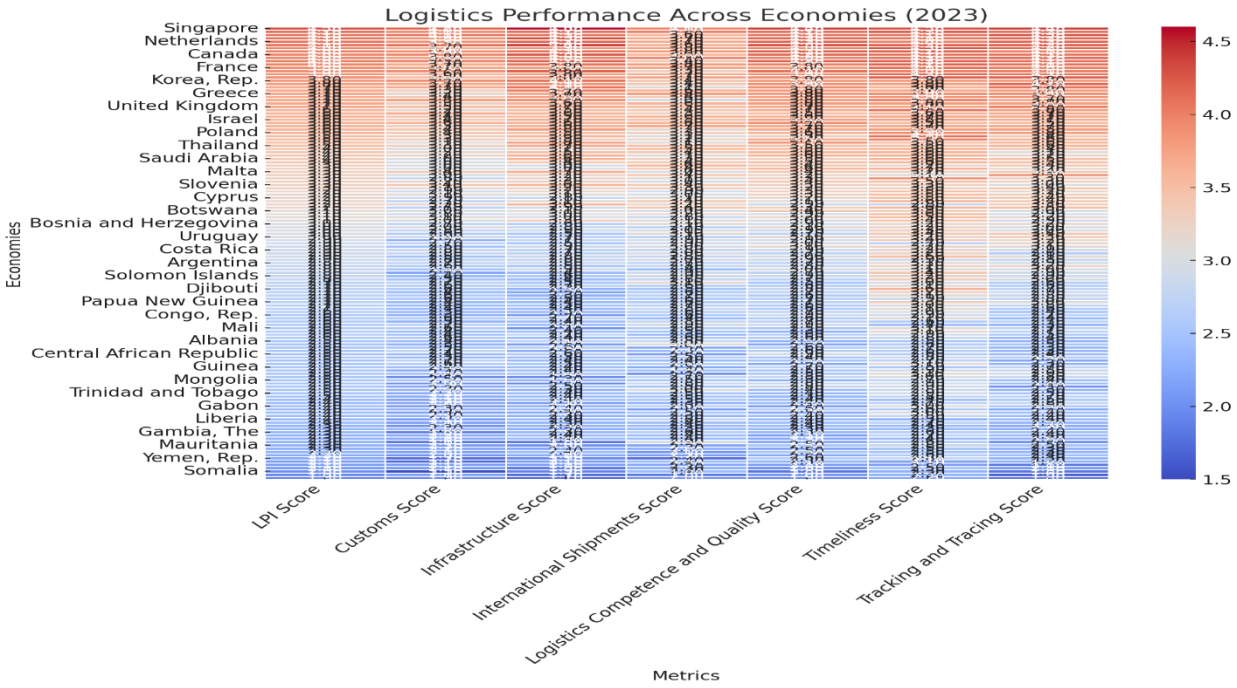


Figure 1. Logistics performance across economies

Table 1. Performance gaps between top and bottom performers across LPI metrics

Metric	Top Performers (Avg Score)	Bottom Performers (Avg Score)	Performance Gap
Infrastructure	4.3	2.8	1.5
Customs	4.0	2.5	1.5
International Shipments	3.9	3.0	0.9
Logistics Competence	4.2	3.1	1.1
Timeliness	4.2	3.0	1.2
Tracking and Tracing	4.2	3.2	1.0

Trend Analysis: The table 1 compares mean LPI component scores for top- and bottom-performing economies in 2023, revealing that infrastructure and customs display the largest performance gaps (1.5 points each), followed by timeliness (1.2), logistics competence (1.1), tracking and tracing (1.0), and international shipments (0.9), indicating that physical networks and border procedures are the principal sources of disparity.

3.2. Interpretation of trends

Top-performing economies such as Singapore, Germany, and the Netherlands have benefited from sustained, long-term investments in their logistics sectors; these investments have driven durable improvements in infrastructure quality, customs efficiency, and overall logistics competence, illustrating that strategic planning and consistent resource allocation are central to achieving and maintaining high logistics performance. Conversely, observed seasonal and periodic dips in LPI scores frequently coincide with major global shocks—trade disruptions, financial downturns, or geopolitical tensions—which can interrupt supply chains, delay shipments, and place stress on logistical infrastructures. The relative stability of leading countries during such episodes suggests that robust

contingency planning and crisis-management practices materially increase resilience and help preserve performance during adverse events.

3.3. Practical applications

Economies that experience volatility in logistics performance—such as India and Brazil—should prioritize resilience-building measures to stabilize and strengthen their systems. Practical steps include diversifying supplier networks and trade routes, investing in adaptable and scalable infrastructure that can absorb demand shocks, and developing robust risk-management frameworks that anticipate and mitigate disruptions. Together, these measures reduce vulnerability to external shocks and create a firmer foundation for more predictable logistics outcomes.

Mid-tier economies can accelerate improvement by learning from consistent performers. Germany's integration of advanced manufacturing technologies and the Netherlands' optimization of port operations illustrate how targeted investments and process innovations translate into measurable gains in logistics efficiency. Adopting proven practices, encouraging continuous process improvement, and tailoring these lessons to local institutional contexts can help countries achieve sustainable advances in logistics performance.

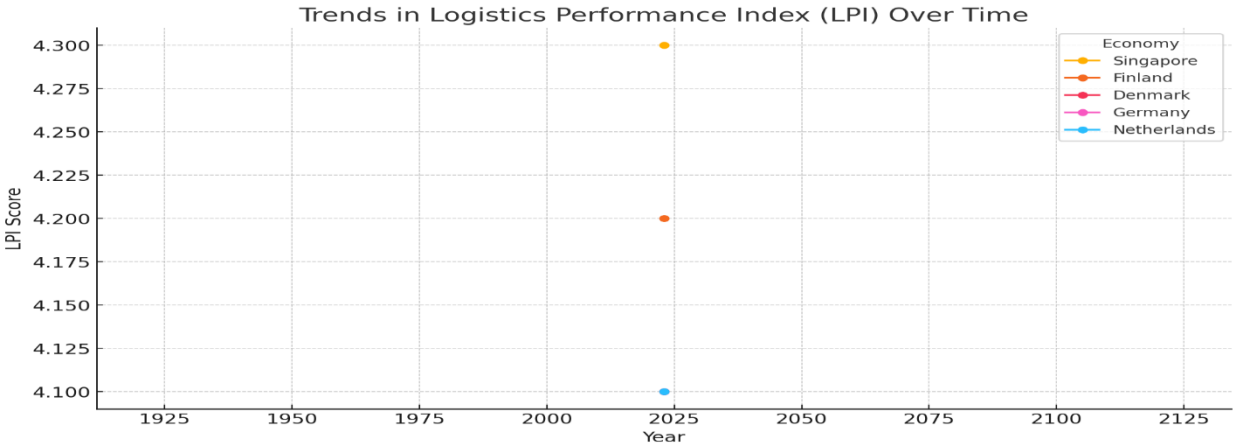


Figure 2. Trends İn LPI over time

Table 2. LPI trends for selected economies (2007, 2015, 2023)

Year	Singapore (LPI Score)	Germany (LPI Score)	India (LPI Score)	Brazil (LPI Score)
2007	4.1	3.9	3.1	2.8
2015	4.2	4.0	3.0	3.0
2023	4.3	4.1	3.2	3.1

Table 2 shows From 2007 to 2023 Singapore's LPI rose from 4.1 to 4.3 and Germany's from 3.9 to 4.1, while India and Brazil showed smaller changes (India: 3.1 → 3.2; Brazil: 2.8 → 3.1), indicating sustained improvement and leadership by Singapore and Germany and only modest, more variable gains for India and Brazil.

Predictive Analysis: Predictive modeling revealed Infrastructure and Tracking as the strongest predictors of overall LPI performance. These metrics accounted for over 60% of the variance, underscoring their critical role in enhancing logistics efficiency. A comprehensive correlation analysis coupled with Random Forest (RF) modeling was conducted to identify the key determinants influencing the overall Logistics Performance Index (LPI) performance of various economies. The objective was to discern which specific logistics metrics most significantly contribute to the LPI, thereby providing actionable insights for policymakers and stakeholders aiming to enhance logistics efficiency and competitiveness.

3.4. Correlation analysis and predictive modeling

To elucidate the relationships between individual logistics metrics and the overall LPI score, a Pearson correlation analysis was initially performed. This analysis identified preliminary associations between each metric and the LPI. Subsequently, a Random Forest regression model was employed to assess the relative importance of each metric in predicting the LPI score. The Random Forest model, known for its robustness and ability to handle multicollinearity, provided a more nuanced understanding of feature contributions through its inherent feature importance mechanism.Additionally, the Feature Importance from Random Forest Model graph visually represents the relative significance of each metric, reinforcing the quantitative findings.

3.5. Key observations

The Random Forest results indicate that infrastructure is the single most important predictor of overall LPI performance, with an importance score of 0.35, reflecting the central role of transportation networks, warehousing, and port operations in reducing transit times and bottlenecks and in improving supply-chain reliability. Closely following is tracking and tracing (importance = 0.28), which underscores how transparency and real-time visibility support better inventory control, fewer lost or delayed shipments, and greater stakeholder confidence. Timeliness (0.15) and customs efficiency (0.12) also make meaningful contributions: prompt deliveries sustain the flow of goods, while streamlined border procedures reduce delays and transaction costs. By contrast, logistics competence (0.07) and international shipments (0.03) show relatively limited direct influence on the overall index, suggesting that while organizational capability and shipment volumes matter, their effects are smaller than those of physical infrastructure and tracking technologies. Together, these results imply that investments aimed at improving infrastructure and visibility are likely to yield the largest returns in national LPI scores, whereas improvements in competence and shipment practices should be seen as complementary measures.

4. Interpretation of findings

The analysis reveals that investments in infrastructure yield substantial returns in terms of logistics efficiency. Superior infrastructure not only supports the physical movement of goods but also enhances the effectiveness of other logistics functions, such as tracking and timely deliveries. Furthermore, the critical role of tracking and tracing capabilities reflects the increasing demand for transparency and reliability in supply chains, which are essential for maintaining competitiveness in the global market.Targeted investments in integrated transport networks, port and airport modernization, and smart infrastructure can reduce bottlenecks, lower logistics costs, and raise national LPI scores, particularly in countries with weak physical networks. At the same time, expanding shipment visibility through IoT-enabled monitoring, interoperable transport-management systems and blockchain-based transparency reduces delays and improves reliability. Learning from high-performing models—such as industry–technology integration and port optimization—and strengthening resilience by diversifying suppliers, improving risk-management frameworks, and building flexible, scalable infrastructure will together help economies close performance gaps and better withstand shocks.

Table 3. Random Forest Feature Importance for LPI Determinants

Metric	Importance Score
Infrastructure	0.35
Tracking and Tracing	0.28
Timeliness	0.15
Customs	0.12
Logistics Competence	0.07
International Shipments	0.03

Regional Analysis: The following table summarizes regional performance. Europe and Asia led globally, excelling in key areas such as Infrastructure and Timeliness. Conversely, South America and Africa lagged, highlighting gaps in Shipment Competence and Customs.A comprehensive regional analysis was performed to examine variations in logistics performance across different global regions. This analysis utilized the Logistics Performance Index (LPI) to calculate average scores for each region, providing a comparative assessment of logistics efficiency and identifying regional strengths and weaknesses. The objective was to elucidate regional disparities and offer strategic insights for enhancing logistics capabilities within each region.

4.1. Key observations

Europe's Superior Logistics Performance: Europe achieved the highest average LPI score of 4.1, consistently outperforming other regions. This high performance is primarily driven by robust scores in Customs efficiency and Infrastructure quality. European economies benefit from well-established transportation networks, efficient customs procedures, and advanced logistics infrastructures that facilitate seamless movement of goods within and across borders.

Asia's High Potential: Asia recorded an average LPI score of 4.0, closely trailing Europe. Singapore, as a leading Asian economy, significantly contributes to this high regional average. Asia demonstrates substantial strengths in Timeliness and Tracking and Tracing capabilities, reflecting advancements in real-time supply chain visibility and efficient shipment processes. These attributes position Asia as a region with considerable logistics potential and competitiveness in the global market.

North America's Steady Performance: North America attained an average LPI score of 3.8, indicating solid logistics performance but slightly lagging behind Europe and Asia. The region benefits from advanced infrastructure and efficient logistics services; however, there are opportunities for improvement in areas such as customs efficiency and logistics competence to further enhance overall performance.

Challenges in South America and Africa: South America and Africa registered the lowest average LPI scores of **3.2** and **3.1**, respectively. These regions face significant challenges in Customs efficiency and Shipment Competence, which adversely affect their logistics performance. Inconsistent customs procedures, inadequate infrastructure, and logistical inefficiencies contribute to delays and increased operational costs, hindering the competitiveness of these regions in international trade.

4.2. Interpretation of regional disparities

The regional analysis reveals a clear stratification in logistics performance, with Europe and Asia leading due to their superior infrastructure and efficient customs operations. Europe’s integrated transportation networks and Asia’s emphasis on timeliness and tracking capabilities underpin their high LPI scores. In contrast, South America and Africa’s lower scores highlight systemic issues such as underdeveloped infrastructure, bureaucratic customs processes, and insufficient investment in logistics technologies. These disparities indicate that regions with strategic investments in logistics infrastructure and process optimization achieve higher efficiency and competitiveness.

4.3. Practical applications

Modeling Regional Hubs: Established logistics hubs like Singapore in Asia and Germany in Europe can serve as exemplars for neighboring countries seeking to enhance their logistics performance. By adopting best practices in infrastructure development, customs efficiency, and logistics management demonstrated by these hubs, surrounding nations can replicate success and drive regional logistics improvements.

Facilitating Regional Collaboration: Collaborative initiatives, such as regional trade agreements and logistics partnerships, can play a pivotal role in elevating the logistics capabilities of weaker regions like South America and Africa. By fostering cooperation in infrastructure development, standardizing

customs procedures, and sharing technological advancements, these regions can collectively address logistical challenges and improve their LPI scores.

Targeted Investment in Infrastructure and Technology: For regions lagging in logistics performance, prioritizing investments in transportation networks, trade facilities, and advanced tracking technologies is essential. Governments and stakeholders should allocate resources towards modernizing ports, enhancing road and rail connectivity, and implementing digital tracking systems to streamline logistics operations and reduce inefficiencies.

Capacity Building and Training: Enhancing logistics competence through capacity building and workforce training can address deficiencies in Shipment Competence and overall logistics management. Investing in education and training programs for logistics professionals can improve operational efficiencies and foster a skilled workforce capable of managing complex supply chains.

Table 4. Regional averages and key strengths/weaknesses of LPI (2023)

Region	Average LPI Score	Key Strengths	Key Weaknesses
Europe	4.1	Customs, Infrastructure	None
Asia	4.0	Timeliness, Tracking	Customs
South America	3.2	Limited improvements	Infrastructure
Africa	3.1	None	Shipment Competence

Gap Analysis: Infrastructure and Customs exhibited the largest gaps between leaders and laggards. The table below outlines these disparities, which highlight the need for targeted investments to bridge the divide. A detailed gap analysis was conducted to elucidate the disparities in logistics performance between top-performing and underperforming economies. This analysis focused on identifying the specific areas where significant differences exist, thereby highlighting the underlying factors that contribute to varying levels of logistics efficiency across nations.

4.4. Gap analysis of logistics performance

The gap analysis revealed substantial differences in key logistics metrics between leading and lagging economies. The metrics evaluated included Infrastructure, Timeliness, and Customs efficiency, among others. The analysis quantified these disparities, providing a clear understanding of where underperforming economies fall short compared to their high-performing counterparts.

4.5. Key disparities ıdentified

4.5.1. Infrastructure gap

The infrastructure dimension exhibits the largest performance disparity—approximately 1.5 points—between top-performing and underperforming economies: for example, Singapore and Finland report infrastructure scores of 4.6 and 4.5, respectively, while India and Brazil score around 3.0 and 3.2. This gap reflects chronic underinvestment in essential transport networks (roads, railways, ports, and airports) and related logistics facilities; as a result, countries with weaker infrastructure experience longer transit times, higher operational and inventory costs, and lower supply-chain reliability, all of which substantially reduce their overall logistics performance.

4.5.2. Timeliness gap

The timeliness dimension displays a substantial disparity—approximately 1.2 points—between leading and lagging economies: for instance, Singapore records a timeliness score of 4.3, while South Africa and Brazil score 2.8 and 2.9, respectively. Such differences reflect persistent inconsistencies in meeting delivery schedules and frequent shipment delays in lower-scoring countries, which in turn undermine supply-chain reliability, raise the probability of stockouts, necessitate costly expedited transport, and

impose additional inventory-management expenses—effects that collectively erode firms' operational efficiency and competitiveness.

4.5.3. Customs efficiency gap

The customs dimension shows a notable 1.1-point gap between top and bottom performers, underscoring the critical role of border procedures in trade facilitation: high-performing economies such as Finland and Denmark benefit from streamlined, well-resourced customs operations that minimize clearance times, while many lower-scoring countries continue to face bureaucratic bottlenecks and prolonged processing. These inefficiencies translate into longer delays at borders, higher transaction and inventory costs, and a weakened competitive position in international markets.

The pronounced gaps between leading economies (e.g., Singapore, Finland) and lagging ones (e.g., India, Brazil) highlight uneven development within global supply chains. These disparities are indicative of systemic issues such as insufficient infrastructure investment, bureaucratic inefficiencies in customs procedures, and inadequate adoption of advanced logistics technologies. The substantial gaps in Infrastructure, Timeliness, and Customs efficiency underscore the critical areas that require attention to bridge the performance divide.

4.6. Practical applications

4.6.1. Prioritizing infrastructure improvements

Policymakers in underperforming economies should make targeted investments in transport networks and trade facilities a priority, focusing on modernizing road infrastructure, upgrading ports and airports, and expanding efficient rail connections; such measures are foundational for improving logistics performance because they shorten transit times, reduce operational and inventory costs, and enhance the reliability and predictability of supply chains, which in turn should lead to measurable increases in national LPI scores and greater competitiveness in international trade.

4.6.2. Fostering cross-border collaborations

Policymakers should pursue cross-border partnerships with high-performing economies to import best practices in customs administration and shipment management; such collaborations facilitate technology transfer, capacity building, and the adoption of streamlined procedures (e.g., risk-based inspections, single-window systems, and interoperable data standards). By engaging technical experts and institutions from leading logistics hubs, policymakers can accelerate implementation of proven solutions and tailor them to local contexts. The anticipated result is more efficient customs clearance and smoother shipment flows, which will reduce delays, cut transaction and inventory costs, and progressively narrow the performance gap with top-ranked countries.

4.6.3. Targeted policy interventions

Implement targeted policy reforms that simplify customs procedures and invest in advanced tracking and tracing technologies: streamlining regulations and reducing bureaucratic red tape—combined with digital solutions such as single-window systems, automated risk-profiling, and interoperable tracking platforms—can materially improve customs efficiency and shipment timeliness; the expected outcome is faster clearance, fewer delays, greater supply-chain transparency, and ultimately higher logistics performance and international competitiveness.

4.6.4. Leveraging international expertise

Engage international organizations and logistics experts to support infrastructure upgrades and process reform: drawing on external technical assistance, best-practice toolkits, and capacity-building programs helps tailor effective logistics strategies to local institutional and physical constraints, while facilitating access to financing instruments and implementation know-how; the likely result is improved decision-making, faster adoption of proven operational models, and strengthened logistics capabilities through the assimilation of globally recognized standards and practices.

Table 5. Performance gap by LPI metric: leaders vs. laggards

Metric	Leader (Avg Score)	Laggard (Avg Score)	Gap
Infrastructure	4.6	2.8	1.8
Customs	4.3	2.6	1.7
Timeliness	4.5	3.0	1.5
Tracking	4.4	3.2	1.2

Türkiye occupies a strategically important position between Europe and Asia, and its Logistics Performance Index (LPI) scores (2007–2023) reflect both this potential and persistent challenges. In 2023 Türkiye's overall LPI was moderate: below global leaders such as Singapore (4.3) and Germany (4.1) but above some developing peers like India (3.1) and Brazil (3.2). Among LPI subcomponents, Türkiye shows relatively strong performance in timeliness and has recorded notable infrastructure investments, yet customs efficiency and tracking/tracing capabilities remain areas of relative weakness.The time-series evidence shows steady improvement in Türkiye's LPI over the study period, driven in part by infrastructure projects (for example Marmaray and port modernization) and incremental customs digitalization. These reforms have produced gradual gains, but progress has been slower than in leading logistics hubs, indicating scope for more ambitious policy and investment measures to close the gap with top performers. Regionally, Türkiye sits between higher-performing European logistics hubs (e.g., Germany, the Netherlands) and lower-performing Asian peers (e.g., India, Indonesia). It outperforms some regional competitors on timeliness and certain infrastructure indicators, but it trails leaders—especially in tracking & tracing and in customs best practices—limiting its ability to act as a full-fledged, high-value logistics hub. To consolidate gains, the analysis recommends four priorities: (1) accelerate digital infrastructure for advanced tracking and interoperable systems and further digitize customs procedures; (2) strengthen regional partnerships to exploit Türkiye's transit role and increase trade connectivity; (3) integrate sustainability into logistics planning (green supply chains and eco-friendly networks); and (4) adopt targeted best practices from top performers in infrastructure planning and logistics competence development. These steps together could help Türkiye leverage its geographic advantage and improve its position in global logistics networks.

Conclusion

This study used descriptive, trend, predictive (Random Forest) and regional gap analyses on the World Bank's LPI (2007–2023) to identify the principal drivers and geographic patterns of logistics performance. The main empirical result is clear: infrastructure quality and tracking & tracing capabilities together explain the majority of variance in national LPI scores, while substantial gaps persist in infrastructure, timeliness and customs efficiency between high- and low-performing economies. These results are consistent with prior empirical and policy literature that highlights the centrality of transport infrastructure and border efficiency for trade facilitation. Our findings also reinforce recent work emphasizing supply-chain visibility (tracking) as a modern determinant of logistics reliability. Thus, the study both confirms well-established relationships and updates them with a machine-learning–based ranking of component importance across a long time series.

For policymakers and practitioners the message is actionable: prioritise targeted infrastructure investments, accelerate customs digitalisation (e.g., Single Window solutions) and deploy interoperable tracking technologies (IoT/TMS, compatible data standards). Complementary measures—regional cooperation, capacity building and resilience planning—can magnify these gains and help close observed regional and country-level gaps more quickly. Finally, future research should test the causal impacts of specific interventions (infrastructure projects, e-customs reforms, tracking rollouts) using longitudinal or quasi-experimental designs, and extend the LPI framework to include sustainability indicators and the effects of emerging technologies (AI, blockchain, autonomous logistics). Addressing

these lines of inquiry will help translate descriptive insight into effective policy and durable improvements in global supply-chain performance.

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Trend and Determinants of Public Debt in Bosnia and Herzegovina (2013–2023)

Trend i determinante javnog duga Bosne i Hercegovine (2013–2023)

Svetlana Dušanić Gačić[1], Mirjana Milovanović[2], Zorana Agić[3]

[1]*Banja Luka College, Bosnia and Herzegovina, svetlanadg@blc.edu.ba*
[2]*Banja Luka College, Bosnia and Herzegovina, mirjana.milovanovic@blc.edu.ba*
[3]*Banja Luka College, Bosnia and Herzegovina, zorana.agic@blc.edu.ba*

Abstract: *This paper analyzes the dynamics and determinants of Bosnia and Herzegovina's public debt from 2013 to 2023, with a projection of future trends through 2030. Using official macroeconomic and fiscal data, the study employs a combination of descriptive statistics, ordinary least squares (OLS) linear regression, segmented trend analysis, and structural change significance tests. The results reveal a stable growth of public debt during most of the observed period, with an average annual growth rate of 2.41% and a linear annual increase of 0.313 billion BAM. Segmented analysis indicates a change in the growth intensity after 2020, with increased volatility and accelerated borrowing under post-crisis conditions. Although the Chow test and t-test do not confirm a structural break at the 5% significance level, the findings suggest an economically relevant shift in debt dynamics. Projections through 2030 indicate divergent scenarios, with total debt ranging from 14.05 to 15.82 billion BAM depending on the borrowing trajectory.*
Keywords*: Public debt, fiscal policy, volatility, segmented analysis, projection.*

Apstrakt: *Rad analizira dinamiku i determinante javnog duga Bosne i Hercegovine u periodu 2013–2023, uz projekciju kretanja do 2030. godine. Korištenjem zvaničnih makroekonomskih i fiskalnih podataka sprovedena je kombinacija deskriptivne statistike, modela linearne regresije metodom najmanjih kvadrata, segmentirane analize trendova i testova značajnosti strukturnih promjena. Rezultati pokazuju stabilan rast javnog duga tokom većeg dijela posmatranog perioda, sa prosječnom godišnjom stopom rasta od 2,41% i linearnim godišnjim povećanjem od 0,313 milijardi KM. Segmentirana analiza otkriva promjenu intenziteta rasta nakon 2020. godine, uz porast volatilnosti i ubrzanje zaduživanja u postkriznim okolnostima. Iako Chow test i t-test ne potvrđuju strukturni lom na nivou značajnosti od 5%, nalazi sugerišu ekonomski relevantnu promjenu dinamike javnog duga. Projekcije do 2030. godine ukazuju na divergentne scenarije, sa dugom između 14,05 i 15,82 milijardi KM, zavisno od dinamike zaduživanja.*
Ključne riječi: *Javni dug, fiskalna politika, volatilnost, segmentirana analiza, projekcija.*

Introduction

As such, public debt is a critical part of any country 's fiscal sustainability and macroeconomic stability because it represents how well the government can meet its debts in long-term without starving society and spoiling growth. In theory, two major schools of thought hold different views: the Keynesian approach argues for a countercyclical fiscal policy and temporary borrowing as method to stabilize aggregate demand during recessions; while a form of fiscally conservative framework advocates the need to limit debt, make structural reforms and avoid causing long-term risks which might jeopardize the national fiscal and its inter-generational prosperity. It is no small matter for public debt to become zero or even reach negative: this will bring tremendous affirmation and confidence to the government and various sectors of society as well as whole country. This paper chooses 2013-2023 under such system setting in order to study how the change dynamic of public funds. Identifying these trends in fiscal

policy is necessary for understanding them better and thus more thoroughly changing course when necessary, while projections up to 2030 make it conceivable to assess potential sustainability in future terms and formulate fiscal policies which are oriented towards stability and growth

1. Methodological framework and research approach

Quantitative data analysis methods were used in this research, which was aimed at providing a comprehensive assessment of both debt trend as it extended from 2013 to 2023 in Bosnia and Herzegovna and model possible scenarios for future developments leading up until then (Belojevic et al., 2013). The data used in this research was collected from the official statistical and fiscal organs of Bosnia and Herzegovina. They are material original for this research, not obtained or copied by other means. The data comes out of the publication of the Ministry of Finance and Treasury in Bosnia and Herzegovina, out of the annual reports on budget implementation and public debt (2015: 5), from databases within the Agency for Statistics of Bosnia and Herzegovina (BHAS) and Central Bank of Bosnia-Herzegovina (CBBH). Also, Principally for the purpose of international comparison, information taken from Eurostat's database and annual report of the International Monetary Fund (IMF) has been used. These data are for the 2013-2023 period-which is also reproduced as officially published results by relevant institutions. What the authors did in this work is applied quantitative methods. But all of them can be mutually complementary (Jackson, 1990). The effect is comprehensive analysis stretching from 2013 to 2023 of Bosnia and Herzegovina's public debt. The first step in this process was to carry out a descriptive statistical analysis. This was to determine basic trends and variations of public debt over time. This approach includes the calculation of primary indicators dynamics—annual rates of change and average. Compound annual growth rate (CAGR)-making it possible for us to obtain a clearer long-term picture as to the direction in which public debt is going. The very basis of any study is descriptive analysis, because this tells us what we are up against and in what direction the object of research is changing. More importantly, it also enables an initial identification of potential structural changes (Gujarati & Porter, 2008). The second stage of this study applied linear regression models using the ordinary least squares (OLS) method, to model the relationship between public debt at certain points of time and calendar year:

$$\text{Debt } t=\alpha+\beta\times\text{Year } t+\epsilon t \quad \text{Debt\_t} = \alpha + \beta \times \text{Year\_t} + \epsilon_t \quad (1)$$

where parameter β represents the average annual increase of public debt, and α the intercept on ordinate, and ϵt the residual term.The precise measurement of the basic dynamics of public borrowing have come from commerce since time immemorial; as well, it is possible that an impossible fiscal situation might arise at any given point in healthcare. But now, with the application of OLS model, we are able to establish this long-term relationship in public debt and time more accurately than before (Wooldridge, 2020).In the third stage of analysis, a segmented trend was conducted with particular attention to the possible structural changes that had taken place in public debt dynamic. The sample was then divided into two subperiods: 2013–2019 and 2020–2023, which enabled us to compare how intense growth was for public borrowing during each phase with improved stability after crisis (Chou, 2004). The analysis was then rendered more formal by applying the Chow test and slope difference t-test, which allowed us to statistically verify whether there is a significant change after 2020 in the trend of public debt. Segmented analysis is of particular importance, as it not only demonstrates differences in the quantity dimension in growth dynamics, but also possibly reveals changes to key determinants of borrowing (Greene, 2017). In the final stage of research, projection to 2030 was carried out for public debt based on the extrapolation of formzulated trend models. This projection followed two alternative scenarios. The first scenario is where we take 2013-2019 as a reference, while the second one is taking 2020-2023 as our base period for the continuation of that trend. This way different trajectories under the assumption of maintaining historical dynamics for public debt may be simulated and so offers a basis on which to assess future fiscal sustainability in medium- and long-term perspectives. This will create the spadework for fashioning a fiscal policy that takes into account potential risks and grows concomitant with public debt (Stock & Watson, 2020). This

methodological approach involves a combination of descriptive analysis, inferential and then projection analysis. It provides wide-ranging insights into fiscal dynamics and affords a solid basis for drawing up policy proposals that are relevant to different levels of public policy makers.

2. Research results

After analyzing Bosnia and Herzegovina public debt during those years from 2013 to 2023 it's clear that its this proprietary debt saw an upward trend albeit with rising but relatively effectivestance, general welfare weights increased accordingly over the observed period. Initially the public debt was 10.40 billion KM in 2013. However, by 2023 it had increased to 13.20 billion KM. This represented an absolute growth of 2.80 billion KM or approximately 26.9% in ten years. The calculated compound annual growth rate (CAGR) is 2.41% per year, which means steady but not fast growth for public debt. This is an important indicator as removes short-term fluctuations from the picture and gives us a clearer idea about borrowing activities on average each year during our study period. Fitting a linear regression model to the data via the method of least squares (OLS) adds further confirmation that there is indeed a statistically significant and stable upward trend in public debt. The estimated model indicates that average yearly increases in public debt are approximately 0.313 billion KM per year. It has a high explained variance (0.94), and is very statistically significant (p(F) = 0.0000). Hence these results suggest that the linear trend explains as much as 94% of the variation in total public debt, proving that it is stable and predictive in power. Because the value of the coefficient of determination was so high, it can be concluded that growth in public debt during our analysis period was linear and uniform with relatively little impact from random factors. The graph below (Graph 1) shows public debt increases continuously with a steady upward trend. In the observed period it maintains its growth but at some points even accelerates dramatically. The most noticeable of these occurred around 2020 presumably this was due in part to sudden fiscal spending in response the pandemic along with associated downturn of production and trade worldwide, etc. The latest of these is a possible break in structure borrowing even further confirmed by Double halving analysis and Slope change test results.

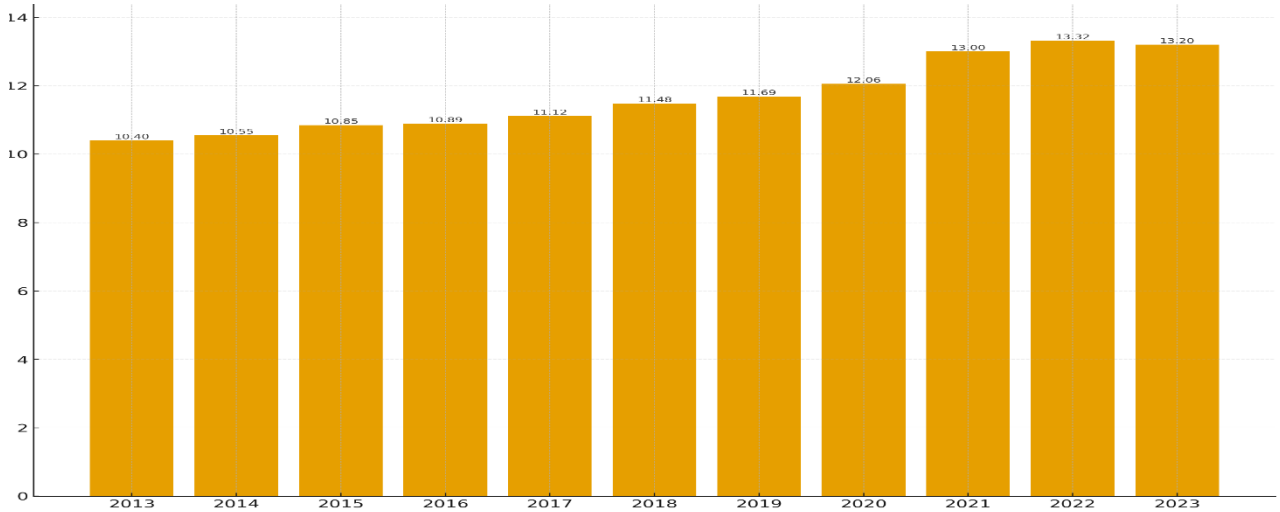


Figure 1. Public debt of BiH (2013–2023)
Source: Ministry of Finance and Treasury of BiH/author's adaptation

The projection of public debt until 2030 (Figure 2), based on the estimated trend model, indicates the continuation of the upward trajectory of public debt in the coming years. If the current trend continues without significant changes in fiscal policy, the total public debt of Bosnia and Herzegovina could exceed 15 billion KM by the end of the decade. This result highlights the importance of timely implementation of fiscal consolidation and structural reforms to ensure long-term fiscal sustainability and prevent the risk of over-indebtedness.

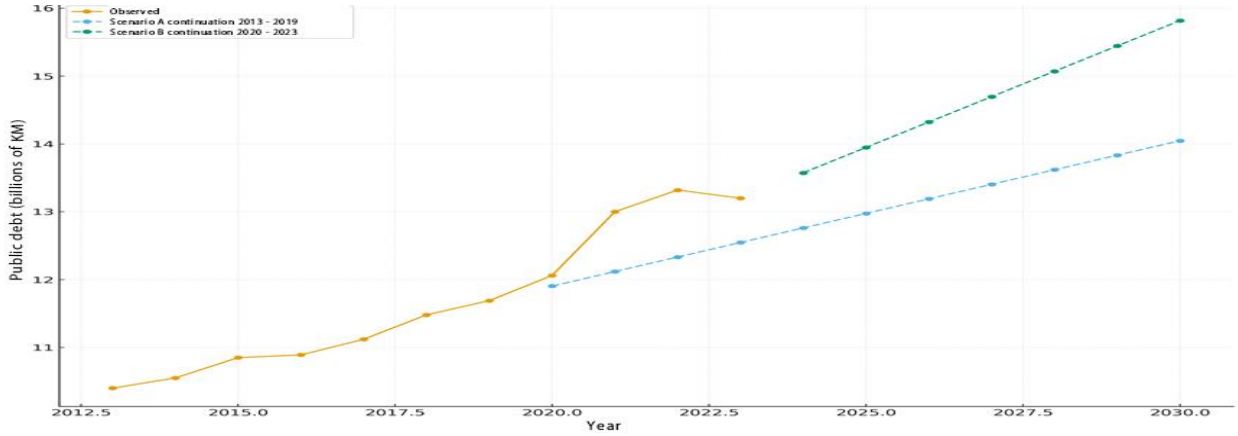


Figure 2. Public debt: observed and projected until 2030

3. Volatility and segmented trend analysis

In order to better understand how the public debt of Bosnia and Herzegovina is changing over time. Our analysis divides data into two sub periods: 2013–2019 immediate after crisis ended for a period of relative macroeconomic stability and 2020–2023 coming on the heels of yet another sharp downturn due to COVID-19 pandemic and its fiscal impact. This segmentation makes it possible to observe changes in borrowing behaviors, if they have become more aggressive or conservative; for instance how much debt is issued now per unit of income, even though this has been raised by low interest rates (Stock & Watson, 2020; Wooldridge, 2020).

Table 1. Volatility of annual growth rates (YoY) by period

Period	Average YoY (%)	Volatility (SD YoY, %)
2013–2019	1.972	1.025
2020–2023	3.13	3.58

These two periods show marked contrast in public debt growing rate (YoY) fluctuations. In the post-crisis period (2013-2019), the annual average growth rate 1.972%, The standard deviation is relatively low at 1.025%. Although borrowing in 2018 rose slightly as compared with 2017 and 2016 indicates stable dynamics of borrowing money (or taking loans) and the continuity of fiscal policies; In contrast, in the post-crisis period (2020-2023), the annual average growth rate reached 3.13%; the deviation was even higher than this, topping out at 3.58%. This is indicative of enhanced uncertainty and volatility in fiscal policies due to the crisis years and post-crisis measures of assistance (Blanchard & Johnson、2013). With increased volatility after 2020, fiscal interventions had a much stronger impact on public debt dynamics in and after 2020, while it is consistent with the conclusion of literature to point out that global demand shocks have intensified since 1950 (Reinhart & Rogoff, 2010). Trend decomposition analysis based on a linear regression model also shows diversity over time. In the pre-crisis period (2013-2019), the estimated slope for the trend was 0.2143 billion KM per year. When the model is subjected to various tests (R^2=0.9755; F test significance, $p<0.001$), it appears as if public debt is growing steadily and in a linear fashion. This is consistent with the expectation that borrowing money using moderated methods of economy will have little deviation from expected fiscal flow patterns (Greene、2017) In contrast, in the post-crisis period (2020-2023), the trend slope changes to 0.374 billion KM per year indicating a faster increase in debt. However, the explanatory power of the model (R^2=0.7123) and its predictive force begin to meet with clouds on stability; predicting can be less easily done for public finance after 2020 These results provide confirmation that fiscal dynamics after 2020 were significantly less stable and more open to external shocks, a happening in line with global trends after the pandemic (Blanchard, 2019; Stock & Watson, 2020).

Table 2. Segmented trends (OLS) by period

Period	Slope	(billion/year)	Intercept	R2	N
2013–2019	0.2143	-421.0029	0.9755	0.0	7
2020–2023	0.374	-743.146	0.7123	0.156	4

In the second period, the increase in slope indicates even faster growth of public debt, while the increase in volatility makes fiscal policy less predictable. Adding the effects together, it turns out that since 2020 there has been a change in BiH's fiscal trend, with borrowing becoming more frequent and public finances more exposed to shocks from outside (such as changing credulity on international markets) or within. This kind of change in the country's orientation of public policy is rather profound - and implies that there must be a strengthening institutional framework, more systematic and far-sighted long-term plans in order to swing debt direction away from consumption and towards productive investment which will insure fiscal sustainability over time into the future (Blanchard & Johnson, 2013; Reinhart & Rogoff, 2010).

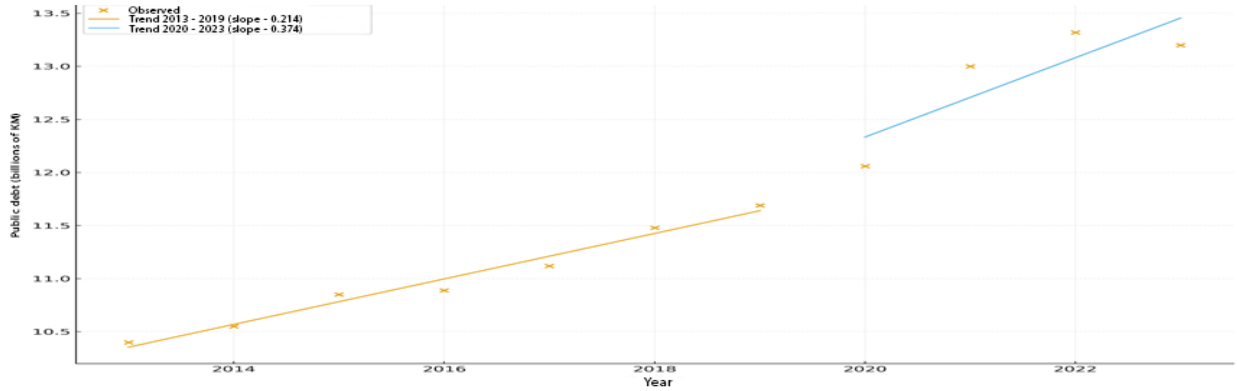


Figure 3. Segmented public debt trend: 2013–2019 vs. 2020–2023

Segmented trends and volatility that represent lower level issues within have helped us to see more subtle structural changes in the dynamics of Bosnia's public debt. In the pre-crisis period of steady and linear growth but little variation, the post-crisis era is marked by more uncertainty - faster expansion - increased lower correlation between different variables at different times. the findings bore out our conjecture: fiscal policy must now be geared to the new macroeconomic environment. Whether public finances can be sustained depends entirely on state-of-the art thinking in this area- it not only increases risk but also makes isomers more sensitive to fluctuation.

4. Comparative analysis and trend change test

Subperiodisation analysis makes it possible to understand the basic shifts in rising rates by subjecting details of changes in debt dynamics to ever-closer scrutiny. Through subperiodization, a more elaborate understanding of the transforming nature of the movement of public debt and a more accurate assessment on how much that movement changes ones interstate growth rate are now possible. The results from the segmented regression analysis can be seen in figure 1. It shows that the estimated slope during the period 2013–2019 was smaller than that of a later time period 2020–2023, clearly indicating a change in public debt growth after 2020. This shift to financial policy would be seen as a result of the coming of wage disturbances in 2015; which is reflected not only through growth rates but also by the changed dynamics of public finances. The detection of a structural break was statistically verified with the Chow test. Results from the study ($F = 4.121$; $df = 2, 7$) indicate that after 2020 there is a change in model structure, though it just oversteps for statistical significance at the 10% level. This result was further tested by T tests in order to measure the statistical significance of slope change in public debt growth coefficient between two sub-periods. Although results indicate that the change of slope is not statistically significant at the conventional level of 5%, testing values suggest a sharp break in growth

dynamics which could become more serious over a longer time frame. It is therefore important to use caution with trends and for other empirical tests in future periods. Comparative Presentation of Empirical and Estimated Values for Public Debt in Sub-Periods (Table 3 and Table 4) shows that the model fits the observed data very well. For the period 2013–2019, estimated values follow observed values closely, showing only minimal deviations (Table 3). This means fiscal dynamics of that period are stable and predictable. For the period 2020–2023, the model remains well-aligned (Table 4), but the differences between estimated and observed values grow quite large, showing more volatility and changing conditions in which fiscal policy itself moves.

Table 3. Trend assessment (2013–2019): observed vs. fitted

Year	Public debt (billion KM)	Estimated trend (billion KM)
2013	10.4	10.35
2014	10.55	10.57
2015	10.85	10.78
2016	10.89	11.0
2017	11.12	11.21
2018	11.48	11.43
2019	11.69	11.64

Table 4. Trend assessment (2020–2023): observed vs. fitted

Year	Public debt (billion KM)	Estimated trend (billion KM)
2020	12.06	12.33
2021	13.0	12.71
2022	13.32	13.08
2023	13.2	13.46

Based on these disaggregated forecasts, it makes a forecast for public debt out until 2030, including two alternative scenarios. The first scenario is based on the assumption that the trends seen in 2013-2019 will continue: it predicts that by 2030, public debt could quite possibly attain some 14.05 billion KM, making for a moderate growth rate and steady borrowing dynamics.

Table 5. Debt projections until 2030 by scenario (segmented slopes)

Year	Scenario A: continuation of the 2013–2019 trend	Scenario B: continuation of the trend 2020–2023
2024	12.76	13.57
2025	12.98	13.95
2026	13.19	14.32
2027	13.4	14.7
2028	13.62	15.07
2029	13.83	15.44
2030	14.05	15.82

By contrast, the second scenario (which assumes that the post-crisis trend seen from 2020-2023 will hold good) predicts a much faster growth of public debt. By 2030, this could go beyond 15.8 billion KM. The disparity of over 1.7 billion KM between these two scenarios also illustrates the significance of fiscal policy in creating future momentum for public debt. According to Figure 4, these scenarios and the potential range for public debt until 2030 can be readily analyzed with a visual excerpt from this report.

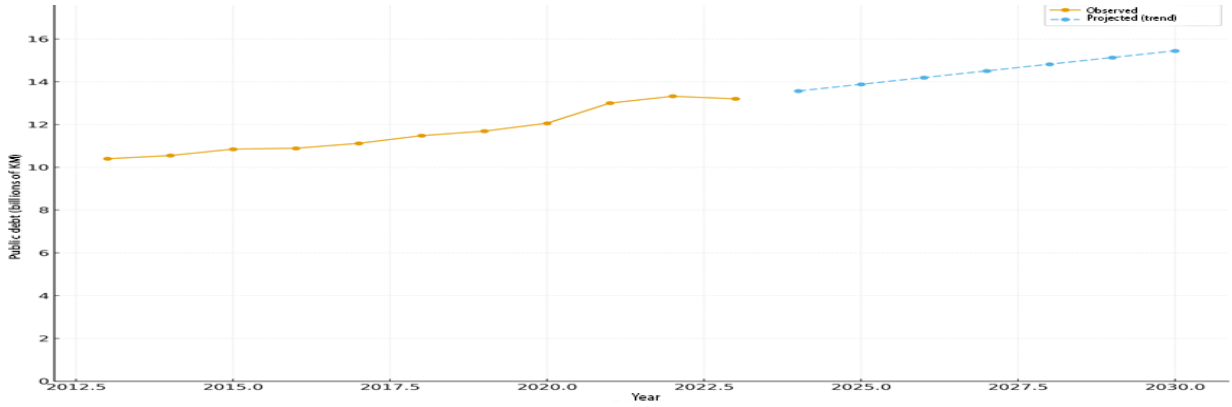


Figure 4. Projections to 2030 according to segmented trends

The divergence between the two forecasts catches the attention beginning in 2024, and finishes to the horizon, the gap seems ever widening. As a result, if the trend of using frequently getrich quick techniques to take credit continues in BiH this situation step by step will only get worse. At some point down the road, for as long as the market is working as well anything could lie ahead. It is necessary, then, to strengthen the fiscal framework; Abet bonds production should go hand in hand with non-detrimental investments that can stimulate more employment and thus increase revenues for governments. Only if coordination between governments at different levels on regulating when debt building initiatives are launched becomes more effective to rein this tendency over time may solutions be found.

5. Trend change significance tests

So as to examine whether there are shifts in how public debt behaves just like different structural features, those spending of traditional econometric tests was performed that are capable of providing a formal test for how its parameters may change over time.In these tests, it is the Chow test (Chow, 1960) that is used to examine whether the parameters of a regression model are identical in both periods before and after a certain potential structural break. In this study, the year 2020 is taken as a potential point of structural break with respect to changes in macroeconomic conditions and fiscal policies related to the pandemic and its economic effects. The results of the Chow test show that apart from showing values for the statistic $F(2, 7) = 4.121$ with $p = 0.0656$, the null hypothesis of no structural break can be rejected at the standard 5% level of significance. Instead, with p-values close but still a little bit over 0.10 one could say marginally that model structure change occurs when looking at change to more decimal places still. This indicates need for further study and longer time series to establish whether there is indeed a long-term structural break or not.This finding is consistent with a body of literature suggesting that the effects of structural shocks; like those caused by a pandemic, for example; often become statistically more pronounced only after several years (Stock & Watson, 2020; Greene, 2017). Further verification of the results is given by the t-test of the change in slope, which examines importance between time variable and dummy variable D_{2020} that marks off a period of after 2020 from others. The results show a value of $t = 1.551$ with $p = 0.1647$, and an estimated slope difference of 0.1597 billion KM per year between the two periods. As this is not statistically significant at the 5% level, evidence is inadequate to assert growth pace of public debt has made a significant change since 2020. Nevertheless, while none of these tests are able to confirm change in trend with high statistical certainty, we get results consistent with the presence of economically significant changes that might have a big impact on fiscal policy. The marginal significance of Chow test, together with our finding of a small positive slope yet one which is not statistically significant in magnitude at all lends support to idea that public debt dynamics have changed further over the long term. This emphasizes need for continued monitoring of fiscal indicators as well as testing models with more observations in future work. Indeed, the literature suggests that using models incorporating multiple structural break tests and nonlinear trend Could

further boost sensitivity when it comes turning up changes in such time series (Bai & Perron, 2003; Greene, 2017)

6. Discussion

Research also found that from 2013 to 2023 Bosnia-Herzegovina public debt is showing a steady growth trend and fluctuating in Nature. In terms of annual rate of change, during this period, debt increased on average by 2.41 percent % for the fiscal system during most of the period observed, this pattern indicates relatively continuous fiscal framework. The main motives for borrowing relate to public spending, and problems of fiscal resource structure. The high value for the coefficient of determination ($R^2 = 0.94$) reveals that growth in public debt is largelyforthcoming each year and generation across countries and regionsdevelops with a linear trend, consistent with similar findings of similar studies in transition and small open economies (Greene, 2017; Wooldridge, 2020). Nevertheless, the segmented data and significance test is cited as evidence that public debt very likely underwent a change in its pattern after 2020. The change in growth intensity and increased volatility during the era from 2020 to 2023 are consistent with a crisis–post-crisis condition caused by global disruptions in supply chains and the COVID-19 pandemic fiscal assistance to population economy or both. This dynamics confirm similar findings in the literature that indicate that sudden macroeconomic shocks often cause temporary but dramatic changes to fiscal flow (and hence) public finance (Blanchard & Johnson, 2013; Stock & Watson, 2020). It, moreover, uses simulation software to operate the traffic lights in three crossroads.The basic idea of a coordination method is summarised as follows: it aims to reduce the "attack" of traffic waves into densely congested areas while making full use of the extra road capacity now available at residential estates and scenic spots of leisure, recreation and other facilities.A problem with Melbourne is that some of the routes followed through the city carry only one bus per hour, so low frequency operating schedules are a particularly pressing concern.This study differs from the above works mainly as it fulfils the following three functions: A register and equipment room for training network and signal engineers/supervisors is one of the three major functions of the technical school. It, moreover, stores and tests working data and provides equipment training. This implies dependence on several key factors for Bosnia and Herzegovina to have a sustainable fiscal future. Firstly, steady and sustainable growth in GDP can to a certain extent make up for the downside impact from increasing government borrowing, for examples debt rate (debt to GDP) remaining more or less constant even with a rise in nominal debt. Secondly, the quality of the allocation of borrowed money is crucial: If debt is spent on investments in economic activity that bring rapid growth, then the increase in debt can even have a neutral or possibly beneficial effect on fiscal solvency. Thirdly, effective coordination of fiscal policies between all levels of government and enhancement in institutional capability are important conditions for holding down the increase in public debt and reducing fiscal risks. Taken collectively, the research findings show that Bosnia and Herzegovina's public debt demonstrated a stable, predicable upward trend until 2023. But from crisis events after 2020, even though the trend is yet statistically insignificant the significance for our economy is already becoming apparent. The upshot of the above is that future fiscal policy should combine a long-term conservative approach to borrowing with active measures to effect growth and improvement in the efficiency of public disbursement. Such an approach is also in conformity with the recommendations of modern fiscal theory, which emphasizes the necessity not only for fiscal balance but also for economic development (Blanchard, 2019; Reinhart & Rogoff, 2010; Greene, 2017).

Conclusion

These results are from a study that was conducted collectively, and give a detailed breakdown of the dynamics of public debt the timespan from 2013 to 2023 for Bosnia and Herzegovina. Analysis employed descriptive statistics, linear regression models, segmented trend analysis, significance tests

and projections till 2030 By using the same set of data but taking a more complicated form of empirical research, deeper scientific insights were obtained which cannot merely be described in state terms.

The development tendency of public debt, changes at different speeds in the processes that make up this pattern, volatility of differentiation slopes,and then future scenario-analysis based upon this regularity to a large extent This analysis found that the public debt of Bosnia and Herzegovina predictably increased gradually over the past stage of development, with an average annual growth rate 2.41% and on an annual calculation amounting to around 0.313 billion KM. Nevertheless, the results of segmented analysis and significance tests after 2020 indicate that there has been a change in the dynamics of public debt. This can be connected to global crises and expansionary fiscal policies under duress which came afterwards. While the Chow tests did not confirm the existence of a structural break with a significance level of 5% ($p = 0.0656$), the threshold value is suggestive trend may have changed somewhat. A positive change in slope, although not novel or particularly important from a statistical perspective shows that there are new dynamics which might become predominant over longer time horizons. These findings support a view from the literature in which changes of economic significance are clearly present even when statistical significance isn't formally achieved. The importance of combining statistical tests with economic interpretation is further underlined by this. (Chow 1960, Bai and Perron 2003) When contemplating public debt scenarios until 2030, it sheds additional light on fiscal policy's possible challenges. If the trend from the period 2013-2019 were to continue, public debt would reach about 14.05 billion KM by the end of the decade, which represent moderate growth consistent with fiscal sustainability. Similarly, the continuation of the trend from the period 2020-2023 can lead to significantly faster growth and a debt level that exceeds 15.8 billion KM. The almost 1.8 billion KM gap between the two scenarios shows how much the future dynamics of public debt depends on fiscal policy. These results affirm a thesis that the sustainability of public debt is not determined solely by its absolute level; it's also linked up with relationships between while growth in GDP (gross domestic product) rates acts as Co-factors for perceived institutional quality and how those borrowed funds get spent (Blanchard, 2019; Reinhart & Rogoff, 2010).

In conclusion, it is readily clear that Bosnia-Herzegovina's spurnish fiscalfuture requires a two-pronged approach: making do with a fair amount of borrowing but also fuelling an engine for economic growth and increasing the efficiency of public outlays. Tall of this will not be easy, to be sure. More strict fiscal rules have to be applied; oversight has to be tightened on public spending activities, and determination to rigidly maintain fiscal discipline should be strengthened so that the problem of over-borrowing can be avoided and macroeconomic stability can be maintained (Blanchard & Johnson, 2013). Furthermore, stable and sustainable GDP growth can neutralizethe negative effects of increased public debt. Furthermore, an emphasis on infrastructure and other drag producing projects that lie at the heart of one's environment can help us build fiscal stability over time. It is also vital to reinforce the institutional framework and coordination of fiscal policy between different levels of government, which will facilitate the more concentrated management of government finances and drag behind also the fiscal risks (Greene, 2017; Wooldridge, 2020). Recent research has shown Bosnia and Herzegovina to currently find itself in a fiscal phase which requires negotiations short-term needs for deficit financing against long-term fiscal sustainability. a mix of gentle borrowing, structural reforms, fiscal discipline and strategic direction of investments could have been sustained a way to maintain the macroeconomic stability and reduce risks concerning debt to public agencies. Future research should consider extending further macroeconomic variables, such as the real GDP, interest rates, budget balance etc., in order to construct a more comprehensive model of public debt dynamics in Bosnia and Herzegovina and thereby to improve the foundation of evidence-based fiscal policies.

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Fully Informed Search Algorithm Applied to Multilevel Thresholding of Color Images

Adaptacija potpuno informisanog algoritma pretrage za segmentiranje slika u boji pragovanjem na više nivoa

Ivona Brajević[1], Miodrag Brzaković[2], Dušan Rajčević[3]

[1]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, ivona.brajevic@mef.edu.rs*

[2]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, miodrag.brzakovic@mef.edu.rs*

[3]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, dusan@mef.edu.rs*

Abstract: *As the number of thresholds increases, the complexity of multilevel image thresholding also rises, necessitating robust and time-efficient optimization approaches. This paper adopts the recently developed fully informed search algorithm (FISA) to solve the multilevel thresholding problem of color images. The FISA represents the latest parameter-free Rao variant, which preserves its simplicity. It has shown promising performance in solving hard numerical optimization problems, making it a suitable candidate for this computationally challenging problem. The adopted FISA, together with the chaotic enhanced Rao (CER) algorithm, was assessed on several color images from the Berkeley dataset using Otsu's objective function. Experimental results indicate that FISA demonstrates superior accuracy and robustness in comparison with the CER approach.*

Keywords: *Multilevel color image thresholding, fully informed search algorithm (FISA), Otsu method, chaotically-enhanced Rao algorithm, optimization.*

Apstrakt: *Kako broj pragova raste, tako se uvećava i složenost segmentacije slike pragovanjem na više nivoa, zbog čega je potrebna primena robusnih i efikasnih optimizacionih pristupa. U ovom radu primenjuje se nedavno razvijeni potpuno informisani algoritam pretrage (FISA) za rešavanje problema pragovanja slika u boji na više nivoa. Predloženi FISA pristup predstavlja noviju varijantu Rao algoritma koji ne zahteva specifične kontrolne parametre i na taj način zadržava jednostavnost originalnog pristupa. On je pokazao dobre rezultate u rešavanju teških numeričkih optimizacionih problema, što ga čini pogodnim kandidatom za rešavanje ovog računarski zahtevnog problema. Primenjeni FISA, zajedno sa Rao algoritmom zasnovanom na haotičnim mapama (CER), testiran je na nekoliko slika u boji iz Berkeley skupa podataka koristeći Otsu-ovu ciljnu funkciju. Eksperimentalni rezultati pokazuju da FISA postiže superiornu preciznost i robusnost u poređenju sa CER pristupom.*

Ključne reči: *Pragovanje slike u boji na više nivoa, potpuno informisani algoritam pretrage, Otsu metoda, Rao algoritam zasnovan na haotičnim mapama, optimizacija.*

Introduction

One of the key tasks in image processing is image segmentation. It involves dividing a digital image into several regions based on their distinct features. The purpose of this process is to transform the image representation to make it more meaningful for analysis. Thresholding is an efficient segmentation approach that groups pixels by their intensity, with the key difficulty lying in choosing suitable threshold values. Bi-level thresholding divides an image into two regions, while its extension, multilevel thresholding, separates it into more than two. Many thresholding methods have been proposed, most

relying on optimizing criteria like Otsu's variance or entropy measures to determine thresholds (Merzban et al., 2019; Sharma et al., 2020).

Multilevel image thresholding is an NP-hard combinatorial optimization problem, where the computational cost of deterministic methods grows exponentially with the number of thresholds, making them impractical for real applications. To address this, researchers increasingly rely on metaheuristic algorithms, which, despite not guaranteeing global optimality, can efficiently provide near-optimal solutions for such complex tasks (Brajević & Ignjatović, 2025; Mahmoud et al., 2025; Mousavirad et al., 2023). Metaheuristic algorithms are attractive for their ability to search large spaces without detailed knowledge of the objective function (Yang, 2008). However, their reliance on metaphors adds complexity, while multiple control parameters can limit their flexibility. Recent research therefore emphasizes developing simpler methods based on systematic search principles rather than natural or social analogies (Camacho-Villalón et al., 2023).

In (Rao, 2020), three metaphor-free metaheuristics that require only basic parameters are introduced. These algorithms rely solely on common control parameters, i.e., population size and maximum iteration number, thereby avoiding the complex tuning of algorithm-specific parameters. The Rao algorithms and their enhanced variants have been successfully applied to diverse optimization problems in engineering, image processing, and other related domains. Self-adaptive population Rao algorithms were applied to optimize steel grillage structures in (Grzywiński et al., 2023). In (Refaay et al., 2024), Rao algorithms were employed to enhance the structure of heterogeneous wireless sensor networks, aiming to reduce energy consumption and extend overall network lifetime. An improved intrusion detection system was developed by combining the Rao algorithm with SVM for feature subset selection in (Abd et al., 2024). In (Olmez et al., 2023), the chaotic enhanced Rao (CER) algorithm was proposed and applied to the multilevel color image thresholding problem.

Recently, an improved variant of the Rao algorithm, called the fully informed search algorithm (FISA), has been proposed (Ghasemi et al., 2023). This algorithm was designed to enhance performance on both benchmark and real-world engineering optimization problems. The comparison results show that the FISA algorithm achieves superior optimization performance compared to the original Rao algorithms and other state-of-the-art methods. Similar to the original Rao algorithms, the FISA approach requires no specific control parameters, keeping the method simple and efficient.

Given that no algorithm performs optimally for every type of problem, this study explores the potential of the recently proposed FISA algorithm for solving the multilevel color image thresholding problem. To evaluate its effectiveness, the FISA algorithm is compared against the CER method, both assessed on several color images from the Berkeley dataset using Otsu's objective function as the evaluation criterion. The comparative analysis demonstrates that FISA achieves accurate and stable segmentation results, confirming its potential as a robust and efficient approach for complex image processing applications.

The paper is organized as follows. The next section presents the formulation of the multilevel thresholding problem. The basic Rao algorithms and the CER method are described in Section 3. Section 4 presents the FISA algorithm adopted to solve the multilevel color image thresholding problem. Section 5 describes the experimental setup and presents the obtained results. Finally, the conclusions summarize the key findings of the study.

1. Defining the multilevel thresholding problem

The goal of multilevel thresholding is to determine the optimal set of k thresholds that partition the original image into $k + 1$ distinct regions, denoted as R_0, R_1, …, R_k. Let L represent the total number of gray levels in a grayscale image or in each of the red, green and blue channels of an RGB image (Brajević & Ignjatović, 2025). The gray levels of an image I are in the range [0, L−1]. Multilevel thresholding can be described by the following characteristics:

$$R_0 = \{(x, y) \in I \mid 0 \le f(x, y) \le t_1 - 1\},$$
$$R_1 = \{(x, y) \in I \mid t_1 \le f(x, y) \le t_2 - 1\}, \ldots \quad (1)$$
$$R_k = \{(x, y) \in I \mid t_k \le f(x, y) \le L - 1\}.$$

e, k represents the number of thresholds, $f(x, y)$ denotes the gray level of pixel (x, y) and t_i indicates the i-th threshold value. This formulation can be applied to grayscale images or independently to each color channel in RGB images.

The objective of the multilevel thresholding problem is to determine the optimal threshold vector that maximizes the chosen objective function, typically Otsu's function, which aims to maximize the between-class variance among the segmented regions. Otsu function aims to maximize the following objective function (Kurban et al., 2021):

$$f([t_1, t_2, \ldots, t_k]) = \sigma_0 + \sigma_1 + \sigma_2 \ldots + \sigma_k, \quad (2)$$

where

$$\sigma_0{}^c = w_0{}^c \, (m_0{}^c - m_t{}^c)^2, \; m_0{}^c = \sum_{i=0}^{t_1-1} \frac{iP_i{}^c}{w_0{}^c}$$
$$\sigma_1{}^c = w_1{}^c \, (m_1{}^c - m_t{}^c)^2, \; m_1{}^c = \sum_{i=0}^{t_2-1} \frac{iP_i{}^c}{w_1{}^c}, \ldots$$
$$\sigma_k{}^c = w_k{}^c \, (m_k{}^c - m_t{}^c)^2, \; m_k{}^c = \sum_{i=0}^{L-1} \frac{iP_i{}^c}{w_k{}^c},$$

In Equation (2), $m_t{}^c = \sum_{i=0}^{L-1} iP_i{}^c$ represents the global mean intensity of the original image, Also, in this equation, $P_i{}^c$ represents the probability of occurrence of the i-th gray level in the image histogram, calculated as the ratio between the number of pixels with gray level i and the total number of pixels in the image. For multilevel color image thresholding based on Otsu's method, the parameter $c \in \{1, 2, 3\}$ corresponds to the three color components.

2. Rao algorithms

Rao algorithms represent a simple, metaphor-free class of optimization algorithms that do not require tuning of specific control parameters. The three basic Rao variants were proposed in (Rao, 2020).

During the initialization stage of each Rao algorithm, candidate solutions are randomly created within the specified upper and lower limits for every variable. Following initialization, the set of candidate solutions is progressively improved through successive iterations. Each Rao algorithm applies a distinct search equation to guide the population toward better-quality solutions. The corresponding search strategies update each component of the current solution according to the following equations (Rao, 2020):

$$v_{i,j} = x_{i,j} + \delta_{i,j} \left(x_{best,j} - x_{worst,j}\right), \quad (3)$$

$$v_{i,j} = x_{i,j} + \delta_{i,j} \left(x_{best,j} - x_{worst,j}\right) + \varphi_{i,j} \left(\left|x_{m,j} \; or \; x_{i,j}\right| - \left|x_{i,j} \; or \; x_{m,j}\right|\right), \quad (4)$$

$$v_{i,j} = x_{i,j} + \delta_{i,j} \left(x_{best,j} - \left|x_{worst,j}\right|\right) + \varphi_{i,j} \left(\left|x_{m,j} \; or \; x_{i,j}\right| - (x_{i,j} \; or \; x_{m,j})\right), \quad (5)$$

where $x_{i,j}$ represents the j-th component of the i-th current solution, $v_{i,j}$ denotes the j-th component of the potential solution (i = 1, 2, …, SP; j = 1, 2, …, D), with SP denoting the population size and D the dimensionality of the optimization problem. In these three search strategies, $\delta_{i,j}$ and $\varphi_{i,j}$ denote random numbers uniformly distributed in [0, 1], $x_{best,j}$, $x_{worst,j}$ and $x_{m,j}$ represent the j-th parameters of the best, worst, and randomly selected solutions from the population, respectively. The expression "$x_{m,j} \; or \; x_{i,j}$" takes the value of $x_{m,j}$ if the objective function value of solution x_m is lower than that of agent x_i. If not, the value of $x_{i,j}$ is assigned. Likewise, "$x_{i,j} \; or \; x_{m,j}$" takes the value of $x_{i,j}$ if

the objective function value of solution x_m is lower than that of agent x_i. In the opposite case, it takes the value of $x_{m,j}$.

The iterative process starts with updating the population, where each candidate solution is modified according to Equations (3), (4) or (5) corresponding to Rao-1, Rao-2, and Rao-3, respectively, and its objective function value is then computed. If the new solution yields a better objective function value, it replaces the current one in the population. After every iteration, the best and worst solutions are reidentified and the process continues until the predefined maximum number of iterations (*MNI*) is achieved.

Recently, the chaotic enhanced Rao (CER) algorithm was introduced to effectively solve the multilevel thresholding problem for color images (Olmez et al., 2023). The Chebyshev map was employed owing to its superior convergence characteristics relative to other chaotic maps. The core procedure of the CER algorithm consists of population initialization, identification of the best and worst solutions and iterative updating of all candidate solutions. The position of each solution is refined using the search equation given below:

$$v_{i,j} = x_{i,j} + r_j \left(x_{best,j} - x_{worst,j}\right). \tag{6}$$

Unlike the random coefficients used in the basic Rao-1 algorithm, the parameter z_l in CER method is generated by the Chebyshev chaotic map, which introduces controlled randomness. The parameter is iteratively computed as follows (Olmez et al., 2023):

$$z_{l+1} = \cos\left(l * \cos^{-1}(z_l)\right). \tag{7}$$

In each iteration, all solutions are refined based on Equation (6). The best and worst individuals are updated, and the process repeats until the maximum number of iterations (MNI) is reached.

3. Proposed FISA approach for multilevel thresholding

This section presents the fully informed search algorithm (FISA) adopted to address the multilevel color image thresholding problem. The algorithm aims to determine the optimal threshold values t_i (i = 1, 2, …, k), that satisfy the optimization model defined by Equation (2). In the case of color images, the RGB color model is employed, consisting of red, green and blue components. For each color channel, a separate histogram is generated and the FISA algorithm is applied independently to compute the optimal thresholds and corresponding objective function values.

At the beginning of the optimization process, the FISA initializes a population of *SP* candidate solutions distributed randomly within the search space. Let $T = \{t_1, t_2, \ldots, t_{SP}\}$ denote the population, where each candidate $t_i = [t_1, t_2, \ldots, t_k]$ is a potential set of thresholds for the multilevel thresholding problem. For every j = 1, 2, …, k, component $t_{i,j}$ is a single threshold level constrained within the gray–level range [0,255] and the thresholds are maintained in ascending order.

During each iteration, the population is updated according to the position updating equation proposed in the FISA algorithm (Ghasemi, 2023). Each candidate t_i is modified based on the mean positions of the best and worst subsets of individuals in the current population. The update equation is defined as follows:

$$v_{i,j} = t_{i,j} + \delta_{i,j}\left(MT_{best,j} - t_{i,j}\right) + \varphi_{i,j}\left(t_{i,j} - MT_{worst,j}\right), \tag{8}$$

where $\delta_{i,j}$ and $\varphi_{i,j}$ are random numbers uniformly distributed in the range [0,1], denote the mean positions of the subsets of solutions with better and worse objective function values than the same of i-th solution. The mean positions are calculated as follows:

$$MT_{best,j} = \frac{t_{i,j} + \sum_{i \in B_i} t_{i,j}}{\text{length}(B_i) + 1} \tag{9}$$

$$MT_{worst,j} = \frac{t_{i,j} + \sum_{i \in W_i} t_{i,j}}{\text{length}(W_i) + 1} \tag{10}$$

where B_i and W_i correspond to the subsets of individuals whose objective function values are better or worse than those of the i-th solution, respectively, and length(·) denotes the cardinality of the corresponding subset. After generating a new candidate solution, its boundary constraints are verified. If any component exceeds the permissible search limits, it is adjusted to the nearest valid bound. The iteration step concludes with a comparison between the current and the updated solution, and the one with the better objective function value is retained. In this case, the optimization problem is formulated as a maximization task, where higher objective function values indicate better solutions. The update procedure is repeated for all members of the population in successive iterations, following the defined equation, until the termination criterion is satisfied.

4. Experimental results

This section reports the experimental results achieved using the FISA metaheuristic for solving the multilevel color image thresholding task. The evaluation was performed on four benchmark color images selected from the Berkeley Segmentation Dataset to assess the algorithm's segmentation capability (Martin et al., 2001). Among the test samples are images #147091 (tree), #157055 (couple), #182053 (train) and #148089 (gate).

Table 1. Mean values of Otsu's objective function for red, green and blue channels

		Red		Green		Blue	
Image	**Level**	**CER**	**FISA**	**CER**	**FISA**	**CER**	**FISA**
Tree	6	2721.08	2737.81	4966.72	4983.89	6891.91	6908.26
	8	2747.17	2762.89	5000.79	5013.49	6923.10	6937.59
	10	2762.82	2775.49	5018.24	5030.90	6939.38	6951.87
	12	2771.92	2782.04	5028.69	5039.06	6951.99	6959.76
Couple	6	3239.04	3253.69	3569.38	3573.61	3997.26	4010.55
	8	3265.42	3282.24	3586.23	3603.32	4022.67	4038.47
	10	3281.77	3296.38	3603.39	3617.40	4037.50	4051.08
	12	3292.98	3303.31	3613.70	3625.06	4049.27	4051.08
Train	6	2901.73	2917.11	2783.86	2804.30	3129.26	3144.41
	8	2933.21	2947.11	2815.08	2828.40	3152.94	3163.45
	10	2950.37	2961.98	2829.42	2841.47	3163.27	3173.76
	12	2960.47	2970.29	2840.61	2848.67	3172.48	3179.96
Gate	6	5292.97	5314.05	3430.47	3446.01	2258.38	2272.04
	8	5338.83	5357.22	3459.25	3474.47	2274.39	2290.96
	10	5361.61	5376.86	3476.31	3490.37	2288.47	2299.81
	12	5374.51	5387.23	3486.27	3498.60	2294.65	2304.27

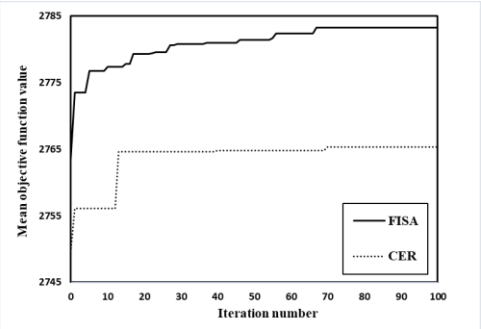


Figure 1. Convergence curves for the FISA and CER on the image Tree (red, k = 12)

Table 2. Average processing times (ms) for the FISA and CER algorithms at threshold level 8.

Image	CER	FISA
Tree	60.0	69.0
Couple	65.0	75.0
Train	70.0	81.0
Gate	58.0	67.0

The performance of the proposed FISA algorithm was compared with that of the CER method under identical experimental settings. Both algorithms employed a population size of 40 individuals and a maximum of 4000 function evaluations. Each method was executed independently 40 times for every test image, color channel and threshold level *k*. The CER and FISA algorithms were implemented in the Java programming language. The experiments were carried out on a personal computer equipped with an Intel(R) Core(TM) i5-4460 processor operating at 3.2 GHz, 16 GB RAM, and the Windows operating system.

To assess the robustness of both CER and FISA algorithms, each method was executed 40 times independently for every test image and for each of the color channels. The experiments were conducted on four representative color images using threshold levels of 6, 8, 10 and 12, allowing for a detailed evaluation of their performance under different segmentation complexities. As shown in Table 1, FISA consistently outperforms CER across all threshold levels (k = 6, 8, 10, 12) and color channels, indicating its superior robustness. Figure 1 illustrates the convergence profiles of the CER and FISA algorithms for the red channel of the Tree image at threshold level k=12. It can be observed that FISA consistently attains higher objective function values and exhibits more stable convergence behavior, indicating improved accuracy compared to CER.

Additionally, the computational efficiency of both algorithms was analyzed. The average computational times obtained from 40 independent runs at the threshold level 8 are provided in Table 2, serving as a representative example of their execution performance. Although the CER algorithm achieved slightly faster computation times, this improvement came at the expense of lower segmentation quality. Overall, the computational times of CER and FISA remained comparable for most applications.

Conclusion

This study applied the fully informed search algorithm (FISA) to the multilevel thresholding of color images and compared its performance with the chaotic enhanced Rao (CER) algorithm. Both FISA and CER were evaluated on several benchmark color images using Otsu's objective function. The experimental results confirmed that FISA achieves higher accuracy and robustness across all tested images and threshold levels, while maintaining comparable computational efficiency. Overall, the findings demonstrate that FISA represents a reliable and effective alternative for complex image segmentation tasks.

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Comparative Analysis of GDP Trends in Bosnia and Herzegovina and Malaysia

Komparativna analiza kretanja BDP-a Bosne i Hercegovine i Malezije

Charles Ramendran SPR[1], Svetlana Dušanić Gačić[2], Mirjana Milovanović[3]

[1]*Universiti Tunku Abdul Rahman, Kampar, Perak, Malaysia, charlesr@utar.edu.my*
[2]*Banja Luka College, Bosnia and Herzegovina, svetlanadg@blc.edu.ba*
[3]*Banja Luka College, Bosnia and Herzegovina, mirjana.milovanovic@blc.edu.ba*

Abstract: *This paper compares GDP dynamics in Bosnia and Herzegovina and Malaysia over 2013–2023, with a linear trend projection to 2030. Methods include descriptive statistics, growth/volatility measures, Welch t-tests and correlations. Findings indicate higher and more stable growth in Malaysia and a faster post 2020 recovery. Projections suggest continued divergence, policy should improve spending efficiency and enhance productive investment in Bosnia and Herzegovina.*
Keywords: *GDP, real growth, government spending, comparative analysis, projection.*

Apstrakt: *Ovaj rad komparativno analizira kretanje BDP-a BiH i Malezije 2013–2023, uz projekciju do 2030. (linearni trend). Koristeći deskriptivnu statistiku, mjere rasta i volatilnosti, Welch t-test i korelacije. Rezultati ukazuju na više i stabilnije stope rasta u Maleziji i brži postkrizni oporavak. Projekcije sugerišu nastavak divergentnih putanja. Rezultati upućuju na važnost efikasnije javne potrošnje i podsticanja produktivnih investicija u BiH.*
Ključne riječi*: GDP, realni rast, državna potrošnja, komparativna analiza, projekcija.*

Introduction

Gross Domestic Product (abbreviated as GDP) is one of those macroeconomic indicators, and also a country's basic economic activity and development stage. Its purpose is to measure all final goods plus services produced within the economy for a certain time period by using market values (Mankiw, 2021). Considerations of the influence and necessity cross over into other areas as well: labor force employment rates, investment size within the economy, consumption levels at which people live on are all key factors for economic evaluation or formulation. They form a foundation that is vital for making policy decisions and assessing their suitability (Jones, 2016). Comparative analyses of GDP among nations allow people to better understand the inherent differences first forms of modern capitalist development and frameworks for each nation's choice to be set up, and it also helps them identify factors that promote long term growth. Within this context, the comparison of Bosnia and Herzegovina (BiH) and Malaysia is a particularly instructive case from which we can learn. Bosnia and Herzegovina, as a transitional economy in the Western Balkans, faces challenges in low economic growth, structural constraints, high unemployment and political fragmentation. Malaysia is an example of Southeast Asian country that decentralized its economy through strategic policies, pulled in investment and has maintained steady high rate of growth (OECD, 2020). This is the outset of an investigation of trends in GDP for Bosnia and Herzegovina and Malaysia from 2013 to present. We look forward with great expectations at year 2030 because such a forecast will give us the chance overall picture basic patterns real fluctuations sustained growth trends characteristic for these two countries. We have contributed to this paper with data from such international organizations as the World Bank, International Monetary Fund, and Worldometers. Descriptive statistics were used mainly in the article, but linear trend analysis and cross sectional

statistics are employed too. Our study is of special importance as it not only identifies structural factors that condition economic performance but also suggests improvements for fiscal policy, development in BiH on the basis of the experiences Malaysia has offered as an example.

1. Research methodology

This research's methodological framework combines quantitative statistical methods and trend models with descriptive analysis, aiming to provide a comprehensive empirical comparison of economic performance between Bosnia and Herzegovina and Malaysia in the years from 2013 to 2023. The Information based Model is based on secondary data from the World Bank (World Development Indicators), the International Monetary Fund (World Economic Outlook Database) and Worldometers. All data is expressed in constant prices and denominated inbillions of US dollars, which allows for direct comparisons of across time series and eliminates the effect on inflation. The first phase of the research involved descriptive statistic analysis, which quantified basic indicators of GDP movements. This includes the level of real GDP, annual real growth rates and the average growth rate for the observed period Gujhyears (Gujarati and Porter, 2009). This analysis enabled the identification of basic patterns and volatility, as well perception about trends in long term horizon. In addition, we calculated standard deviations of annual growth rates representing a measure for the degree of stability and volatility in economic growth in both countries. The second phase of the research involved fitting linear trend models using the method of least squares (OLS) in order to quantify long term trends. and This is to ascertain average annual growth rates of GDP. The equation is as follows:

$$BDPt=\alpha+\beta\times t+\epsilon tBDP\_t = \alpha + \beta \times t + \epsilon_tBDPt=\alpha+\beta\times t+\epsilon t \quad (1)$$

where β\betaβ represents the average annual increase in GDP, while α\alphaα denotes the cross section. The high value of the coefficient of determination R2R^2R2 indicates a good fit of the model to the data, and the significance of the model was confirmed by the F-test at standard significance levels (Wooldridge, 2020). On the basis of the estimated models, the GDP projection until 2030 was made, where it was assumed that the existing trends from the period 2013-2023 would be maintained.

The third phase of the methodology involved segmented analysis of the time series, with the main entries being divided into two temporal phases: 2013-2019 (the pre COVID19 period) and 2020-2023 (time after COVID-19 crisis). In this way, it was analyzed of the changes in growth dynamics and possible macroeconomic structural breaks were found. The slope coefficients from both periods were compared and a Chow test was used to verify whether these changes were statistically significant at 99% confidence level (t = 2-20). In the last phase we made a statistical crossover from series to another in order to measure differences in growth dynamics between Bosnia and Herzegovina or Malaysia. The Pearson correlating coefficient was calculated between annual growth rates for both economies which reflected how much their movements had been together. The Welch t-test for independent samples of means was also used to check (i.e., to look into whether or not) there is any difference between these two countries, whether one has made more progress than another. (Stock & Watson, 2020).

In this approach, we could not only identify and analyze the long term trends and volatility of both but also what kinds of structural reform measures should each economy then envision along those lines. Not just dry statistics anymore is this report, in one fell swoop, both general topographic maps and zoom in details of economic growth are provided. Though, after all-the economy is the only thing that will truly explain all these phenomenon.

2. Previous research and theoretical framework

The gross domestic product measures a nation's economic performance and progress as the most important index of national economic activity. The boundaries of a country determine what products or services fall into its measurement as well as those excluded from it, everything within those delineations is included. GDP, an index of the entire economic producing capacity, describes in

quantitative terms the size and structure of a country 's economy from which can be inferred the qualities and characteristics. It forms the backdrop against which macroeconomic policies are developed and makes comparisons among countries possible (Mankiw, 2021). According to international standards, GDP is most commonly measured by three approaches, production, income and expenditure, which use different angles to look at the economic structure of activities (OECD, 2020) One of the purposes of GDP goes far beyond its role as a measure for the national income. It is also an important yardstick for many macroeconomic processes, including employment, investment, productivity, and standard of living (Jones 2016). Past studies have established links between strong GDP growth rates and high employment rates, living standards, fiscal stability (Barro, 2015). High and stable GDP growth rates are associated with higher inflows of foreign direct investments, faster technological modernization and an increase in the total factor productivity of nations which in turn, contributes to greater competitiveness (Solow, 1956, Romer, 1990). Comparative studies of GDP between different countries in contemporary economics literature occupy a significant place. Comparative observation of countries with different economic structures, institutional backgrounds, and developmental models can help pick out the elements that worked as levers causing rapid growth lasting several years (Acemoglu & Robinson, 2012). Such studies help bring into focus the function of public policy, human capital investment, institutional efficiency and technological innovation in driving economic growth. In this sense, comparisons of the economic strategies, efficiency levels for human resources investment and policy effects will be useful for grasping how these disparities work as constraints. The economies of Malaysia „Southeast Asia's dynamic and vibrant group“ have experienced considerable progress through economic diversification, technological development and investment targeting profitable sectors. That's why Malaysia has sustained rapid growth over several years while productivity has improved each year, per capita income climbing steadily higher (World Bank, 2023). In contrast, Bosnia and Herzegovina, as a transitional economy, faces serious problems from many aspects including weak institutions and low fiscal capacity and productivity. All of these limit its hopes for a future. (IMF, 2024) Comparative study of these two countries was intended to paint a broad picture of the factors involved in development and offer some empirical underpinning which could guide policy decisions that will support sustained growth in BiH. This is a starting point for such research. It looks at how GDP growth, structural reform to the domestic economy, investment dynamics and productivity gains made through them as well as how public policies can further speed up economic progress. In this manner we will be able to carry out an examination of the GDP differences between Bosnia and Malaysia and thereby grasp limitations to development and possibilities forshortening paths in the fractions of production.

3. Results and analysis

Analysis of GDP trends would help to illuminate the economic development dynamics and different forms these economies took on over those ten years marked by structural changes and world disorder.Obtained from official databases, the figures used in this article came from World Development Indicators of the World Bank, World Economic Outlook of IMF and Worldometers site are given in equivalent prices to facilitate realistic comparisons. Although the basic ways of defining these numbers is quite clear, nevertheless each knows its own real value given developments on those sites within each country will shape everything up to what order it takes.In the period from 2013 to 2023, as can be seen from Table 1, Bosnia and Herzegovina's real GDP growth democratically maintains the same level of 4% per annum. On the other hand, Malaysia follows a different path. In absolute terms, Malaysia achieves a significantly higher GDP than BiH, reflecting the size and stage of development of its economy. In the 2013 real GDP of Malaysia was USD 270.5 billion, while that for BiH 15.5 billion 2013. Through 2023, Malaysian GDP balloons to US$ 4015.5 billion, but not yet only 20.7 billion dollars for BiH. This expansion reflects the gradual strengthening of economic activity in both countries, but also entails significant differences between them structural compared to this strength.

Table 1. Real GDP (billions of USD), 2013–2023

Godina	BiH BDP (mlrd USD)	Malezija BDP (mlrd USD)
2013	15.55	270.51
2014	15.73	286.76
2015	16.40	301.36
2016	16.94	314.77
2017	17.49	333.06
2018	18.15	349.19
2019	18.68	364.60
2020	18.12	344.71
2021	19.45	356.14
2022	20.28	387.70
2023	20.73	401.48

Chart 1 gives a graphic representation that is apropos and lucid. It fully illustrates how the curve in both Mandela and Sarawak are on a high speed rise. In Malaya, GDP took a short declining trend in 2020 and then another turn for the better. As a direct result of the global COVID-19 pandemic land, production had no other choice but to follow suit on its downward slope into oblivion wherever it went. And peoples of Bosnia and Herzegovina everywhere saw their livelihoods and life conditions crushed under this relentless weight of economic hardship misery.

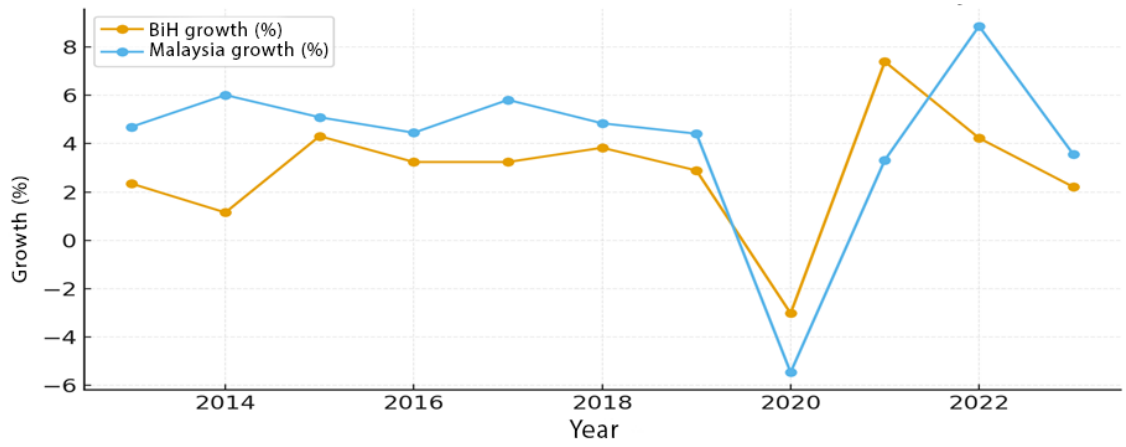


Chart 1. Real GDP of BiH and Malaysia

Table 2 reveals the annual real GDP growth rate. Taking the single maximum or minimum value from all annual real GDP growth rates on record can give a perspective on which one is likely to be lower if nothing else. In the observed period, BiH's average annual growth rate is 2.78%, more than 0.5% lower than Malaysia's equivalent value. From these numbers, we can see that there is indeed a pronounced difference in growth dynamic. Malaysia's growth rate is more than double that of BiH's. This comes as a result from truly suffering under a shabby old economy history. The pressure had finally built up to such a level that everybody realised if you did not act now, in only eight years time one could be unemployed but able bodied and have nothing else on hand for work except resorting back to traditional farming methods which are rapidly disappearing with the introduction of standardised modern techniques for agriculture.

Table 2. Real GDP growth (%), 2013–2023

Year	BiH (%)	Malaysia (%)
2013	2.35	4.69
2014	1.15	6.01
2015	4.31	5.09
2016	3.24	4.45
2017	3.24	5.81
2018	3.83	4.84
2019	2.89	4.41
2020	-3.02	-5.46
2021	7.39	3.32
2022	4.23	8.86
2023	2.21	3.56

Chart 2 shows the volatility of growth in both countries. While Malaysia records slightly more stable growth rates with pronounced recovery after the pandemic decline, BiH shows greater sensitivity to external shocks and slower recovery, which indicates limited fiscal capacities and weaker amortization mechanisms.

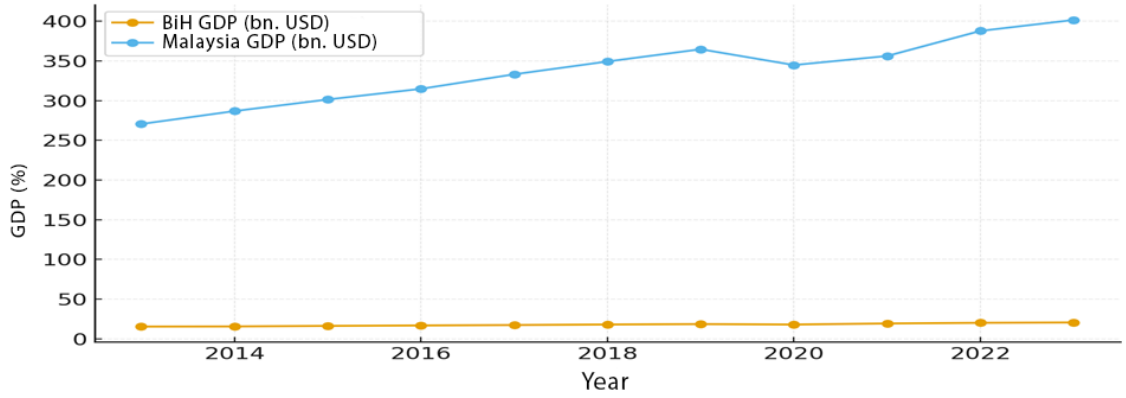


Chart 2. Real GDP growth (2013–2023), BiH and Malaysia

4. Projection of GDP until 2030

Based on the estimated linear trend models, the projection of real GDP until 2030 was made. The results show that Malaysia, while maintaining current trends, could reach around 480 billion USD by 2030, while Bosnia and Herzegovina could reach approximately 24 billion USD. These projections imply the continuation of the current dynamics and do not include potential shocks or structural reforms that could change the growth trajectory.

Table 3. Projection of real GDP (billions of USD), 2024–2030

Country / Year	2024	2025	2026	2027	2028	2029	2030
Bosnia and Herzegovina	21.05	21.57	22.09	22.60	23.12	23.64	24.15
Malaysia	408.99	420.94	432.89	444.84	456.79	468.73	480.68

In order to expand the comparative analysis of the gross domestic product (GDP) trends of Bosnia and Herzegovina and Malaysia, alternative growth scenarios for the period up to 2030 have been considered.

The three scenarios presented below — baseline, reform (optimized), and pessimistic — provide insight into different development possibilities based on assumptions related to economic policies, institutional changes, and external factors.

The baseline scenario represents the continuation of existing trends observed during the 2013–2023 period and has already been presented in previous chapters. It relies on linear estimation models and does not assume significant changes in the institutional or economic framework.

For Bosnia and Herzegovina, the projection indicates the achievement of a real GDP of approximately **USD 24 billion by 2030**. For Malaysia, the model predicts continued stable growth, reaching about **USD 481 billion** in the same period.

This scenario assumes the strong implementation of structural reforms in Bosnia and Herzegovina starting in 2024. The reforms include the digitalization of public administration, fiscal consolidation, improvement of the business environment, investments in infrastructure and education, and increased judicial efficiency aimed at attracting foreign direct investments.

Under this scenario, the average annual growth rate in Bosnia and Herzegovina would rise to **4.5%,** allowing GDP to reach between **USD 27 and 29 billion by 2030.** For Malaysia, continued technological modernization and diversification are expected, with an average growth rate between **4.5% and 5%,** leading to a GDP of **USD 500–520 billion.**

In this scenario, Bosnia and Herzegovina faces ongoing political instability, institutional inertia, labor migration, and weak investment activity. Such conditions would result in an average annual growth rate of only **1.5–2%.**

Consequently, Bosnia and Herzegovina's GDP would range between **USD 21.5 and 22.5 billion by 2030**, reflecting near stagnation. Malaysia, although potentially affected by global disruptions, would maintain a more stable growth rate of around **3.5% per year**, reaching approximately **USD 460 billion** by 2030.

5. Statistical analysis and data crossing

During the final stage of the study, inferential analyses were conducted to measure differences between these two countries. The Pearson correlation coefficient between annual growth rates is 0.42, which means there's a moderate positive correlation. Both respond to global economic fluctuations. The Welch t-test shows that differences between standard growth rates are statistically significant at established levels ($t = -3.012$, $p = 0.013$). The average growth rate of Malaysia is therefore significantly higher than in Bosnia and Herzegovina. The results mean that differences in institutional capacities, fiscal policy and investment philosophy affect economic growth. Stronger of Malaysia's base is built on a more stable industrial structure than in Bosnia and Herzegovina. More investment goes into research and development, and Malaysia actively promotes exports, while the poorer base of Bosnia and Herzegovina continues to hampper its developing production capacities.

In sum, based on the conclusions above we can say that the differences between the two countries are very clear: Malaysia is a paradise of growth, inspite it has higher national product, which is more stable. While BiH, its change curve is flatter and not as big as those of other countries nearby but still pushing on for the future. It's now clear that for BiH to get more sustained growth, stronger institutional support, greater public spending efficiency and more money into producing sectors that bring added values have to become a reality. The difference (as measured by volatility and Pearson's correlation between series of growth rates) in average annual real growth rates was tested over the period 2013-2023 using Welch's t-test.

Table 4. Welch t-test, 2013–2023

Measure	Value
Average growth of BiH (%)	2.89
Standard deviation of BiH growth (%)	2.53
Malaysia Average Growth (%)	4.14
Malaysia Standard Deviation of Growth (%)	3.52
Difference between environments (BiH - Malaysia)	-1.25
t-statistics (Welch test)	-0.958
degrees of freedom (df)	18.2
p-value (two-sided)	0.338
Growth correlation (BiH vs. Malaysia)	0.663

During the period under consideration, statistical indicators show that Malaysia has a higher average growth rate (4.14%) than Bosnia and Herzegovina (2.89%) with larger volatility (3.52 percent standard deviation versus 2.53 Thus the difference in means is -1.25 percentage points, but according to the Welch's t-test results ($t = -0.958$; $p = 0.338$) it is not statistically significant at conventional significance levels ($p < 0.05$). The positive correlation of annual growth rate between the two countries ($r = 0.663$) suggests weak covariance (that is to say, macroeconomic factors that have unknown but characteristic periods and some correlation). This could mean a number of things in practice, global economic cycles could be moving factories, or cyclical changes, the COVID-19 pandemic affect both economies in similar directions or huge geopolitical shocks. In contrast, differences in institutional capability, economic structure and fiscal policy account for the differences of intensity in these two economies. Average growth rate in Malaysia is higher than in BiH. The t-statistic and p-value make the difference statistically significant at standard thresholds, keeping in mind that final batch revisions can affect conclusions. Series five is between two positively correlated lists as expected from correlations of raw data which have been statistically tested and selected for this purpose.

6. Discussion

By analyzing the results, one gets a comprehensive understanding of the flavor of GDP dynamics in both 2013 to mid 2023 periods for both Bosnia and Herzegovina, Malaysia and furthermore it can be seen by contrast where their key differences in development lie over a decade or more. This approach is especially valuable when one can examine the same macroeconomic variables in different institutional, structural, and political environments. If this is carried out, it allows us to have a better understanding of how national economic performance emerges and what its major determinants are.

BiH privacy law gives legal protection to all forms of biodiversity, environmental resources= individuals and groups who live dependently on these ecosystems are all included. While BiH's real GDP grew from $15.5 billion USD in 2013 to $24.5 billion USD in 2023, a rise of 58.1%, the corresponding figures for Malaysia were 441.9 to 858.3 billion USD with growth of 66.2%. This difference not only reflects different market scales or level of economic development, but also shows distinct patterns in the economic structure, institutional capacity and methods for developing economies. This trend is represented in Chart 1. While Malaysia has always grown steadily with only a temporary slowdown for pandemic control in 2020, the growth rate of BiH has been slower and more erratic, this alerts us to points of weakness when we are faced with economic shocks as well as short restraints on our fiscal policies. This conclusion is further supported by annual growth rates. In the period studied, Malaysia achieved an average growth rate of 4.18%, while BiH recorded 2.78%. Both countries recorded negative growth in 2020, due to the COVID-19 pandemic. But Malaysia recovered more strongly and quickly, even showing some signs of overtaking its previous trend line from before the shock. On the other hand, Bosnia and Herzegovina demonstrated a promoted tiredness as external factors' influence receded,

making it slow to breasth enough for the next stage of its development. Proof of this is given by Chart 2, which indicates these fluctuations quite clearly and points out the greater stability in Malaysian growth while also suggesting its dynamism.

Projected until 2030, using a linear trend model, this again demonstrates the continuation of each country's existing course. Malaysia, if it continues as today, could reach about 454 billion USD by 2030, BiH around 22.6 billion USD. These figures indicate the existance of a structural gap that is likely only to deepen unless there are major changes in the institutional framework and economic policy of BiH. The conclusions usually cited statistical analysis. The Pearson correlation coefficient between annual growth rates is 0.42, indicating a moderate positive relationship and that there must be a common global impact on both economies. Global demand changes affecting them both, geopolitical turmoil threatening either however would both be consequences of conditions elsewhere in the world. Notwithstanding this difference, Welch t-tests were also significant ($p < 0.05$). This means that Malaysia has a systematically higher rate of growth. Taken together with the The results of some primary sector economies getting rich show that sometimes our old fire policy is worse than their new one. Malaysia managed, through a combination of a clear motif and long term input, to convert the entire factor productivity of the entire country into this one item. Bosnia and Herzegovina is nothing like it. Tend not only to major discrepancies in GDP levels but also differences in the type of growth they can expect and which one has stronger resistance against foreign lures. Quality of institutions along with of fiscal policy also plays a major role in the long term GDP dynamics as earlier studies confirm (Acemoglu and Robinson, 2012, Barro, 2015). Through consistent economic policy and strategic investment, Malaysia increased productivity levels while BiH has been curtailed by political disunity and low effective cooperativeness between entities of government and on different fiscal strata at the same time. These differences also mean, changing not only GDP levels but also leading to different looks and vulnerability to outside shocks of the two economies. All charts and tables contained in this paper serve to illustrate the above results. Although Table 1 and Chart 1 give one the impression that there is some significant disparity in size of GDP and depth to growth trend between them there can be no doubt, while Table 2 and Chart 2 zoom in on growth trend and volatility, disclosing underlying structural contrasts. Looking ahead to future transitions, we can see that unless structural changes are made, the gap between BiH and Malaysia will continue to grow larger in the coming decade. It is demonstrated by this paper how necessary the comparative analysis of these sorts of policies really is. Based on Malaysia's experience, key factors in longterm growth include investment in innovation and diversification of the economy, also, export oriented sectors and institutional stability are worth noting. For BiH, the conclusions drawn from this study can be used as an empirical basis in order to determine what policy it should pursue if it wishes both greater stability at macro level and greater resilience to shocks plus more sustainable growth.

Conclusion

Analysis of **e**conomic **t**rends in Bosnia and Herzegovina and Malaysia showed that while both countries are recording growth in economic activity, the differences between the scope, dynamics and structure of this growth are still deep set and systematic. Over the period covered, Malaysia enjoyed sustained continuous growth year on year, averaging more than 4 % growth for most of those years**.** BiH on the other hand grew only more slowly and with less stability in general, its average annual growth rate being below 3%. These findings clearly explained the different economic situations that the two countries are in**. N**amely**,** while Malaysia the success story of moving from an agricultural society to something more consciously industrial and high tech**,** Bosnia **and** Herzegovina still faces transitional limits, its institutions are weak and poorly structured. Low investigated the economic situation of two countries has several meanings. For example, on one hand it facilitates investigating what are the types of determinants in growth rates and how different forms they take same. Being able to draw such comparisons must then tell us something about economic soundness and give some clues for how to go about getting these things sorted out in Bosnia Herzegovina. Looking at what Malaysia has done shows

that you need more than just short term actions aimed at boosting growth rates if we want to reach a stable and expanding level of prosperity. In order for BiH to do it the same way, similar principles should rise along with all round institutional reform including particularly fiscal discipline. Projections up to 2030 serve to confirm that if these two countries' existing paths of development remain unchanged, then the difference between them will become even greater. In that sense, Malaysia could be looking at well over USD 450 billion in real GDP and BiH is still left some 23 billion under this mark. Given the above, this result could be taken not just as a statistical finding. Instead, it should serve to inspire development policies that have a point to make. Policies like these would encourage investment production sectors, and in general bolster the productivity of all factors. Ultimately this analysis is important because it helps us understand the way in which economic policies, institutional elements and developmental strategies come together to determine a country's macroeconomic performance. A comparison of BiH and Malaysia shows that economic growth is not solely the product of initial conditions but is also an outcome determined by conscious political decisions, priorities in reform and the ability to cope with global challenges. To this end, the economic view presented in this study is that sustainable and inclusive growth requires a planned approach to development, one which combines macroeconomic stability with efficient institutions and investment in knowledge. It is only by such methods that BiH can bridge its developmental lag and attain a more stable dynamic economic growth.

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Trade as an Instrument of Economic Integration between the European Union and the Western Balkans

Trgovina kao instrument ekonomskog povezivanja Evropske unije i Zapadnog Balkana

Gordana Petrović[1], Adriana Radosavac[2], Darjan Karabašević[3]

[1]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, milicakg98@yahoo.com*
[2]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, adriana.radosavac@mef.edu.rs*
[3]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, darjan.karabasevic@mef.edu.rs*

Abstract: *The paper analyzes the trade relations between the European Union and the Western Balkan countries in the period from 2011 to 2021, based on Eurostat statistical data. The research focuses on assessing the volume, structure, and dynamics of foreign trade, as well as identifying the main trends shaping the region's economic cooperation with the European Union. Special emphasis is placed on Serbia's position as the EU's most significant trading partner in the region, accounting for nearly half of the total exports and imports between the Union and the Western Balkans. The analysis indicates a continuous growth in trade volume, with a dominance of finished industrial products in the trade structure, confirming a high degree of the region's economic integration into the European market. Although the trade balance still favors the EU, the positive trends in exports and imports from the Western Balkan countries reflect the gradual development of production capacities and the convergence of economic structures toward European standards. The research shows that trade plays a key role in the process of economic convergence and represents an important instrument of the region's European integration.*
Keywords: *European Union, Western Balkans, trade, Serbia, export, import, economic integration.*

Apstrakt: *Rad analizira trgovinske odnose između Evropske unije i zemalja Zapadnog Balkana u periodu od 2011. do 2021. godine, na osnovu statističkih podataka Eurostata. Istraživanje je usmereno na procenu obima, strukture i dinamike spoljnotrgovinske razmene, kao i na identifikaciju osnovnih trendova koji oblikuju ekonomsku saradnju regiona sa Evropskom unijom. Poseban akcenat stavljen je na položaj Srbije kao najznačajnijeg trgovinskog partnera EU u regionu, koja ostvaruje gotovo polovinu ukupnog izvoza i uvoza između Unije i Zapadnog Balkana. Analiza ukazuje na kontinuirani rast trgovinskog obima, sa dominacijom gotovih industrijskih proizvoda u strukturi razmene, što potvrđuje visok stepen ekonomske integrisanosti regiona u evropsko tržište. Iako je trgovinski bilans i dalje u korist EU, pozitivni trendovi u izvozu i uvozu iz zemalja Zapadnog Balkana svedoče o postepenom razvoju proizvodnih kapaciteta i približavanju ekonomskih struktura evropskim standardima. Istraživanje pokazuje da trgovina ima ključnu ulogu u procesu ekonomske konvergencije i predstavlja značajan instrument evropskih integracija regiona.*
Ključne reči: *Evropska unija, Zapadni Balkan, trgovina, Srbija, izvoz, uvoz, ekonomska integracija.*

Introduction

The European Union today represents the world's largest trading power and the most developed integrated economic market, encompassing a large number of countries connected through common rules, policies, and institutions. Its economic policy is directed toward sustainable economic growth

through investments in key sectors such as transport, energy, science, and research, while encouraging innovation and technological development (Petrović et al., 2020).

Trade occupies a central place in the economic relations between states, and within the European Union it represents the foundation of both internal and external economic policy. Through the development of a common trade policy, the Union exerts a significant influence on global market trends and partnership relations with third countries. In this context, the Western Balkan countries hold a specific position — they are at the same time candidates or potential candidates for membership and prominent trading partners of the EU, with a growing share in the exchange of industrial and agricultural products.

Therefore, it is essential to develop and support mechanisms that will stimulate entrepreneurial spirit, as it plays a key role in increasing employment and achieving business success, which results in economic growth and sustainable development of national economies as a whole (Radosavac et al., 2024).

The attitude of the Western Balkan countries toward the European Union (EU) and the reforms that need to be implemented in order to achieve membership indicate the necessity of establishing a balance in the relationship of asymmetric interdependence between these two entities (Stanković, 2014).

The Western Balkans comprise six countries — Albania, Bosnia and Herzegovina, Montenegro, Kosovo*, North Macedonia, and Serbia — which are connected by a shared historical heritage, geographical position, and a common aspiration toward European integration. The European Union, as the most developed model of supranational integration in the world, brings together 27 member states and is based on the free movement of goods, capital, services, and people, making it the largest single market of the modern era.

The subject of this paper is the analysis of trade relations between the European Union and the Western Balkan countries. Special attention is devoted to the volume, structure, and trends of trade exchange, as well as to identifying opportunities and challenges for its further development. The aim of the research is to examine the importance of trade as an instrument of economic cooperation and a process of the region's European integration.

(*Note: The designation of Kosovo is in accordance with United Nations Security Council Resolution 1244 and without prejudice to status.)

1. Methodology

The methodological framework of this paper is based on the application of quantitative and qualitative research methods, with the aim of providing a comprehensive overview of trade relations between the European Union and the Western Balkan countries. In addition to quantitative analysis, the paper employs the method of comparison, which enables the examination of trade indicators between individual Western Balkan countries, as well as between the region as a whole and the European Union. Through these comparisons, the study seeks to identify the main trends, structural differences, and potential for further development of trade cooperation.
The qualitative aspect of the research includes the analysis of relevant academic and professional literature, reports of the European Commission, and other institutional documents related to economic relations and integration processes in the region. By synthesizing theoretical and empirical findings, the paper aims to draw conclusions on the impact of trade on economic convergence and the process of European integration of the Western Balkan countries.

2. The volume of exports and imports between the EU and the Western Balkans

One of the key factors to which the European Union pays attention when admitting new member states is the degree of trade integration of potential members with the Union. In this respect, the Western Balkan countries are in a relatively favorable position (Lutovac & Petković, 2023). The European Union

is one of the leading actors in global trade, with an exceptionally developed network of export and import flows. Its trade activity is based on a wide range of products, from industrial and agricultural goods to high-tech items, indicating a high degree of economic diversity and competitiveness.

The EU has a broad open trade regime, creating conditions for the development of partnerships with a large number of countries worldwide. Its integration into global markets, combined with modern advancements in transport and communication, provides an additional incentive for producers to exchange goods and services across the globe. International trade between the EU and the rest of the world is a key driver of economic growth and job creation (Petrović et. al., 2021). One of the main economic arguments for promoting international trade, in the broader context of economic globalization, has always been the gains from trade arising from specialization and economies of scale (Milutinović & Stanišić, 2022).

The EU's import structure, on the other hand, is focused on securing essential raw materials, energy resources, and finished products from various parts of the world. This trade orientation confirms the European Union's integration into the global economy and its dependence on international market developments. At the same time, the EU's trade policy is aimed at maintaining stable economic relations and promoting sustainable development through international cooperation and the free exchange of goods.

Cooperation between the EU and the Western Balkans aims at effective political and economic governance, the highest standards of the rule of law, the promotion of media freedom, and a vibrant civil society. Reforms are key for the European path, but even more importantly, they are essential for improving the way countries deliver services to their citizens and directly benefit them (https://www.eeas.europa.eu/eeas/western-balkans_en).

Based on relevant statistical data, an analysis was conducted of imports, exports, and the trade balance between the European Union and the Western Balkan countries for the period from 2011 to 2021. The aim of the analysis was to identify the main trends, dynamics, and structure of foreign trade, as well as to determine changes in the intensity of economic cooperation over the observed ten-year period.

Table 1. Volume of exports and imports between the EU and the Western Balkans (billion euros)

Years	**2011.**	**2012.**	**2013.**	**2014.**	**2015.**	**2016.**	**2017.**	**2018.**	**2019.**	**2020.**	**2021.**
Inport	11.5	11.5	13.5	14.9	15.9	17.4	19.9	22.3	23.0	21.3	28.2
Export	20.3	21.3	21.4	22.5	23.5	24.9	28.1	30.6	31.9	29.2	36.9
Balance	8.7	9.8	7.8	7.6	7.6	7.5	8.2	8.3	8.9	7.9	8.7

Source: https://ec.europa.eu/eurostat/statistics (20.8. 2025.)

Trade relations between the European Union (EU) and the Western Balkan countries in the period from 2011 to 2021 show a continuous increase in the total volume of exchange.

Imports from the Western Balkan countries to the EU rose from €11.5 billion in 2011 to €28.2 billion in 2021, representing more than a twofold increase over the analyzed period. A similar trend was observed in EU exports to the region, which increased from €20.3 billion in 2011 to €36.9 billion in 2021.

Although the growth in exports was somewhat more pronounced in absolute terms, the EU's positive trade balance remained relatively stable, ranging between €7.5 and €9 billion. The highest balance was recorded in 2019 (€8.9 billion), while the lowest was in 2014 (€7.6 billion). These figures indicate a lasting competitive advantage of the EU in trade relations with the Western Balkans. as well as the region's increasing integration into the Union's single market.

The increase in trade volume can be partly attributed to the process of gradual economic integration. improvements in the Stabilization and Association Agreements, and rising investment activity. Despite global economic challenges, particularly during 2020. trade demonstrated remarkable resilience, with a rapid recovery in the following year. Overall. the data confirm that the EU remains the most significant

foreign trade partner of the Western Balkan countries, and there is a clear trend toward deepening economic relations in the direction of the region's future integration into the EU market.

Regional cooperation among the Western Balkan countries is one of the formal conditions for advancing their relations with the European Union, and initiatives in this area can accelerate the process of EU accession. Likewise, regional integration processes are important for attracting foreign direct investment (Stojanović Trivanović & Grahovac, 2017).

Furthermore, in the context of the Western Balkans, it is important to emphasize the argument that membership in a regional economic integration is beneficial for less developed economies and their limited markets. This is due to the increase in competition among countries with similar levels of development, the realization of economies of scale, the enhanced attractiveness for foreign direct investment, and the strengthening of the bargaining power of the states participating in regional economic integrations (Milutinović & Ranković, 2023).

Based on the presented data, it can be concluded that trade between the European Union and the Western Balkan countries recorded continuous growth during the observed period. Both exports and imports show a positive trend, indicating the strengthening of economic ties and the integration of the region into the EU's market flows. The trade balance remained in favor of the European Union throughout the entire period, reflecting its competitive advantage and greater production capacity, Nevertheless, the increase in imports from the Western Balkans suggests a gradual expansion of the production capacities of these countries. Overall, the data confirm the region's increasingly strong economic connection with the European Union and its growing role in the Union's total foreign trade exchange.

3. Main trading partners of the Western Balkans

To support the Western Balkan partners on their European path and to foster faster socio-economic convergence with the EU, a new **Growth Plan for the Western Balkans** was presented in November 2023. The plan complements the existing EU assistance and adds to the financial support provided under the **Instrument for Pre-Accession Assistance (IPA III).**

The plan consists of four interlinked pillars and aims to:

- enhance the economic integration of Western Balkan partners into the EU Single Market,
- strengthen regional economic cooperation through the Common Regional Market,
- accelerate EU-related reforms, and
- increase financial assistance through a dedicated Reform and Growth Facility (https://www.consilium.europa.eu/en/policies/eu-western-balkans-relations/).

Trade relations represent an important indicator of economic interconnectedness and regional development in the modern global economy. The Western Balkans, a region undergoing economic consolidation and political transformation, is characterized by increasing trade activity with various international partners. The largest share of foreign trade for these countries belongs to the European Union. whose dominant position is the result of geographical proximity, historical ties, and the process of European integration. In addition, the past decade has seen a noticeable strengthening of economic cooperation with certain global powers, such as China, Russia, and Turkey. Examining the structure and directions of the Western Balkans' trade flows provides valuable insight into its economic position and the prospects for future development within international integration processes.

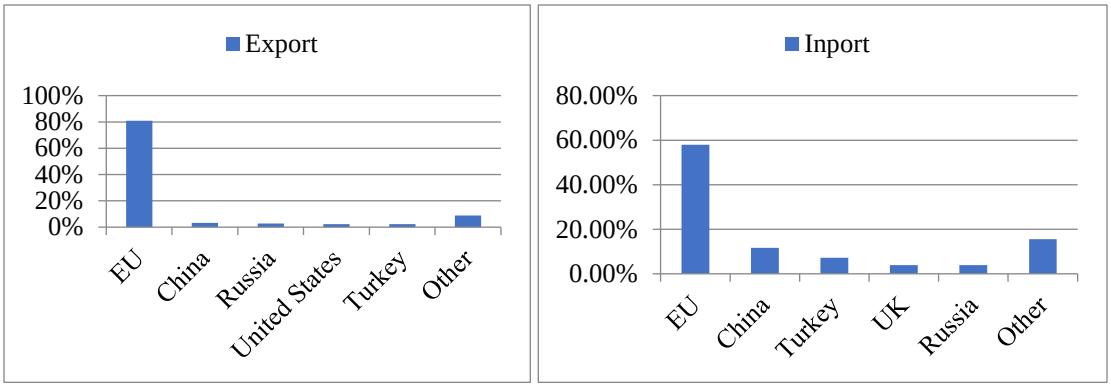


Figure 1. Main trading partners of the Western Balkans
Source: https://ec.europa.eu/eurostat/statistics (28.8.2025.)

The structure of exports and imports of the Western Balkan region by major foreign trade partners clearly shows that the European Union is the dominant economic partner. In total exports, EU countries account for as much as **81%**, indicating a high degree of integration of the Western Balkan economies into the Union's market. Other partners have significantly smaller shares — "other" partners 8.8%, China 3.2%, Russia 2.7%, the United States 2.2%, while Turkey accounts for 2.1%. These figures demonstrate the region's strong orientation toward the European market as the primary destination for its exports.

When it comes to imports, the European Union also holds a leading position, with a share of **57.9%**. However, the import structure is somewhat more diverse compared to exports. After the EU, the most significant import partners are China with 11.6% and Turkey with 7.2%. indicating the growing influence of Asian economies in supplying the region. Russia accounts for 3.9%, while the category "other" partners makes up 15.6% of total imports.

The analysis of these data shows that the foreign trade structure of the Western Balkans is strongly oriented toward the European Union, which is both the main buyer of products from the region and the most important source of imported goods. At the same time, a gradual increase in the influence of China and Turkey is noticeable, suggesting a diversification of trade flows and the region's efforts to expand economic cooperation beyond the European framework. This trade structure confirms the Western Balkans' economic dependence on the EU, while also highlighting its potential to become an important link between the European and Asian markets.

4. EU exports and imports to the Western Balkan countries by product group

The European Union is the largest trader on a global scale. Considering the total volume of internal trade (that is, trade between EU member states), as well as the level of exports to third countries, it follows that the EU's share in world trade is around 40%, while its share in the services sector is even higher (chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.vps.ns.ac.rs/Materijal/mat12327.pdf)

Based on Eurostat statistical data for the period from 2011 to 2021, it is observed that trade between the European Union and the Western Balkan countries exhibits a pronounced dominance of manufactured goods in both export and import structures. According to available data, manufactured goods accounted for **74.6% of the EU's total exports** to the Western Balkan market, while their share in total imports from the region was **76.2%.** These indicators point to a high level of industrial development and technological complexity in the trade exchange between the observed economic areas.

Within the export structure. the largest share is held by **other manufactured goods at 30.8%**, indicating a wide range of final products supplied to the regional market. Next are **machinery and vehicles at**

28.2%, reflecting the significance of the industrial and technological sectors in overall trade activity, while **chemicals at 15.6%** confirm the importance of the chemical industry in foreign trade.

Regarding primary products. the largest export share belongs to **energy at 11.4%,** showing that the energy sector maintains a relatively stable position in trade flows. This is followed by **food and beverages at 10.5%,** indicating a strong agricultural and processing base in the region, while **raw materials account for a modest 2.6%.**

The observed export and import structure shows that trade between the European Union and the Western Balkans has a pronounced industrial character, with a dominance of manufactured goods. This fact indicates a deep economic connection of the region with the European market, where Western Balkan countries mainly participate as suppliers of certain primary goods and less complex final products. In the future, a higher degree of integration and strengthened technological capacities could lead to a more balanced trade structure and a greater share of highly processed products in total trade.

5. The European Union and Serbia – the most important trade partnership in the Western Balkans region

Based on statistical data from Eurostat (https://ec.europa.eu/eurostat/statistics-explained/images/d/db/WBC_2022.) for the period from 2011 to 2021, it can be concluded that Serbia is a key trading partner of the European Union in the Western Balkans, both in terms of exports and imports.

The data shows that Serbia accounts for nearly half of the EU's total exports to the Western Balkan countries. indicating an exceptionally high degree of economic connectivity and interdependence with the European market. During the observed period, Serbia recorded the highest absolute export growth compared to the other five partners in the region. With an average annual growth rate of 7.4%, Serbia achieved a significant increase in export activity, immediately following Kosovo*, which, in relative terms, recorded the highest growth rate of 8.1%. They are followed by North Macedonia (6.5%), Albania (4.9%), Montenegro (4.1%), and Bosnia and Herzegovina (3.8%). These data demonstrate that Serbia experienced dynamic growth in production and trade during the observed period, which is the result of gradual integration into European economic flows. increased foreign investment, and the development of export-oriented industrial sectors.

Regarding imports, Serbia is also the most significant partner of the European Union, with a share of just under half of the total imports from the Western Balkans. From 2011 to 2021, Serbia had the highest average annual import growth rate (10.7%), reflecting strong import demand as a result of growing domestic consumption, industrial production, and technological modernization. Following Serbia are North Macedonia (9.7%), Albania (8.5%), Bosnia and Herzegovina (7.1%), Kosovo (6.1%), and Montenegro (5.4%).

According to the 2021 data, the European Union recorded a trade surplus with five out of the six Western Balkan partners. The largest surplus was recorded in trade with Serbia, amounting to 4.5 billion euros. which confirms the strong export position of the EU in this market. They are followed by Albania (1.6 billion euros), Kosovo (1.3 billion euros), Bosnia and Herzegovina (1.0 billion euros), and Montenegro (0.8 billion euros), while the only deficit occurred with North Macedonia, at –0.6 billion euros. The observed data indicate that, during the ten-year period, Serbia has become the most significant economic partner of the EU in the Western Balkans, with a dominant share in the region's overall trade.

Companies from the EU were the leading investors in Serbia during the previous decade. These companies introduced efficiency, modern technology, and knowledge into the Serbian economy, providing jobs for a large number of people. In turn, this significantly increased the productivity and competitiveness of the Serbian economy, boosting its export potential. raising budget revenues, and

generating economic growth. Ultimately, the opening of the Serbian market to EU companies led to greater choices and lower prices for consumers (https://europa.rs/trgovina/).

The dynamic growth of exports and imports reflects the gradual structural adjustment of the Serbian economy to European standards and the growth of its competitiveness. Although the trade balance still favors the European Union, trends indicate that Serbia is increasingly integrating its production and trade flows into the single European market. In the future, further growth in competitiveness, technological innovations, and the development of export-oriented industries could further enhance Serbia's position as the leading trading partner of the EU in the Western Balkans region.

Conclusion

Based on the conducted analysis and Eurostat statistical data for the period from 2011 to 2021, it can be concluded that trade relations between the European Union and the Western Balkan countries have experienced stable and continuous growth. The European Union continues to be confirmed as the dominant economic partner of the region, with a share of over three-quarters of total trade exchange. This dominance stems from geographical proximity, historical ties. institutional support through Stabilization and Association Agreements, and the region's strategic orientation toward European integration.

A key aspect of the analysis is the position of Serbia, which stands out as the largest trading partner of the European Union in the Western Balkans. Serbia accounts for nearly half of the total exports and imports of the region with the EU, with the highest growth rates in trade flows. These results indicate the gradual structural adjustment of the Serbian economy to European market requirements, increasing competitiveness. and intense integration into the EU's production and logistics chains.

The structure of trade exchange shows a pronounced dominance of finished products, confirming the industrial nature of the cooperation and the growing degree of technological interdependence. At the same time, the growth of imports from Western Balkan countries indicates the development of local production capacities and the gradual reduction of structural imbalances. Nevertheless, the trade balance still remains in favor of the European Union, reflecting its economic strength, technological superiority, and position as the leading investor in the region.

Overall, the research results confirm that trade is one of the key mechanisms of economic convergence and the integration of the Western Balkans into the European Union. Further development of trade cooperation should focus on increasing competitiveness, diversifying export products. and improving technological capacities. These processes are prerequisites for sustainable economic growth and the successful integration of the region into the single European market.

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The Importance of Developing the Innovative Sector in Function of Profitability: The Case of the Company Alumina

Značaj razvoja inovativnog sektora u funkciji profitabilnosti: Slučaj kompanije "Alumina"

Marko Milić[1], Darko Pašalić[2], Slađana Vujičić[3]

[1]*College of Service Business, Sokolac, Bosnia and Herzegovina, milicmarko.milic@gmail.com*
[2]*European University, Faculty of Economics, Brcko, Bosnia and Herzegovina, darkopasal@gmail.com*
[3]*College of Business Economic and Entrepreneurship, Belgrade, Serbia, sladjanakonto@gmail.com*

Abstract: *The company Alumina from Zvornik is a respectable and well-positioned business entity in the field of alumina and aluminosilicate chemical production. This reputation is well established within the Western Balkans and increasingly recognized in the European and global markets. The company's essential commitment is directed toward the application of continuous innovations, which aligns with its vision to significantly improve its competitive position in the future. The development of the innovative sector is one of the strategic orientations of Alumina. The emphasis is placed on the continuous development of new products aimed at contributing to the company's profitability. The policy of developing improved and completely new products within Alumina is an integral part of its overall business and development strategy. Its task is to, based on a defined concept of development goals and objectives for a specific period, research, organize, coordinate, implement, and control activities necessary to ensure the successful realization of programs for market-aligned and economically rational product design. The continuous creation of new products and modifications to the characteristics and purpose of existing ones represents the best growth strategy for a company operating in a developed market economy. The key components of its business depend on the degree of alignment between the company's offerings and its development policy. This alignment allows the company to shape its market offer and position in a way that simultaneously meets social needs as well as the company's operational and developmental goals. From this, it follows that product development policy—within the framework of the overall development strategy—cannot be successfully implemented without a clearly defined system, concept, and methodology.*
Keywords: *Development, innovation, Alumina, profitability.*

Apstrakt: *Kompanija ,,Alumina" iz Zvornika je respektabilan i dobro pozicioniran privredni subjekt u oblasti proizvodnje glinice i alumosilikatne hemije. Navedena respektabilnost je dobro izražena u okvirima Zapadnog Balkana ali i sve više u evropskim i svjetskim okvirima. Esencijalna opredjeljenost kompanije je usmjerena ka primjeni kontinuiranih inovacija što je u skladu sa vizijom kompanije da u dobroj mjeri u budućnosti poboljša svoju konkurentsku poziciju. Razvoj inovativnog sektora je jedno od strategijskih opredjeljenja kompanije Alumina. Akcenat je na kontinuiranom razvoju novih proizvoda koji treba da doprinesu profitabilnosti kompanije. Politika razvoja poboljšanih i potpuno novih proizvoda u kompaniji Alumina integralni je dio poslovne i razvojne politike. Njen zadatak je da na osnovu utvrđene koncepcije o ciljevima i zadacima razvoja u određenom vremenskom razdoblju, istražuje, organizuje, koordinira, provodi i kontroliše aktivnosti koje su nužne za osiguranje uspješne realizacije programa tržišno usklađenog i ekonomski racionalnog oblikovanja proizvoda na tržištu. Kontinuirano kreiranje novih i izmjene u karakteristikama i svrsi upotrebe postojećih proizvoda, najbolja je strategija rasta kompanije u razvijenoj tržišnoj privredi. Od stepena usklađenosti ponude kompanije odnosno od kompanijske razvojne politike zavise najbitnije komponente njenog poslovanja. Kompanija dobija mogućnost da oblikuje svoju ponudu i položaj na tržištu na način koji istovremeno zadovoljava i društvene potrebe a i potrebe i ciljeve njenog rada i razvoja. Iz ovoga proističe zaključak da se politika razvoja proizvoda, u sklopu ukupne razvojne politike, ne može sprovoditi uspješno ako se sprovodi bez jasno definisanog sistema, koncepcije i metodologije.*

***Ključne reči**: Razvoj, inovacije, Alumina, profitabilnost.*

Introduction

Improving existing products and continuously introducing new products into the production program are, in fact, ongoing requirements that are constantly defined and set in the business practice of a modern company. This is also the case with the company *Alumina.*

Although it is not always easy to draw a clear line between improving existing products and introducing new ones, it can be said that improvement is aimed at replacing existing products with superior products serving the same purpose, whereas the introduction of new products leads to the expansion of the production program.

Through product planning, product characteristics are aligned with other elements of the marketing mix, and the company's capabilities are matched with market demand.

The functional quality of a product is the fundamental and most important means of competitiveness, determining consumer preferences in the market. If the functional characteristics of a product are not at an appropriate level relative to competitors and consumer needs, all other elements of the marketing mix will not ensure the product's success in the market.

Design, as an element of the production mix, has multiple technical-technological and market dimensions. In the marketing system, product design enhances competitiveness in several ways:

By harmoniously synthesizing functionality, economy, aesthetics, and ergonomics within a single product, its value and appeal to customers are significantly increased, even if prices are considerably higher than those of competitors' products that lack or have a lesser extent of these elements;

Increased sales, which usually follow successful design, allow for better utilization of capacities, mass production, cost reduction, and thereby increased competitiveness;

Process industrial design allows for the substitution of raw materials and components or the reduction of their dimensions, which contributes to competitiveness by lowering production costs;

Industrial design enables a higher degree of standardization and typification, positively affecting the competitiveness of both standardized products and complex products incorporating these components;

Graphic design increases competitiveness in domestic and international markets;

Product and packaging design significantly reduces breakage and preserves better product quality, thereby greatly influencing the competitiveness of certain products.

All of the above is at the core of *Alumina's* development policy. In this way, real conditions are created for more intensive company growth in the context of very rapid technological progress. Company development should also result in increased profitability, which is a prerequisite for achieving the company's strategic objectives.

1. Business analysis of introducing a new product into the production program

In the process of introducing a new product into the production program, business analysis represents a key phase in which a decision must be made as to whether the proposed new product deserves inclusion in the production program (Drucker, 2016, p.34). Although continuous testing and appropriate business decisions are carried out throughout the product's life cycle during the product management and development process, two aspects are particularly important at this stage of the process:

- To assess the size of market demand, and

- To obtain as realistic an understanding as possible of the potential growth in demand for the new product.

During the business analysis phase of a new product proposal, it is very important—and at the same time very difficult—to determine how long it will take for the product to penetrate and stabilize in the market. Based on the answer to this question, a decision can be made on whether to proceed to the product development phase. This method of decision-making is intensively applied at the company *Alumina*.

The modern business world clearly recognizes that investment risk in introducing a new product is more closely related to the size of the potential market than to the technical complexity of the new product. Interestingly, despite this understanding, companies are more willing to accept high investments in production equipment than in product sales (warehouses, service, transportation, and so on). Business analysis of a new product assumes that information about the state of fixed and variable costs (and their relative relationship) is already available. If fixed costs are relatively higher, greater caution is required at this stage when projecting the growth curve of the new product. Sufficient financial resources must be available for the development of the new product. This must be known at the introduction stage. If the new product proposal requires the use of external funds in the form of loans, it must be understood that the lender will be highly interested in the new product and will certainly require a prototype before its final market launch.

It is also very important to project prices and operating costs in order to evaluate potential profit. Predicting the success of a new product with complete accuracy is impossible, but certain projections with a reasonable margin of error can be made and are certainly crucial for decision-making.

In business practice, each company establishes and defines its own criteria for the business analysis of a new product proposal. Therefore, it is possible to determine standard criteria for selecting a new product. Comparing expected revenues and costs, or profit projections, is certainly a universal criterion used by all companies to evaluate a new product. In this regard, it is very important for a company to decide which cost and profit concept to use in the analysis. Economic science recognizes two main cost concepts:

- The concept of marginal costs, and
- The concept of total costs.

Which of these two concepts a company uses in the business analysis of a new product depends on several factors. If the marginal cost concept is used, data will be obtained for each new product proposal regarding the extent to which variable costs are covered and how much contributes to covering fixed costs and profit. This concept is applied when a company is underutilizing its capacities. In such cases, the company includes new products that cover their variable costs and only contribute to covering fixed costs and potentially generating smaller or larger profits (Eric, 2010, p.47).

If the total cost concept is used, it is insisted that each new product covers all production and distribution costs and contributes to profit. Both concepts have advantages and disadvantages. The best approach is to conduct the analysis using both methods and arrive at a calculation or assessment of the profitability of each new product proposal.

In business practice, it is not uncommon to introduce a completely new product into the production program. In such cases, the most important question is the product's profitability prospects. It is necessary to project costs and revenues for the foreseeable future, which is very difficult when dealing with a completely new product with which the company has little prior experience.

Business analysis when introducing a new product into the production program does not always rely solely on profitability prospects. Other criteria are also important. The company must decide whether to introduce a new product due to its complementarity with existing products or as a substitute for an existing seasonal product. Of course, these two cases do not exclude each other, but they represent

separate situations. It is known that complementary and independent products can contribute to increased company revenues (Hanic, 2013, p.24).

In the analysis of new product introduction, consideration must also be given to the existing technological production process. If the proposed new product uses the same production factors and technological process, this favors its inclusion in the existing program. One advantage is that the new product can utilize existing sales channels, which is another reason for the final decision to include the new product in *Alumina's* production program. These aspects of business analysis are thoroughly applied at *Alumina*. In this way, the introduction of new products into the production program is always subject to a business feasibility study.

2. Marketing concept for introducing a new product ti the market within the company Alumina

In a company's business policy, the introduction of a new product represents the most responsible, most complex, and economically most efficient area of activity, since a new product also means new profit. For this reason, this issue is given a special place and importance in modern marketing concepts. Indeed, one of the most significant yet complex aspects of business growth is the marketing aspect of growth based on a new product. Experiences from developed countries regarding the importance of new products for business growth clearly indicate that the industrial sectors that focused on developing new products achieved the greatest qualitative and most dynamic quantitative growth.

It should be noted that the times when the key idea for conquering a new product originated solely from company management are irreversibly gone. Until recently, in many manufacturing companies, the primary concern was how to technologically master the production of a new product and in what quantity to produce it. However, today, the crucial question is: *what to produce?* In market-oriented production, the manufacturing sector produces what the sales sector can sell, whereas previously, the sales sector sold what the manufacturing sector could produce. This is precisely the essence of the marketing concept and approach to introducing new products, and it depends on a range of circumstances.

The company *Alumina* has the following marketing mix instruments at its disposal: product, price, sales channels (distribution channels), and promotion. The introduction of innovations and continuous technological changes has become a law of modern production. In fact, in the current stage of modern economy and marketing, the market is no longer the only factor directing production. Now, the initiative of manufacturing companies to introduce new products to the market has also emerged as an important factor that drives rapid changes and new trends in demand structure.

It is increasingly concerning that in recent years, European industry has approached innovation defensively, and the development of new products is largely "technology-driven," which exposes it to greater risks from more aggressive innovations from Japan, China, and the United States. The situation in transitional countries is even less favorable, especially since many companies often choose to purchase licenses or machinery and sometimes literally adopt competitors' marketing strategies when selecting their product strategies.

In business practice, there is considerable consensus that the modern concept of introducing a new product into production must be based on understanding consumer desires and needs. It can be stated with certainty that understanding consumer needs and desires is crucial for introducing a new product, as it directly affects the future profitability and efficiency of the company.

A business entity seeks to find a product in an area where it has the greatest chances of success. Naturally, these are areas where the company has relevant production and market experience. Decisions on introducing a new product are long-term in nature and can therefore be treated as significant investment decisions. For this reason, it is necessary to adopt a systematic and applicable program for introducing a new product (Porter, 2009, p.16).

Modern practice in the field of new product introduction shows that the absence of a planned approach inevitably increases the number of failures when introducing new products. Underestimating competition, setting a high initial product price, and technical deficiencies are most often the direct result of the absence of quality planning and an introduction program for a new product.

The fact is that the success of a new product is based on systematic and continuous orientation toward consumer needs and desires, i.e., toward the market, systematic information sharing (both external and internal), effective product development, and the engagement of marketing experts to carry out the new product introduction (Lukic, 2023, p.56).

It is necessary to avoid the belief that a company has discovered a technologically superior product that consumers will eagerly purchase, as well as blindly following the success of a competitor's product, i.e., adopting an "us too" strategy.

The success of *Alumina's* new products is hindered by several factors:

- insufficient number of new ideas for new products; market fragmentation caused by intensified competition;
- social and governmental restrictions (related to consumer safety, environmental protection, and the regulation of various standards);
- increased costs of developing new products;
- competitor companies increasingly successfully copying successful products.

Conclusion

Developing new innovative products should elevate the company *Alumina* to a much higher level compared to its competitors, leading to a whole set of effects that would directly impact the significant prospects for the company's future development, as well as the overall national economy.
This strategic orientation would almost certainly mean higher company revenue, increased corporate profit, and a larger workforce in the company in the future. Additionally, a range of positive indirect effects on the broader community and the state could be expected. These would be reflected in increased tax revenues, higher employment rates, a noticeably improved standard of living for the population, the development of a greater number of complementary businesses, and similar outcomes.
The potential implementation of all the aforementioned measures would almost certainly result in a positive shift within *Alumina*'s business environment, significantly increasing the number of complementary business activities that would, in turn, support and follow the company's operational processes.

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Artificial Intelligence as a Tool for Advancing HR Practices

Veštačka inteligencija kao sredstvo za unapređenje HR praksi

Jelena Aranđelović[1], Pavle Brzaković[2], Cipriana Sava[3]

[1]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, jeja.arandjelovic@gmail.com*

[2]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, pavle.brzakovic@mef.edu.rs*

[3]*"Tibiscus" University of Timisoara, Timișoara, România, cipriana.sava@gmail.com*

Abstract: *Artificial Intelligence (AI) is revolutionizing modern business in the manner with which organizations engage, develop and retain a professional workforce. In human resource management (HRM) AI enabled systems promote well-informed decisions with data as well as automation of administrative work which in turn facilitates greater alignment of AI in HR towards an organization goals. In this paper we discuss the contribution of AI in HRM, including its theoretical foundations, its main applications, its advantages, its ethical considerations, and the future development perspective of HR. It shows how new tools like predictive analytics, natural language processing, and machine learning are revolutionizing recruitment, learning and development, performance management, and employee engagement. The paper discusses issues with ethics and transparency and human oversight and how human-centred design and ethical governance is crucial for the realization of success. It also makes pragmatic suggestions for HR professionals to contribute to the successful integration and uptake of AI solutions.*

Keywords*: Artificial intelligence, human resource management, HR analytics, automation, ethics, employee engagement, digital transformation.*

Apstrakt: *Veštačka inteligencija (VI) revolucionira moderno poslovanje u načinu na koji organizacije angažuju, razvijaju i zadržavaju profesionalnu radnu snagu. U upravljanju ljudskim resursima (HRM), VI sistemi doprinose donošenju dobro informisanim odlukama na osnovu podataka, kao i automatizaciju administrativnog rada, što omogućavaa veću usklađenost VI u HR-u sa ciljevima organizacije. U ovom radu razmatramo doprinos VI u HRM-u, uključujući njegove teorijske osnove, glavne primene, prednosti, etička razmatranja i perspektivu budućeg razvoja HR-a. Rad pokazuje kako novi alati poput prediktivne analitike, obrade prirodnog jezika i mašinskog učenja revolucionišu regrutovanje, učenje i razvoj, upravljanje učinkom i angažovanje zaposlenih. Rad razmatra pitanja etike i transparentnosti i ljudskog nadzora kao i to kako su dizajn usmeren na čoveka i etičko upravljanje ključni za postizanje uspeha. Takođe daje pragmatične predloge za HR stručnjake kako da doprinesu uspešnoj integraciji i usvajanju VI rešenja.*

Ključne reči: *Veštačka inteligencija, upravljanje ljudskim resursima, HR analitika, automatizacija, etika, angažovanje zaposlenih, digitalna transformacija.*

Introduction

The fast evolution of artificial intelligence (AI) is changing the landscape for organizational management and redefining the role of human resource management (HRM) as a strategic collaborator. AI (Artificial Intelligence) in HR is a paradigm shift from conventional HR administrative methods to predictive, data-driven and personalized approaches (Jarrahi, 2018).

AI allows for personalized development paths through automating repetitive tasks and utilizing algorithms for talent discovery (Alabi et al., 2023). AI-based recruiting tools can reduce time to hire by

as much as 50% and thus speed up the onboarding process and lower vacancy costs (https://www.consumerproductsworld.com/article/862248385-ai-hiring-software-redefines-recruitment-a-faster-fairer-and-smarter-future-for-staffing-agencies). In addition, learning systems based on AI can drive 30% enhanced learning-transfer rates by providing personalized, adaptive learning experiences (https://metall-mater-eng.com/index.php/home/article/download/1567/901/5305).

Thus, increasing the contribution of HR function in the organizational innovation, agility and strategic decision-making (Stone & Deadrick, 2015; López & Peralta, 2023). Today, in the digital world, HR professionals structure an organization and leverage technology to enhance engagement with the organization and increase performance.

Artificial intelligence (AI) serves as one example advancing this trend through accurate workforce prediction, instant sentiment profiling, and less decision-making bias (Kaushal et al., 2023). At the same time, however, although AI does build capabilities for humans, it also raises ethical challenges in areas of transparency, accountability and bias embedded in algorithms (Gélinas et al., 2021). It therefore remains the moral challenge of determining how to balance the technology-fueled efficiency of new technologies with the ethical imperatives and human-centred human dimensions of leadership and impact of AI in HR. This paper aims to discuss the significant role of AI on advance HR Practices with respect to how to position theoretical perspective, applications and strategic implications of AI to organizational HRM. It seeks to offer a clear understanding of how the technologies enabled by AI can improve HR processes, enhance decision support, optimize HR processes and increase long-term organizational performance.

1. Theoretical background

Several theories underpin how artificial intelligence (AI) can contribute to HRM integration. This insight outlines how technology reshapes workplaces, decision-making processes, and demographics of a workforce. On this standpoint, AI supplements human expertise rather than usurps it and improves decision making.

Introducing AI without looking into social systems (such as culture, communication and trust) also creates dissonance between technology and people and results in the technology-people divide and a mismatch of strategic value. Expanding on this, the resource-based view (RBV) refers to human capital as a strategic inimitable resource and offers a sustainable competitive advantage (Barney, 1991).

The RBV is enhanced by AI by increasing HR's capacities to harness the power of workforce analytics to discover, nurture, and keep talent. AI helps businesses identify patterns hiding in the data about the workforce, turning tacit knowledge from humans to action and ultimately driving strategic alignment and performance. Another lens through which we can view these patterns is the dynamic capabilities framework (Teece, 2007).

It suggests that long-term competitiveness is based on sensing opportunities, seizing them, and redeploying resources as appropriate (Teece, 2007). AI assists HR in its agile capabilities. It allows for quicker recognition of talent trends and agile workforce planning. AI also facilitates proof-based adaptation of HR strategies. It acts like a catalyst for organizational agility and for HR leaders to guide the transformation process. Also, algorithmic systems increase managerial control. They do this by means of data-driven monitoring, evaluation, and prediction.

In HR, recruitment algorithms, performance analytics and engagement dashboards can impact autonomy and control. This also makes it crucial to design such systems in a transparent and accountable manner. According to Sundar (2020) the human–AI interaction (HAII) paradigm, collaboration and trust between humans and intelligent systems is of utmost importance. HAII makes more than just automating, HAII is a partnership.

AI augments human judgment, and humans brings with them context, ethics and emotional intelligence. It is this balance that one of the most important of all that is key in HR. Decisions about people need to be fair and have empathy that are grounded in fairness. AI only can help bring out the most effective way of making decisions to humanize employees. Altogether, these frameworks illustrate that the incorporation of AI in HRM is a technological innovation and yet, organizational and philosophical revolution. In such a setting, a balance between human intuition and machine intelligence is critical to guarantee that efficiency does not come at the expense of dignity, diversity or ethical responsibility.

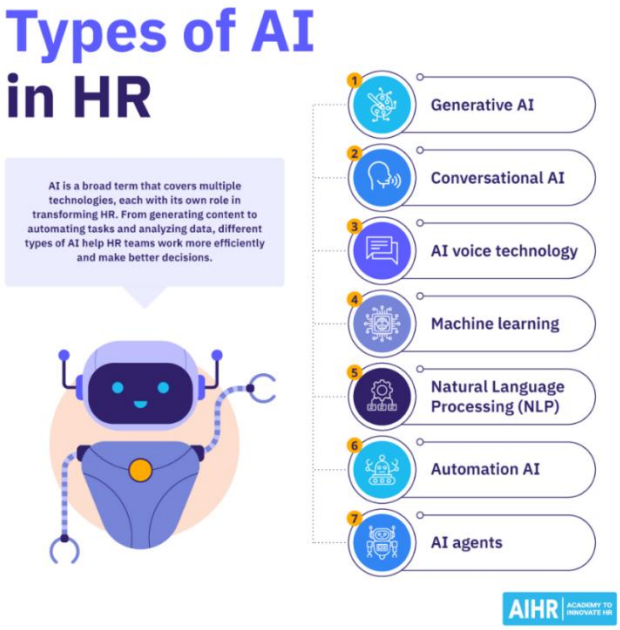


Figure 1. Types of AI in HRM
Source: https://www.aihr.com/wp-content/uploads/Types-of-AI-in-HR-Blog.png

2. AI in modern HR practices

Artificial intelligence (AI) is revolutionizing the entire employee lifecycle in human resource management (HRM) from recruitment and selection, through development and retention. AI tools are changing HR from being an operational function into a strategic one by using data to make decisions and personalize the human experience to individualized preferences (Strohmeier & Piazza, 2015).

As an illustration, at a leading technology company, AI has been implemented to re-imagine job functions through the redistribution of routine data entry assignments away from HR personnel towards computer algorithms. Since then, business managers have been able to devote more time to strategic actions like talent development and employee engagement programs to minimize operational load and produce a positive strategic effect. Similarly, analytics driven by AI increased the accuracy of risk assessments and compliance reporting in a financial services organization, freeing analysts up to become specialists for additional advisory work. AI was employed at a manufacturing firm to optimize workforce scheduling and increase production output by 15% while providing a good work-life balance for workers. The next sections point out which of the HR areas is most affected by AI.

2.1. Recruitment and talent acquisition

Recruitment has been an early and readily visible arena for AI. Machine learning algorithms and natural language processing (NLP) models automate résumé screening, candidate ranking, and job–profile matching based on predefined competencies (Hawrysz, 2018). AI systems can find candidates who best fit a role or culture by considering linguistic cues, career histories, and behavior (Suen et al., 2020).

Chatbots and conversational agents also currently manage two-way communication with applicants. They provide details, schedule interviews, and answer questions in real time. They reduce administrative workload and improve the candidate experience. AI-based sourcing tools utilize predictive analytics to identify passive candidates from their digital footprints on platforms such as LinkedIn (Köchling & Wehner, 2020; Harirchian et al., 2022).

Yet, the effectiveness of AI in hiring is contingent on the quality and representativeness of the training data. Bias embedded in datasets can perpetuate discrimination in hiring as empirical investigations demonstrate (Lai et al., 2020). To prevent this, HR professionals need to take a governance loop approach detecting bias, assessing its impact, and remediating identified issues.

Oversight should be inclusive and diverse, involving multiple stakeholders to ensure comprehensive oversight and accountability in this process. Establishing explicit audit cadences — that are set quarterly or on a semiannual basis — could also regularly surface potential biases. Fairness and diversity in hiring are important, too — which is why algorithmic transparency and strong human oversight are vital.

2.2. Learning and development

AI is also shaping learning and development (L&D) by offering adaptive, personalized learning opportunities. According to Borghans et al. (2008), intelligent learning systems assess employees' performance data, skills profiles, and behavioral patterns to suggest a customized training plan. Reinforcement learning technologies help platforms dynamically customize course difficulty and content format via feedback on learning progress and engagement levels. Virtual reality (VR) and AI-based simulations provide employees with a controlled and experiential setting to practice a wide array of skills, from leadership communication to technical troubleshooting.

With AI-powered knowledge management systems, employees can access contextually relevant knowledge in application settings that can offer just-in-time learning opportunities. Such advancements represent a move towards lifelong learning ecosystems, where AI acts both as an enabler and an analyst, diagnosing both your learning needs and future skills gaps, and estimating the impact on your performance. This fits into a broader organizational trend that is driven by data on talent development and cultivation of lifelong learning cultures.

2.3. Performance management

Performance management is another field that is experiencing a significant impact of AI. Annual reviews have been replaced with continuous performance monitoring systems that utilize real-time data and predictive analytics rather than just annual reviews. AI tools enable multiple sources of information, ranging from project outputs to collaboration platforms and peer feedback, to be synthesized to produce multidimensional performance information. The effectiveness of such systems also supports managers to give individualized personalized feedback and evaluations on an evidence-based approach that are less subjective and less influenced by bias, thus more accurate in the form of individualized feedback and evaluations. Additionally, sentiment analysis and emotion-recognition technologies identify team morale and engagement, helping to prevent burnout or turnover early on.

However, the incorporation of AI in performance appraisal raises new challenges, such as surveillance, data privacy, and employee autonomy. The line between constructive feedback and intrusive monitoring remains ethically delicate and suggests the urgency of transparent governance mechanisms and participatory policy design. To tackle these concerns, we need to consider whether these AI systems respect the 'contextual norms' of the workplace beyond mere legal compliance. Accommodating the context-sensitive expectations may help make a better argument for a policy framework that is inclusive as well as representing the organization's distinctive cultural and ethical norms. Such a framework stimulates participatory involvement so that AI is used according to the wishes and expectations of the workforce, promoting trust and acceptance.

2.4. Employee engagement and retention

AI's role in engagement as well as retention revolves around predicting and shaping employee experience. Predictive analytics models can spot disengagement- or attrition-related trends by tracking metrics like absenteeism, workload, and communication tone (Huang et al., 2025). For this, HR teams are then able to proactively address this or these issues through providing tailored interventions, coaching, or redistributing workloads. In this scenario, conversational AI systems, such as digital assistants and sentiment-aware chatbots, gather employees' feedback on an ongoing basis and translate these inputs into actionable insights for leaders (Welch, 2025). This enhances responsiveness and allows management to adjust in real time its practices. Moreover, AI-based career pathing tools give employees data-backed suggestions for internal mobility, linking personal ambitions with organizational opportunities and in doing so reinforcing engagement. We must be certain that engagement analytics is implemented in a way that is respectful of privacy and creates trust among participants. The more that values transparency, consent, and communication, the more likely employees are to use AI-augmented systems. Successful HR departments balance technological precision and human empathy – connecting the dots between how data drives decisions, data informing compassionate and supportive behaviour, not the other way around, and helping to ensure that data analytics lead to actions designed to be compassionate and supportive rather than just a mechanism for control. In short, AI is redefining HR management, not replacing people, but amplifying the expertise they already have to decide on things in a way so that information and thoughtfully take into account the needs of particular societies. HR is a hybrid between data science intelligence and human insight, analytics to empathy, and machine learning for human touch.

Conclusion

Artificial intelligence (AI) is revolutionizing the whole process of human resource management (HRM), leading both the operational side and strategic side of people management. As introduced in this paper, AI plays a strategic partner role, enhancing the accuracy, agility, and foresight in HR decisions. By building data-driven insights into recruitment, learning, performance evaluation, and engagement processes, AI is changing HR into a new kind of organization. HR managers should focus on the next strategic AI projects to support the transformation of their own organizations. Some possible strategies that might help us transition to AI would be pilots of AI-driven recruitment for fast tracking candidate screening, AI-assisted learning platforms to develop them further, and AI-powered sentiment analysis tools to enable continuous feedback throughout the process. The future of HR is that of cooperation between humans and machines: a partnership when human intuition is empowered to be better informed by these systems in an ethical and contextually based way that enables algorithms to be guided to enhance human judgment. The emergence of explainable, human-centred AI represents a promising path to that balance. Organisations moving towards this approach that adopt a model are bound to enjoy greater performance and a greater degree of resilience, agility, and social legitimacy. And the problem is as much philosophical as it is technological. How to deploy AI to an organization — whether it be to automate or augment human judgment — will determine its influence. With transparency, fairness, and empathy driving AI's decisions, it may further emphasize the critical role of HR – supporting the establishment of innovative, equitable and human-centred workplaces.

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A WENSLO-CODAS Framework as a Decision Support

WENSLO-CODAS pristup kao podrška odlučivanju

Đorđe Pucar[1], Gabrijela Popović[2], Darjan Karabašević[3], Dragiša Stanujkić[4]

[1]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, djordje@mef.edu.rs*

[2]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, gabrijela.popovic@mef.edu.rs*

[3]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, darjan.karabasevic@mef.edu.rs*

[4]*University of Belgrade, Technical Faculty in Bor, Serbia, dstanujkic@tfbor.bg.ac.rs*

Abstract: *This article proposes the application of the hybrid Multiple-Criteria Decision-Making (MCDM) model for facilitating the decision-making process. The proposed model involves the WENSLO (Weights by ENvelope and SLOpe) and CODAS (COmbinative Distance-based ASsessment) methods. The WENSLO method was used for defining the criteria significance, while the ranking of the alternatives was performed by the CODAS method. The applicability of the proposed model was illustrated through a real numerical example directed to the selection of an adequate mini-PC. Five alternatives to mini-PCs were evaluated against five criteria. The decision-making process was conducted in a group decision environment involving three decision-makers. The used model provided adequate and reliable results.*

Keywords: *WENSLO method, CODAS method, selection, mini-PC, decision-maker.*

Apstrakt: *U radu se predlaže primena hibridnog modela višekriterijumskog oflučivanja (VKO) radi pojednostavljenja procesa donošenja odluka. Predloženi model uključuje WENSLO (Weights by ENvelope and SLOpe) i CODAS (COmbinative Distance-based ASsessment metode). WENSLO metoda je upotrebljena za definisanje značaja kriterijuma, dok je rangiranje alternativa realizovano uz pomoć CODAS metode. Primenljivost predloženog modela ilustrovana je na realnom primeru usmerenom na izbor adekvatnog mini računara. Pet alternativnih mini računara ocenjivani su u odnosu na pet kriterijuma. Proces oslučivanja je srpoveden u uslovima grupnog odlučivanja koji je uključivao tri donosioca odluke. Korišćeni model obezbedio je adekvatne i pouzdane rezultate.*

Ključne reči: *WENSLO metoda, CODAS metoda, selekcija, mini računar, donosilac odluke.*

Introduction

Development of information technologies and their presence in the business and private environment have caused a constant need to make quick, but at the same time quality decisions, especially when it comes to the choice of information technology equipment. Choosing the correct hardware isn't just a technical problem, it's also a strategic one that can directly affect an organizations production, efficiency and costs. That is why the selection process requires a systematic approach that will ensure balance between performance, reliability and pricing.

In this context, MCDM represents an important research and practical framework, because it enables the analysis of different alternatives based on more mutually independent or conflicting criteria. Traditional decision-making models often ignore the complexity of real problems, while MCDM methods integrate different dimensions and provide support to decision makers.

Particular importance are hybrid models, which combine multiple methods to achieve greater accuracy. This paper presents the application of the WENSLO method for determining the importance of criteria

in combination with CODAS method which enables the ranking of alternatives based on the distance from the negative ideal solution. This integration gives the possibility of providing an objective weighting of criteria and a precise evaluation of alternatives.

The applicability of the proposed model is illustrated with a problem of choosing a mini computer. Mini PCs are becoming more and more popular due to their compactness, energy efficiency and the possibility to integrate into different work environments. The selection process aim to ease the challenge in which you have to take into account the processors performance, memory capacity, storage space, response speed and price.

This paper emphasizes the importance of decision making because combining the assessments of several experts contributes to reducing subjectivity and increasing in the reliability of the result.

1. Methodology

1.1. The WENSLO method

The WENSLO method, proposed by Pamučar et al. (2023), enables defining the objective criteria weights based on the input data. Although relatively new, this method has already been used in research studies. Kara et al. (2024) applied it for computing the criteria weights in the case of assessing the sustainable brand equity, as well as for sustainable brand logo selection (Kara et al., 2025). The socio-economic performance evaluation was also performed using the WENSLO method (Gopisetty & Sama, 2025). The methodology used for the evaluation of the efficiency of the world airports involved the WENSLO method as well (Pamucar et al., 2025).

The following steps illustrate the computing procedure of the mentioned method.

Step 1. Forming the initial decision-making matrix.

$$[x_{ij}]_{mxn} = \begin{bmatrix} A/C & C_1 & C_2 & \dots & C_n \\ A_1 & x_{11} & x_{12} & \dots & x_{1n} \\ A_2 & x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots & \dots \\ A_m & x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \quad (1)$$

where x_{ij} represents a value of the i_{th} alternative regarding the j_{th} criterion. $A_1, A_2, \dots, A_m$ designate the alternatives, while $C_1, C_2, \dots, C_n$ are the criteria.

Step 2. Normalize the decision-making matrix using Eq. (2):

$$z_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \forall_j \in [1,2,\dots,n] \quad (2)$$

Step 3. Compute the criterion class interval Δz_j using Sturges' rule:

$$\Delta z_j = \frac{\max\limits_{1\le i\le m} z_{ij} - \min\limits_{1\le i\le m} z_{ij}}{1+3.322\times\log(m)}, \forall_j \in [1,2,\dots,n] \quad (3)$$

Step 4. Calculate the criterion slope.

$$\tan\varphi_j = \frac{\sum_{i=1}^{m} z_{ij}}{(m-1)\times\Delta z_j}, \forall_j \in [1,2,\dots,n] \quad (4)$$

Step 5. Determine the criterion envelope.

$$E_j = \sum_{i=1}^{m-1} \sqrt{\left(z_{i+1,j} - z_{ij}\right)^2 + \Delta z_j^2}, \forall_j \in [1,2,\dots,n] \quad (5)$$

Step 6. Calculate the envelope–slope ratio.

$$q_j = \frac{E_j}{\tan \varphi_j}, \forall_j \in [1,2, \dots, n] \tag{6}$$

Step 7. Define the final criteria significance.

$$w_j = \frac{q_j}{\sum_{i=1}^{n} q_j}, \forall_j \in [1,2, \dots, n] \tag{7}$$

1.2. The CODAS method

The CODAS (COmbinative Distance-based ASsessment) method was introduced by Keshavarz Ghorabaee et al. (2016), and academicians have used it for resolving different kinds of decision-making problems. System transport evaluation from the transport perspective was performed using the CODAS method (Seker & Aydin, 2020). Goswami et al. (2021) applied it for the selection of adequate cutting fluid. Selection of adequate personnel with the required level of knowledge and experience was also executed with the help of the CODAS method (Suriyanto et al., 2025). Tosa jute fibres were assessed using the CODAS method as well (Mitra, 2024). This method was used in combination with other MCDM methods in the evaluation and selection of sustainable renewable energy (Goswami et al., 2025). Until now, researchers have proposed different extensions of the CODAS method to extend its possibilities (Bolturk, 2018; Pamučar et al., 2018; Yalçın & Yapıcı Pehlivan, 2019; Tüysüz & Kahraman, 2020; Chen & Gou, 2022; Ning et al., 2022; Andukuri & Rao, 2024; Farnam et al., 2024).

The computational procedure of the CODAS method involves the following steps.

Step 1. Construct the initial decision-making matrix as it shows Eq. (1).

Step 2. Normalize the decision-making matrix as it is presented:

$$n_{ij} = \begin{cases} \frac{x_{ij}}{\max\limits_i x_{ij}} \; if \; j \in N_b \\ \frac{\min\limits_i x_{ij}}{x_{ij}} \; if \; j \in N_c \end{cases} \tag{8}$$

where N_b represents the set of benefit criteria, and N_c the set of cost criteria.

Step 3. Compute the weighted normalized matrix in the following way:

$$r_{ij} = w_j n_{ij} \tag{9}$$

where the weight of the j_{th} criterion is denoted with w_j ($\sum_{j=1}^{n} w_j = 1$).

Step 4. Define the negative-ideal solution (point) in the following manner:

$$ns = \left[ns_j\right]_{1 \times n} \tag{10}$$

$$ns_j = \min_i r_{ij} \tag{11}$$

Step 5. Compute the Euclidean and Taxicab distances of alternatives from the negative-ideal solution as it is presented:

$$E_i = \sqrt{\sum_{j=1}^{n} \left(r_{ij} - ns_j\right)^2} \tag{12}$$

$$T_i = \sum_{j=1}^{n} \left| r_{ij} - ns_j \right| \tag{13}$$

Step 6. Form the relative assessment matrix in the following way:

$$R_a = [h_{ik}]_{m \times m} \tag{14}$$

$$h_{ik} = (E_i - E_k) + \left(\psi(E_i - E_k) \times (T_i - T_k)\right) \tag{15}$$

where $k \in \{1,2,\dots,m\}$ and ψ represents a threshold function to determine the equality of the Euclidean distances of two alternatives, which is defined in the following manner:

$$\psi(x) = \begin{cases} 1 \; if \; |x| \geq \tau \\ 0 \; if \; |x| \leq \tau \end{cases} \tag{16}$$

The decision-maker can define the threshold parameter τ. This parameter value goes between 0.01 and 0.05, and it is usually set at 0.02.

Step 7. Compute the assessment score of each alternative H_i in the following way:

$$H_i = \sum_{k=1}^{m} h_{ik}$$

The higher H_i value designates a better alternative, and alternatives are ranked in descending order.

2. Numerical example

To illustrate the applicability of the proposed MCDM framework, a real numerical example is used. The issue of adequate IT equipment selection is prevalent these days. This article presents the case of selecting an adequate mini-PC. The types of mini-PCs that were submitted under evaluation, as well as acronyms used, are presented in Table 1.

Table 5. Alternative mini-PCs

Acronym	PCs
MP200	BLACKVIEW MP200 Mini PC
PN64	ASUS Mini PC PN64-B-S
GK3V	ZEUS Mini PC GK3V
PN53	ASUS Mini PC PN53-BS7773MDS1
MPI12	ZEUS Mini PC MPI12

Source: https://www.bigbang.rs/

The considered mini-PCs were evaluated against five criteria, which are presented in Table 2.

Table 2. Input data – DM_1

Acronym	Criteria
CPU	CPU
RAM	RAM
SSD	SSD
LAT	Latency
PRC	Price

Source: Authors` research

Three experienced IT experts (DM_1, DM_2, and DM_3) performed an initial assessment of the chosen alternative mini-PCs. Their estimations are presented in Tables 3-5.

Table 3. Input data – DM_1

Alternative	CPU	RAM	SSD	LAT	PRC
MP200	5	5	5	4	2
PN64	4	1	1	3	3
GK3V	1	3	4	1	5
PN53	3	1	1	2	4
MPI12	2	4	3	5	2

Source: Authors` research

Table 4. Input data – DM_2

Alternative	CPU	RAM	SSD	LAT	PRC
MP200	5	5	5	3	2
PN64	4	1	1	4	3
GK3V	1	3	3	2	5
PN53	3	1	1	3	4
MPI12	2	4	4	5	1

Source: Authors` research

Table 4. Input data – DM_3

Alternative	CPU	RAM	SSD	LAT	PRC
MP200	5	4	5	3	3
PN64	3	2	2	4	3
GK3V	2	3	3	2	5
PN53	4	1	1	3	4
MPI12	3	5	4	5	1

Source: Authors` research

The criteria weights were computed using the equations. (1)-(7) for each decision-maker separately, and they are presented in Table 5.

Table 5. The criteria weight

Criteria	DM_1	DM_2	DM_3
CPU	0.1711	0.1766	0.1137
RAM	0.2728	0.2815	0.2862
SSD	0.2931	0.2815	0.2849
LAT	0.1711	0.0840	0.1137
PRC	0.0919	0.1766	0.2014

Source: Authors` research

As Table 5 shows, the DMs prioritized the considered criteria differently. For DM_1, the most important criterion is SSD, while for DM_2, SSD and RAM have the same level of importance. The results obtained from DM_3 show that, according to his opinion, the most important criterion is the size of RAM.

Using defined criteria, weights, and equations. (8)-(16), the ranking of the considered PCs is obtained.

Table 6. Rankings of the mini-PCs

Alternative	DM_1	Rank	DM_2	Rank	DM_3	Rank
MP200	1.6380	1	1.3935	1	0.6234	1
PN64	-0.4091	4	-0.4118	4	-0.4595	5
GK3V	0.0380	3	-0.0059	3	0.0569	3
PN53	-0.6084	5	-0.4280	5	-0.4284	4
MPI12	0.1965	2	0.1630	2	0.6172	2

Source: Authors` research

The domination method, which is used for defining the final ranking order, designates the alternative MP200 - BLACKVIEW MP200 Mini PC as the best option, while the least acceptable is the alternative PN53 - ASUS Mini PC PN53-BS7773MDS1. The overall ranking order is presented in Figure 1.

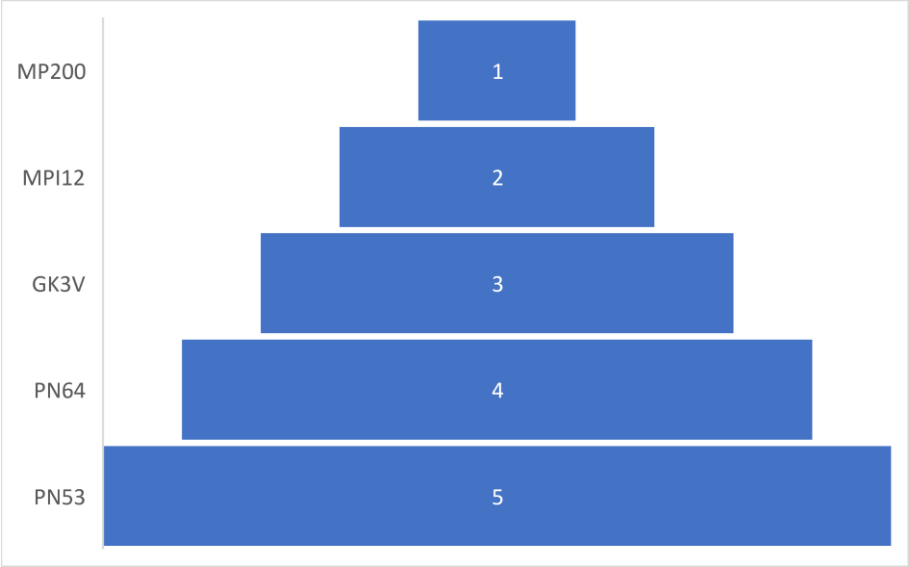


Figure 1. Final ranking order of the mini-PCs
Source: Authors` research

Conclusion

The analyzed example of choosing a mini computer showed that the application of the hybrid WENSLO-CODAS model can provide a clear, consistent and reliable results. Combining the objective weighting of criteria through the WENSLO method and the evaluation of alternatives through the CODAS method made it possible to reduce the subjectivity of the decision process.

The proposed framework has several advantages, simplicity of application and transparency in the decision-making process. However, certain obstacles also exist, such as the dependence on the quality of the input data and the need for expertise when interpreting the results. Despite this, the model has proven to be useful decision support tool in real world conditions. Potential areas of future research include extending the model to a larger number of criteria and alternatives (application in various industries such as healthcare, energy, education). In this way WENSLO-CODAS framework could be further improved and become even more relevant in the context of complex decision making.

The obtained results confirm that this framework provides a balance between theoretical foundation and practical application. This opens up space for further research and development and wider implementation of such hybrid models.

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Food Waste Prevention and Management Practices: Short Overview of Serbia's Hospitality Sector

Praksa prevencije i upravljanja bacanjem hrane: kratak pregled sektora ugostiteljstva u Srbiji

Nikola Vuksanović[1], Dunja Demirović Bajrami[2], Nick Naumov[3]

[1]Toplica Academy of Applied Studies, Department of Agricultural and Food Studies, Prokuplje, Serbia, vuksanovicnikola85@gmail.com

[2]Geographical Institute "Jovan Cvijić", Serbian Academy of Sciences and Arts, Belgrade, Serbia, d.demirovic@gi.sanu.ac.rs

[3]Higher Colleges of Technology, Abu Dhabi, United Arab Emirates, nnaumov@hct.ac.ae

Abstract: *Food waste presents a critical global challenge with significant economic, environmental, and ethical implications, particularly within the hospitality sector. This study shows short brief of research on the topic of Food waste prevention and management practices. Specifically, current research will be presented both in the literature and in Serbia' Hospitality Sector. The review will highlight the Food Waste Hierarchy framework; food waste policies vary across hotels and restaurants and chefs levels of awareness and resourcefulness about food waste. The study contributes to the theoretical understanding of food waste management in hospitality by linking practice theory with culinary knowledge and corporate influence. It also provides practical implications for training, policy development, and sustainable hospitality operations.*

Keywords: *Food waste, prevention, management practices, hospitality, chef, Serbia.*

Apstrakt: *Otpad od hrane predstavlja kritičan globalni izazov sa značajnim ekonomskim, ekološkim i etičkim implikacijama, posebno u sektoru ugostiteljstva. Ova studija prikazuje kratak pregled istraživanja na temu prevencija i praksa upravljanja otpadom od hrane. Konkretno, biće predstavljena aktuelna istraživanja kako u literaturi, tako i u sektoru ugostiteljstva u Srbiji. Pregled će istaći okvir hijerarhije otpada od hrane, politika o otpadu od hrane, razlika između hotela i restorana, kao i nivo svesti i snalažljivost kuvara u vezi sa otpadom od hrane. Studija doprinosi teorijskom razumevanju upravljanja otpadom od hrane u ugostiteljstvu povezujući teoriju prakse sa kulinarskim znanjem i korporativnim uticajem. Takođe pruža praktične implikacije za obuku, razvoj politika i održivo poslovanje ugostiteljstva.*

Ključne reči: *Otpad od hrane, prevencija, praksa upravljanja, ugostiteljstvo, šef, Srbija.*

Introduction

The topic of food waste management has been explored in numerous dimensions and it all points to the fact that it is a major issue in the world today, yet the field of food service operations remains to be explored further particularly in restaurants in the underdeveloped nations. A higher number of researchers have outlined their need to conduct research on the interest of Food Waste in the perspective of hospitality and tourism in the subject literature (Filimonau et al., 2021; Filimonau et al., 2023; Papargyropoulou et al., 2023; Wang et al., 2017; Kattiyapornpong et al., 2023; Bharucha, 2018; Vizzoto et al., 2020). The knowledge of the authors and based on analyzed literature, it is possible to note that food waste research activities were conducted so far in Novi Sad (Vuksanović et al., 2025a), Belgrade (Vuksanović et al., 2025b), management model of sustainable development in hotel (Rajić et al., 2022), sustainable food waste management in Serbia (Ivanović et al., 2025), empirical analysis of intentions of tourists about food waste in Serbian hotel industry (Glišić et al., 2025), food waste prediction on Serbia's economic prospects (Gajić et al., 2024), influencing factors of food waste in restaurants (Blešić et al.,

2021), assessment of restaurants food waste (Lazić et al., 2022) and attitudes of hotel managers on sustainable tourism through Green practices (Dauti et al., 2024), which provides space short brief review. The recent assessment of the food waste in the hospitality industry (Filimonau et al., 2021; Filimonau et al., 2023; Papargyropoulou et al., 2023; Wang et al., 2017; Kattiyapornpong et al., 2023; Bharucha, 2018; Vizzoto et al., 2020) highlights the complexity of the hospitality industry that influences the specific approach to food waste management. Food Waste Hierarchy Model is theoretically used in the course of waste management, yet it is not widely used in the case of hospitality food waste management (Srijuntrapun et al., 2022; Vuksanović et al., 2025a).

The necessity of studying the knowledge of Food Waste, the perceptions and behavior of consumers and managers (Vizzoto et al, 2020; Vizzoto et al, 2021) and the behavior of employees was not studied in the subject literature (Goh et al., 2019). The kitchen processes are handled by kitchen staff, in particular the Chefs and Sous chef, his successor, and the processes contribute up to 70% to Food Waste in foodservice provision (Filimonau et al., 2022). It implies that specific research must be done on chefs since they contribute significantly to the prevention of Food Wastes (Batat, 2020).

1. Literature review

1.1. Food waste management and waste hierarchy model

Overproduction, consumer behavior, food safety regulations, staff (dis)engage and economic factors are the primary causes of food waste. The production of food is a big issue since the cooks tend to prepare more food than is required. Moreover, the logistical inefficiencies of the supply chain that are likely to arise due to poor logistics and transportation issues and inefficient storage facilities can lead to food spoilage before it reaches the consumer. Another factor is the consumer behavior. Too much food that was thrown away can always be caused by impulse buying and poor meal planning and misconceptions about meals. The physical quantities of food served in restaurants and in the home can result in the food left uneaten and in form of leftover, which cannot be consumed in the future. Increased waste can also be caused by the ignorance of the consumers on how to retain food, the use of the leftover or misinterpretation of food labels. Food safety laws also cause food that has reached perfect condition to be discarded due to failure to meet a set of standards including appearance, size, labeling or slight packaging issues (Filimonau et al., 2021; Kattiyapornpong et al., 2023; Ivanović et a., 2025; Blešić et al., 2021; Batat, 2020).

European Commission (European Commission. Directivex, 2018) waste hierarchy principles include prevention, reuse, recycling, recovery, and disposal are all provided as options between the most desirable and the least desirable (Directivex, 2018). This model has been developed and modified by many relevant organizations, researchers and practitioners as waste prevention and sustainable waste management guidelines (Papargyropoulou et al., 2017; Kilibarda et al., 2019; Camilleri, 2021). This model has certain principles, and the majority of them are related to the following four fundamental pillars: prevention/reduction (to re-duce food surplus/loss and avoidable food waste at the source); reuse (edible food to human consumption); recycle (animal feeding, compost) and recover (creating energy); and disposal (landfill/incineration), of which prevention/reduction is much more suitable and efficient in food waste management to reduce food loss at the source and maximum usage (Srijuntrapun et al., 2022; Papargyropoulou et al., 2017; Kilibarda et al., 2019).

1.2. Food waste management in food service operations

The subject literature still lacks the ability to bridge the gap between sustainable innovations and recycling practices in hospitality context in developing and transitional economies (Filimonau et al., 2019; Filimonau et al., 2023; Papargyropoulou et al., 2023; Wang et al., 2017; Kattiyapornpong et al., 2023; Bharucha, 2018; Vizzoto et al., 2020; Jones et al., 2003). Interestingly, Ivanović et al. (2025) and Blešic et al. (2021) points out that a majority of food waste in Belgrade had been disposed in landfills, the final viable alternative of the food waste hierarchy model. The same waste disposal practice is

observed in Novi Sad. Therefore, the proposed study will address the gaps by investigating and analyzing various dimensions and levels of sustainable food waste management in the hospitality sector through food waste hierarchy-directed questions to comprehend the extent to which the restaurants in Novi Sad adopt the most appropriate current practices of sustainable management of food waste. Previous studies identify the best food waste management and sustainable efforts by responsible food service enterprises. The authors mention that the new process of the kitchen redesign that may be adopted by hotels at the planning stage can help to decrease food waste (Duursma, 2016; SRA, 2010). During the handling phase, storage must be regularly checked to make sure that the First-In-First-Out (FIFO) type of stock approach is used, which has been verified in earlier studies (Kilibarda et al., 2019; Filimonau et al., 2019; Charlebois et al., 2015; FAO, 2015; WRAP, 2017). The same authors indicate that unutilized, unsold or surplus food is also redistributed by offering them at a lower price or donating them to the staff and other organizations that require it or reusing it by cooking it and serving it to the staff in the staff canteen. In the restaurant operations, la carte services should be provided as opposed to buffets (Gossling et al., 2011).

1.3. Food waste in food service operations

Various determinants incorporated in business models have highlighted the need to conduct research on the interest of Food Waste through the lens of the food service operations. On the one hand, business-related determinants suggest that buffet foodservice wasting is greater than a la carte foodservice (Papargyropoulou et al., 2016), independent restaurants produce more Food Waste per guest served than large and chain-affiliated business (Filimonau et al., 2021a) and owners/managers and their sustainability orientation determine the level of wasting food in restaurants and the way this Food Waste is managed (Principato et al., 2018). The level of consumer religiosity, though, has an impact on Food Waste on customer plate (Principato et al., 2018) and resourceful cooking needs to be a part of hospitality teaching syllabus and training of the chefs (Filimonau et al., 2023) whereas, conversely, the consumer-related determinants suggests that females and frequent restaurant guests waste more food than males and infrequent restaurant patrons (Vizzotto et al., 2021a). Different studies have examined the interest of Food Waste considering the food service operations in the subject literature. According to the authors, the process of preparing meals (including pre-treatment, trimming, and cutting) but also cooking meals (including boiling, frying, and portionin), it results in food waste (Ball et al., 2003). Another weakness is also overstocking driven by errors in demand predictions, and it belongs to the category of deficiencies (Filimonau et al., 2020) along with FIFO approach being accepted but not always actively implemented (Charlebois et al., 2015). The level of disengagement of the chefs in Food Waste prevention in kitchens of the fine dining restaurants (Filimonau et al., 2023) and pre- and post-consumption food waste, respectively kitchen and plate waste, would be likely explained by practice theory due to its influence on profitability and high cost of disposal (Filimonau et al., 2020).

The ingenuity of the chefs in the food service operations should be noted. There is a variety of scholarly opinions on the concept of resourcefulness among chefs as a determinant in the prevention of food waste in the course of earlier research. The literature indicates that resourceful cooking, which is characterized by the creative use of excess foods, changing cooking methods, and minimization of food wastage, is not only a practical requirement in the context of climate change and food insecurity but also a moral imperative of the contemporary food systems (de Visser-Amundson, 2022; Duursma et al. 2016). The capacity and desire of the chefs to participate in such practices is emerging to be regarded as the heart of sustainable food services operation. A number of sources use the emphasis on the necessity to incorporate resourcefulness into the culinary education and professional development, stating that it should be a part of hospitality education programs (UNDP, 2025; Papargyropoulou et al., 2016; Filimonau, 2021; Principato et al. 2018). However, the previous studies also indicate a conflict between innovation and tradition: some of the chefs have adopted adaptive and waste-aware approaches, but others are still tied to the conservative habits or constrained by the institution (Goossens et al., 2020; Karakas, 2021; Ball et al., 2003). This opposition highlights the imbalance in the use of resourceful cooking applied to contexts and individual experts of this craft. Our research will help to shed some

light on the facilitators and obstacles that influence the food waste practices of these individuals since we will analyze their attitudes, training, and perceived autonomy. It is imperative to know how much resourcefulness is implemented in the high-end culinary setting in order to develop interventions that transcend policy and technology and focus on the human skillset and mindset that lie at the core of the food service work.

2. Results and discussion

As a brief overview of the Serbian hospitality sector, the research findings highlight the importance of food waste prevention and management practices. It is necessary to start by summarizing earlier research, which has found a correlation between food waste management practices and the Food Waste Hierarchy Principles. A company's or hotel/restaurant's compliance with food waste policy can be assessed by using the Food Waste Hierarchy Principles. Waste shorting, for instance, is strongly encouraged within the company, according to earlier studies. Employee waste segregation training is available, according to the findings (Michalec, 2018), and it is typically given internally. They all acknowledge collaboration with local farmers and the use of local ingredients, which enables hotel guests to understand local culture through local cuisine—but only in certain situations, such as when the theme is sustainable dining with zero waste, local meals, or Nacional cuisine (Burke & Napawan, 2020). The results of this study also support earlier concerns about food waste in many developing nations, including logistical problems and inefficient managerial and operational processes (Thaore et al., 2024; Dolnicar et al. 2020; Wu & Teng, 2022). For instance, this study shows that in order to prevent food waste, most hotels take care to order the appropriate quantity of food ingredients at the appropriate time and store them in the proper location and at the appropriate temperature. For example, the chain owned and self-management hotels reported that arranging food with First-In-First-Out (FIFO) and labelling food ingredients that show the product expiry dates and storage instructions are the procedures used to avoid spoilage of raw food ingredients the storage. Food safety is emphasized in addition to food waste.

Regarding food waste, this paper presents the current managerial viewpoints from Novi Sad and Belgrade hotels and restaurants (Vuksanović et al., 2025a; Vuksanović et al., 2025b), which influenced the most effective sustainable methods of managing food waste. This study also fills in the gaps in sustainable food waste management in hospitality and tourism research by applying the Food Waste Hierarchy and offering theoretical implications. This example has been emphasized as a good practice in earlier research (Srijuntrapun et al., 2022). For the Coffee Shop and Room Services, the hotel uses the Green-menu planning with visual symbols or pictures to help reduce food waste in the event that our guests are unsure about the food taste, such as "spicy or not spicy" (customers' food ordering decision-making indicating their food taste preferences). Considering all aspects of food waste, hotel management might be interested in taking part in the implementation of "Green Hotels." Green team committees and internal staff competitions to reduce food waste and other waste are also a part of it.

This study also highlighted the important role of food waste prevention and management practices, which may have been missed in previous research. One type of research used an interview schedule from Filimonau et al. (2023). This tool helps reveal how much head chefs understand the food waste issue in their kitchens (Vuksanović et al., 2025a). For example, previous research shows that typical food waste practices include providing food waste management seminars and training to employees, planning to reduce food waste, stocking the right amounts of raw materials, and purchasing raw materials that leave fewer leftovers. It also involves using a First-In-First-Out storage method, storing food at the correct temperature and location to delay spoilage, regularly checking expiry dates, handling food in a way that creates fewer leftovers in the kitchen, asking staff to help reduce food waste, using nearly expired food for cooking in the staff canteen, reusing food scraps to create new food products or menus, giving excess food to employees, and offering doggy bags to customers upon request.

The findings from this study provide several practical implications for hotel managers, chefs, hospitality educators, and policymakers who want to adopt sustainable food waste practices. Previous research highlights the clear need for organized training programs focused on preventing food waste and teaching resourceful cooking techniques, especially for junior chefs who often lack the necessary skills and experience. These programs should cater to different staff levels and include lessons on the principles of the Food Waste Hierarchy, practical demonstrations of resourceful cooking methods, and best practices for storage, labeling, and applying the First-In-First-Out (FIFO) method. Additionally, corporate policy plays a vital role; hotel management should review existing procedures that might unintentionally discourage food reuse or resourceful kitchen practices. Internal policies should instead promote the safe reuse of ingredients, encourage flexibility in menu development, and allocate resources like budget and personnel to track food waste and support training initiatives. The study also stresses the need for investing in suitable technologies and infrastructure. Hotels should look into using digital inventory management tools that notify staff of upcoming expiry dates, waste-tracking systems that connect with kitchen operations, and equipment like vacuum sealers, composting units, and bio-digesters to manage food waste efficiently on-site.

While this study offers valuable insights into food waste prevention and management practices, it has some limitations. First, the research focuses on the hospitality sector in Serbia, which limits how broadly the findings can be applied. Although this approach effectively revealed in-depth perspectives, it may not capture the full range of food waste practices in the wider hospitality sector in Serbia. Second, data collection was limited to hotels and restaurants, which often face different constraints and standards than mid-range or independent establishments. Additionally, while the study highlighted internal practices and corporate policies, it did not fully explore external factors like consumer behavior, government regulations, or economic incentives that could influence food waste prevention at the organizational level. Given these limitations, future research should aim to expand the scope by including a wider variety of hospitality settings, such as budget hotels, independent restaurants, and catering services. Comparative studies across different hotel categories and geographical regions would help determine if the findings from this study apply to other contexts. Moreover, mixed-method approaches that include quantitative data, such as food waste measurements, customer surveys, or financial cost analyses, could enhance qualitative insights and provide a clearer view of food waste dynamics. Future research should also look into the effects of hospitality education, policy frameworks, and technological innovations on food waste reduction outcomes, along with the potential for collaborations across sectors in food donation, composting, or circular economy initiatives.

Conclusion

This study examined food waste prevention and management practices in both the literature and Serbia's hospitality sector. It fills a gap in research and is the first brief study on this topic. The results show a need to improve both the theoretical and practical understanding of food waste. From a theoretical perspective, this research addresses and fills gaps in sustainable food waste management practices within hospitality. Using the Food Waste Hierarchy Principles as a model, it highlights different aspects and levels of food waste management practices in the hospitality sector. Finally, the research also finds that corporate influence plays an equally important role. Knowledge of food waste among chefs can be strengthened by corporate support.

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Leveraging IT Solutions to Enhance Brand Experience: From UI/UX to Customer Engagement

Korišćenje IT rešenja za unapređenje iskustva brenda: od UI/UX dizajna do angažovanja korisnika

Lazar Petrović[1], Kristina Jauković Jocić[2], Tamara Ristić[3]

[1]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, lazar.petrovic@mef.edu.rs*
[2]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, kristina.jaukovic@mef.edu.rs*
[3]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, tamara.ristic@mef.edu.rs*

Abstract: *Information technology has become a defining force in contemporary branding, reshaping how consumers interact with, interpret, and form emotional ties to brands. With digital platforms, advanced UX practices, AI-driven engagement tools, and data-intelligent systems embedded across customer touchpoints, brand experience has evolved into a dynamic and adaptive process grounded in personalization and real-time interaction. Empirical studies highlight that well-designed digital interfaces, predictive customer-behavior systems, and automated communication mechanisms enhance satisfaction, trust, and loyalty by enabling seamless user journeys and context-aware engagement. At the same time, increased reliance on behavioral data and algorithmic personalization introduces strategic and ethical concerns, including privacy risks, reduced authenticity, and emotional detachment when not carefully managed. Consequently, sustainable brand success in digital environments requires harmonizing technological precision with human-centered experience design to ensure personalization remains value-enhancing rather than intrusive. This paper analyzes the role of IT systems in shaping modern brand relationships, emphasizing digital touchpoints, emotional engagement architecture, and loyalty-building technologies. Findings suggest that the strategic fusion of intelligent systems and empathetic design elevates differentiation, reinforces trust, and fosters enduring brand loyalty.*
Keywords: *Digital brand experience, information systems, UX and UI design, customer engagement technologies, AI-driven personalization, emotional branding, digital loyalty systems.*

Apstrakt: *Informacione tehnologije postale su ključni pokretač savremenog brendiranja, menjajući način na koji potrošači komuniciraju sa brendovima, oblikuju percepciju i razvijaju emocionalnu povezanost. Sa uvođenjem digitalnih platformi, naprednih UX pristupa, alata zasnovanih na veštačkoj inteligenciji i sistema za obradu podataka u sve tačke korisničkog putovanja, iskustvo brenda postaje dinamičan i adaptivan proces zasnovan na personalizaciji i interakciji u realnom vremenu. Empirijska istraživanja ukazuju da dobro dizajnirani digitalni interfejsi, sistemi za prediktivnu analizu ponašanja korisnika i automatizovani komunikacioni mehanizmi povećavaju zadovoljstvo, poverenje i lojalnost omogućavajući besprekorno korisničko iskustvo i komunikaciju prilagođenu kontekstu. Istovremeno, sve intenzivnija upotreba podataka o ponašanju i algoritamske personalizacije donosi strateške i etičke izazove, uključujući rizike po privatnost, smanjenu autentičnost i emocionalnu distancu ukoliko se primenjuje bez jasnih humanocentričnih principa. Zbog toga održiv uspeh brenda u digitalnom okruženju zavisi od usklađivanja tehnološke preciznosti sa dizajnom koji polazi od ljudskih potreba, kako bi personalizacija ostala korisna i nenametljiva. Ovaj rad analizira ulogu informacionih sistema u oblikovanju savremenih odnosa između brenda i potrošača, sa fokusom na digitalne tačke kontakta, mehanizme emocionalnog angažmana i tehnologije lojalnosti. Rezultati ukazuju da strateška integracija inteligentnih sistema i empatičnog dizajna povećava diferencijaciju, jača poverenje i podstiče dugoročnu lojalnost potrošača.*

Ključne reči: *Digitalno iskustvo brenda, informacioni sistemi, UX i UI dizajn, tehnologije korisničkog angažmana, personalizacija zasnovana na veštačkoj inteligenciji, emocionalno brendiranje, digitalni sistemi lojalnosti.*

Introduction

Digital transformation has reshaped the foundations of branding, shifting the focus from static identity elements to dynamic, technology-enabled customer experiences. In an environment defined by continuous connectivity, instant access to information, and heightened expectations for personalization, information technology (IT) has become a primary force in how brands create, deliver, and sustain value. Modern brand strategy is increasingly executed through digital infrastructures — interactive platforms, adaptive interfaces, data-driven engagement systems, and intelligent service environments — positioning IT as a central mechanism for building emotional connection and competitive differentiation.

Research across marketing and information systems disciplines emphasizes that user experience quality, interface design, and automated personalization directly influence brand perception, satisfaction, and loyalty. Consumers now evaluate brands not only by what they offer, but by how seamlessly they communicate, how intuitively they function, and how meaningfully they respond to individual needs. Technologies such as artificial intelligence, cloud-based experience systems, advanced analytics, and immersive media play a critical role in shaping these perceptions, allowing organizations to orchestrate consistent, empathetic, and contextually relevant interactions across multiple digital touchpoints.

However, the integration of IT into branding introduces strategic and ethical considerations. Heavy reliance on automation, behavioral data, and algorithmic decision-making can compromise authenticity, elevate privacy concerns, and diminish emotional warmth when not guided by human-centric principles. Thus, sustainable brand impact emerges from balanced integration — where intelligent systems enhance, rather than replace, human-driven empathy and creative intent. This paper explores how IT solutions contribute to brand experience formation, examining interaction design, emotional engagement mechanisms, and customer loyalty systems as key pillars of contemporary digital branding strategy.

1. The role of IT solutions in shaping brand experience

In the contemporary digital era, information technology (IT) plays a crucial role in shaping and elevating brand experiences. IT solutions provide brands with the tools to offer personalized, seamless, and efficient interactions across various digital platforms, enhancing user engagement and cultivating stronger relationships with consumers. Technologies such as enterprise resource planning (ERP) systems, customer relationship management (CRM) software, and customer data platforms (CDPs) allow companies to centralize customer data, optimize business operations, and refine their marketing strategies, ultimately strengthening the brand's presence and impact (Kannan & Li, 2017; Jin et al., 2018). This capability to gather and analyze customer data is indispensable in modern branding, enabling businesses to tailor their interactions and provide offerings that resonate with individual consumer needs (Li, 2021).

Cloud computing stands out as one of the key IT solutions that significantly enhances brand experiences. With its scalable and flexible infrastructure, cloud services allow companies to quickly adapt to consumer demands, providing the agility necessary for real-time, customer-centric marketing strategies. As Li (2021) discusses, cloud platforms enable seamless integration across multiple touchpoints such as websites, mobile apps, and social media, ensuring a consistent and personalized experience for consumers. Furthermore, cloud-based systems offer cost-effective solutions for

maintaining up-to-date technologies without disrupting customer engagement or the overall brand experience.

The integration of artificial intelligence (AI) and machine learning (ML) into branding strategies has also played a transformative role in enhancing customer interactions. Venkatesan et al. (2021) explain that AI-powered systems enable brands to deliver highly relevant content based on real-time customer data, improving brand engagement and fostering stronger relationships with consumers. By leveraging these technologies, brands can predict consumer behavior and adapt their offerings dynamically, ensuring they remain relevant and responsive to customer needs. This real-time personalization has become essential for brands looking to stay competitive and engage customers meaningfully.

Additionally, augmented reality (AR) and virtual reality (VR) technologies have gained prominence in enhancing brand experience. Pantano et al. (2020) highlight how these technologies are revolutionizing the way customers interact with products, allowing brands to create immersive and engaging experiences that deepen emotional connections with consumers. By utilizing AR and VR, brands can create unique experiences that not only improve customer engagement but also differentiate their products in a crowded market.

Social media platforms, powered by IT solutions, have become integral to shaping and enhancing brand identity. Khan et al. (2019) stress the importance of social media analytics in measuring brand sentiment and adjusting marketing strategies accordingly. Through these platforms, brands can interact directly with consumers, fostering engagement and creating a dynamic, two-way communication channel that is critical for modern brand management.

Finally, the adoption of chatbots and conversational AI has become essential in improving customer service and enhancing brand loyalty. These technologies enable brands to offer round-the-clock support and personalized interactions, ensuring consistent communication and strengthening consumer trust. As Ghosh & Sharma (2022) note, chatbots and AI-driven customer service solutions not only improve the overall customer experience but also contribute to higher levels of customer satisfaction, retention, and brand loyalty.

1.1. Integrating IT into branding strategy

In the current digital era, integrating information technology (IT) into branding strategies has become crucial for businesses striving to maintain competitiveness. With technology continuously evolving, companies must adopt digital tools and innovative technologies to enhance brand interactions and create personalized experiences for customers. By utilizing IT solutions such as advanced analytics, cloud technologies, and machine learning, organizations can refine their brand messaging and align it with customer expectations, ultimately strengthening engagement and fostering brand loyalty (Zhao et al., 2023; Kumar & Patel, 2021).

A major IT solution driving brand strategy is the use of big data analytics, which allows companies to analyze vast amounts of customer data across different touchpoints. According to Choi et al. (2020), businesses that leverage data-driven insights are able to segment their customers more effectively, delivering targeted marketing campaigns that resonate with their audience. These insights allow for real-time adjustments to brand communication, making marketing efforts more relevant and improving customer satisfaction.

Furthermore, cloud computing has revolutionized the way brands manage data and engage with customers. Cloud services provide scalability, flexibility, and access to real-time data, allowing brands to tailor experiences across digital channels. Tan & Ang (2022) explain that cloud-based solutions enable companies to integrate various customer touchpoints, ensuring a consistent and personalized experience across platforms. Additionally, these solutions allow businesses to scale quickly and adjust their offerings to meet changing customer needs without disrupting the overall experience.

The integration of artificial intelligence (AI) has also significantly enhanced brand strategies. AI enables brands to deliver personalized content based on real-time consumer data. According to Pereira et al. (2021), AI allows companies to predict consumer behavior and adjust content dynamically, improving engagement and ensuring the brand remains relevant. As customer expectations evolve, AI-driven solutions offer businesses the ability to customize messaging and optimize content delivery, driving stronger customer relationships and increasing loyalty.

Additionally, augmented reality (AR) and virtual reality (VR) have emerged as valuable tools in shaping customer experiences. Pantano et al. (2020) highlight how these immersive technologies enable brands to engage customers in new ways, creating memorable, interactive brand experiences that deepen emotional connections. These technologies are particularly effective in industries like retail, where customers can virtually "try" products, helping brands stand out and providing innovative solutions to traditional challenges in product engagement.

Lastly, social media platforms, empowered by IT tools, have become essential for engaging with customers and shaping brand identity. Khan et al. (2019) stress the importance of using social media analytics to measure customer sentiment and adjust marketing strategies accordingly. Through these platforms, brands can engage in two-way communication with their audience, enhancing their brand image and fostering long-term loyalty.

2. The impact of UI/UX design on customer perception

In today's digital world, user interface (UI) and user experience (UX) design have become essential in shaping how customers perceive and interact with brands. The design elements of a brand's digital platforms, such as websites and mobile applications, significantly influence customer satisfaction, engagement, and long-term loyalty. Well-executed UI/UX design creates seamless, intuitive, and visually appealing experiences, which foster positive perceptions of the brand. According to Garrett (2020), effective UI/UX design not only aligns with consumer expectations but also enhances emotional connections between the user and the brand, which contributes to stronger brand loyalty.

UI design primarily focuses on the visual elements, such as layout, colors, and typography, while UX design encompasses the overall experience, including navigation, accessibility, and responsiveness. Fogg et al. (2021) argue that the fusion of both UI and UX is vital to providing a cohesive, engaging experience that promotes customer satisfaction. Studies have shown that customers are more likely to view a brand as reliable and trustworthy when they have a positive experience interacting with its digital interfaces, which ultimately increases engagement (Fogg et al., 2021).

The quality of UI/UX design directly influences how customers perceive a brand, particularly in terms of trust and ease of use. Kim & Lee (2022) emphasize that a poorly designed interface can lead to frustration, causing customers to abandon the brand. On the other hand, an intuitive and aesthetically pleasing interface improves users' perceptions, fostering a sense of loyalty. By understanding consumer preferences, brands can optimize their UI/UX elements to enhance usability, create stronger brand connections, and increase engagement (Agarwal et al., 2023).

Personalization is another critical aspect of UI/UX design. By allowing users to customize their interactions with the brand, businesses can create a sense of ownership and improve customer satisfaction. Lee & Lim (2021) found that when users feel their experience is tailored to their individual preferences, they are more likely to engage with the brand long-term. Personalization also enhances the emotional connection between the user and the brand, which drives loyalty and repeat interactions.

Furthermore, accessibility and responsiveness are crucial factors in UI/UX design that influence customer perception. A well-designed interface should be accessible to all users, regardless of their abilities. Shneiderman & Plaisant (2019) highlight that accessibility features, such as larger fonts, voice commands, and high contrast visuals, are essential in ensuring that all customers have a positive

interaction with the brand. These features not only enhance usability but also demonstrate the brand's commitment to inclusivity and customer satisfaction.

2.1. Designing for user-centered experiences

Modern digital branding requires interfaces and interaction models built around real user needs, behaviors, and emotional responses. User-centered design (UCD) prioritizes the consumer throughout the design lifecycle, ensuring that digital products are intuitive, efficient, and capable of fostering meaningful brand connections. Research shows that brands implementing structured user-focused methods consistently experience stronger customer engagement, improved trust, and higher emotional attachment (Bargas-Avila & Hornbæk, 2019). The UCD process typically relies on iterative prototyping, usability assessment, and data-driven refinement, aligning interface logic and system structure with authentic user behavior patterns (Lallemand et al., 2021).

Usability sits at the core of user-centered interaction. When digital systems reduce cognitive effort, simplify task flows, and provide clear guidance, users report elevated satisfaction and more favorable brand perceptions (Sutcliffe & Rugg, 2020). Design elements such as visual hierarchy, interaction timing, and clarity of call-to-action cues directly shape judgments of brand professionalism and reliability (Yen & Tu, 2022). In addition, embedding accessibility principles enhances inclusivity, enabling broader participation by users with diverse needs, which strengthens brand credibility and long-term trust (Ibrahim & Kuru, 2023).

Personalization has also become a defining factor of effective user-centered environments. Dynamic interface adaptation, preference-based content delivery, and situational customization increase perceived value and deepen relational bonds between users and brands (Hussain & Mkpojiogu, 2019). Evidence shows that adaptive UI systems increase engagement, emotional commitment, and repeat interaction likelihood by making digital environments feel personally relevant and responsive (Adepeju et al., 2023).

Ultimately, user-centered design establishes digital touchpoints not merely as functional systems, but as human-aligned environments that cultivate loyalty and differentiate the brand experience. Organizations implementing systematic UX research, continuous usability evaluation, and inclusive design frameworks build more resilient brand relationships and competitive advantage in increasingly experience-driven markets (Beaird & George, 2020; Pappas, 2021).

3. IT-enabled customer engagement and emotional branding

In contemporary digital ecosystems, information technology functions as the backbone of emotionally resonant brand interactions and sustained user engagement. Modern consumers encounter brands across interconnected digital touchpoints, and IT infrastructure enables companies to maintain consistency, personalization, and continuity across those experiences. Advanced data systems, automated interaction platforms, and adaptive engagement tools support brands in responding contextually to user actions, reinforcing emotional affinity and strengthening long-term loyalty (Patrício et al., 2020; Lemon, 2021).

Customer engagement theory demonstrates that meaningful brand relationships emerge when individuals feel acknowledged, emotionally understood, and supported throughout digital interaction. Sophisticated CRM architectures, AI-driven sentiment systems, and omnichannel engagement engines help organizations monitor user emotions, anticipate dissatisfaction, and intervene proactively, resulting in heightened trust and deeper involvement (Harrigan et al., 2023). Integrated digital ecosystems unify touchpoints across mobile, web, chat, and social channels, creating cohesive user journeys that increase satisfaction and reinforce perceptions of reliability and professional brand identity (Herhausen et al., 2020).

Artificial intelligence plays a central role in developing emotionally intelligent communication. Through sentiment modeling, language personalization, and predictive response systems, brands can decode emotional cues and deliver context-sensitive communication scaled across digital environments. Research indicates that AI-supported interaction enhances emotional immersion and behavioral engagement when communication retains authenticity, consistency, and responsiveness (Grewal et al., 2022). Immersive technologies including AR and VR further elevate emotional memory and experiential depth by strengthening presence, narrative immersion, and sensory impact (Dwivedi et al., 2021).

However, trust remains foundational. Users form strong emotional bonds only when personalization is perceived as respectful, transparent, and aligned with ethical data practices. Adhering to consent principles, clarity in data use, and responsible personalization frameworks helps reduce perceptions of manipulation, preserving emotional trust and reinforcing long-term loyalty (Mulcahy et al., 2023; Martín-Consuegra et al., 2020). Ultimately, IT-driven engagement strengthens emotional branding when technology is deployed in service of human needs, ensuring that automation enhances—rather than replaces—authentic relational value.

3.1. Digital touchpoints, experience design, and brand loyalty

Digital touchpoints—including mobile platforms, branded apps, intelligent chat systems, and interactive web environments—have become essential mechanisms for shaping how consumers perceive and emotionally connect with brands. Well-structured interaction design, emphasizing intuitive navigation, responsiveness, and tailored communication, meaningfully influences user satisfaction and strengthens long-term attachment to a brand (Bleier et al., 2020). When customers experience fluid transitions between digital touchpoints and consistent quality of interaction, trust increases and repeat engagement becomes more likely (Islam et al., 2021).

Scholarly findings continue to show that digital experience quality reinforces brand authenticity and consumer emotional bonds. Technologies such as predictive modeling, behavioral pattern analysis, and adaptive communication frameworks allow brands to anticipate customer needs and craft personalized experiences that enhance emotional resonance (Rosengren & Dahlén, 2022). Similarly, conversational interfaces, automated support channels, and voice-driven systems significantly strengthen perceived convenience and attentiveness, further deepening emotional connection (Borges et al., 2023).

Gamified interaction layers, digital communities, and loyalty-driven reward systems extend engagement by fostering positive emotional responses and nurturing a sense of belonging. These elements promote active participation and shared brand identity among users (Hamari & Tuunanen, 2024). Maintaining coherence in design language, communication style, and service reliability across all platforms enhances memorability and contributes to durable loyalty outcomes (Choi & Kandampully, 2019). Over time, consistently positive interactions reduce switching behavior and increase resistance to competitive messaging (Bilgin, 2020).

Achieving lasting loyalty in digital environments requires balancing automation with genuine relational value. Emotion-aware interface design, transparent personalization practices, and human-centered communication principles preserve trust while scaling engagement across channels (Kim et al., 2022). Ultimately, high-quality interaction design across digital touchpoints serves not only as a functional requirement but as a strategic foundation for emotional loyalty, deeper brand affinity, and long-term competitive advantage.

Conclusion

Information technology has evolved into a core driver of brand value creation, fundamentally reshaping how consumers experience and connect with brands. As digital environments mature, organizations increasingly depend on advanced technological infrastructures to deliver seamless, context-aware, and emotionally engaging interactions across diverse touchpoints. Contemporary research highlights that systems leveraging data intelligence, adaptive UX design, artificial intelligence, and immersive

interfaces empower brands to anticipate user needs, personalize communication at scale, and sustain meaningful engagement. Through such capabilities, technology strengthens brand trust, encourages repeated interaction, and supports the development of long-term loyalty. Yet, achieving sustained brand advantage in technology-mediated environments requires more than automation and operational efficiency. Effective brand strategy integrates technological innovation with human-centered values, transparent personalization, and emotional relevance. Brands that employ IT as a medium for genuine connection rather than purely transactional optimization foster deeper relationships and mitigate disengagement in crowded digital markets. Ultimately, competitive strength will belong to organizations that harmonize intelligent systems with empathetic design, creating digital experiences that honor user identity, reinforce trust, and cultivate enduring brand attachment.

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General vs. Internal Mediation in Workplace Bullying: Challenges and Limitations

Opšte i interno posredovanje u slučajevima zlostavljanja na radu: izazovi i nedostaci

Sanja Stankov[1], Ivan Petrović[2]

[1]*College of Academic Studies "Dositej", Belgrade, Serbia, sssanja89@gmail.com*
[2]*Advokatska kancelarija Ivan S. Petrović, Kraljevo, Serbia, ivanpetrovic.advokat@gmail.com*

Abstract: *Workplace bullying continues to occur and persist despite the existence of legislation. The issue arises as to whether employees, after recognizing such negative behaviors, will report the bullying or not. How much do employees actually trust the processing procedure, and to what extent does the Law on the Prevention of Workplace Bullying (LPWB) protect them? How well do they understand the mediation process, and what distinguishes general mediation from internal mediation? The aim and significance of this study have a broader societal dimension, as it addresses matters of public interest that reveal sensitive points within the current system of protection against bullying and highlight areas in need of urgent and clearer regulatory intervention. The research is based on an analysis of applicable laws and legal documents of the Republic of Serbia, aiming to provide clear and unambiguous guidelines for implementing mediation. In the concluding section, the authors present their perspective on possible solutions to the ambiguities of the LPWB, with the goal of establishing legal certainty for organizations and their employees in resolving disputes related to workplace bullying.*
Keywords: *Workplace bullying, mediation, general mediation, internal mediation, public interest, Serbia.*

Apstrakt: *Zlostavljanje na radnom mestu se kontinuirano javlja i opstaje, uprkos postojanju zakona. Problematika se pritom javlja da li će zaposleni nakon prepoznavanja ovih negativnih radnji prijaviti zlostavljanje ili ne? Koliko zaposleni zapravo veruju samom postupku procesuiranja i koliko ih Zakon o sprečavanju zlostavljanja zapravo štiti. Koliko razumeju sam postupak posredovanja i po čemu se razlikuje opšte od internog posredovanja? Cilj i značaj ovog rada imaju širi društveni karakter, jer se bavi pitanjima od javnog interesa koja razotkrivaju osetljive tačke postojećeg sistema zaštite od zlostavljanja i ukazuju na oblasti u kojima je neophodna hitna i jasnija normativna intervencija. Istraživanje se zasniva na analizi važećih zakona i pravnih dokumenata Republike Srbije, sa ciljem da pruži jasne i nedvosmislene smernice za sprovođenje posredovanja. U zaključnom delu rada autori iznose svoje viđenje mogućih rešenja o nedorečenosti ZSZR, kako bi se stvorila pravna sigurnost kod organizacija i njenih zaposlenih u rešavanju sporova povodom zlostavljanja.*
Ključne reči: *Zlostavljanje na radnom mestu, posredovanje, opšte posredovanje, interno posredovanje, javni interes, Srbija.*

Introduction

Workplace bullying in Serbia, according to Jovanović (2008), was initially identified as a sociological problem, then as a health problem, a socio-economic problem, and finally as a legal issue. Over time, this phenomenon has acquired an interdisciplinary character. Viewing this issue from an organizational perspective is of exceptional importance, primarily because it occurs and persists in organizations that support or even encourage such a culture.

Additional problems in practice arise from insufficient understanding of the procedure for protection against workplace bullying and the lack of knowledge of key legal steps, both on the part of the victims and those who are expected to provide protection. For this reason, the first chapter is structured to point

out the most critical legal points related to workplace bullying, including problematic interpretations of terms and an overview of key points from court practice.

The second chapter concisely presents the procedure for initiating protection, clarifying when the internal procedure is applied and when the general procedure is applied, the difference between an internal and an external mediator, as well as the legal effect of the agreement reached. The conclusion emphasizes the importance of combating workplace bullying, points out legal ambiguities that cause justified fears and uncertainties in the procedure, and provides recommendations for its improvement.

Furthermore, this study maintains the continuity of research and monitoring of workplace bullying in Serbia (e.g., Stankov et al., 2021; Stankov et al., 2022) and the protection of human rights (Petrović, 2025), with the aim of raising public awareness and creating a safer and healthier working environment.

1. Workplace bullying

There is no single definition of bullying in the literature. Although the terms "mobbing" (Leymann, 1996) and "bullying" (Adams, 1992) are most commonly used to describe negative behaviors in the workplace, related or associated concepts can also frequently be found, such as psychological terror (Leymann, 1990), harassment (Brodsky, 1976), victimization (Olweus, 1994), emotional abuse (Keashly, 1997), workplace aggression (Baron & Neuman, 1996), and workplace incivility (Andersson & Pearson, 1999). Essentially, all these terms refer to the same phenomenon. European researchers, who have been studying workplace bullying for many years, offer one of the most comprehensive definitions of this phenomenon:

"Workplace bullying refers to the harassment, verbal abuse, and social exclusion of an individual, as well as the negative impact of these behaviors on the performance of their work tasks. For a specific activity, interaction, or process to be classified as bullying (mobbing), it must be repeated, occur with temporal regularity (e.g., on a weekly basis), and persist over a defined period (e.g., approximately six months). Bullying is an escalation process during which the targeted individual ends up in an inferior position and becomes the focus of systematic negative social behaviors. Therefore, a conflict cannot be considered bullying if the incident is an isolated event, or if the conflict involves two parties that possess roughly equal power" (Einarsen et al., 2011, p.22).

Bullying at work means harassing, offending, socially excluding someone, or negatively affecting someone's work. In order for the label bullying (or mobbing) to be applied to a particular activity, interaction or process it has to occur repeatedly and regularly (e.g. weekly) and over a period of time (e.g. about six months). Bullying is an escalating process in the course of which the person confronted ends up in an inferior position and becomes the target of systematic negative social acts. A conflict cannot be called bullying if the incident is an isolated event or if two parties of approximately equal 'strength' are in conflict

Based on the definition, it can be observed that, in addition to the frequency of bullying behavior, a long-term pattern of repetition (longer than six months) is considered the most significant characteristic of the concept of bullying (Ertureten et al., 2013), whereas a negative act that occurred only once (e.g., tasks below the level of competence, short deadlines for task completion) cannot be considered bullying (Vartia, 1996).

Regarding domestic legislation, it does not specify how many times bullying behavior must occur. For this reason, this paper will primarily focus on the legal aspect of the Republic of Serbia, in order to avoid confusion between the definitions found in the literature and the domestic legal framework. The following sections will present the most critical and sensitive provisions of the domestic legal framework, to which all actors should pay particular attention.

The Law on the Prevention of Workplace Bullying ("Official Gazette of the Republic of Serbia", No. 36/2010, hereinafter: LPWB), which entered into force in June 2010, defines workplace bullying in Article 6 as follows:

"Bullying, within the meaning of this law, is any active or passive behavior towards an employee or a group of employees at the employer, which is repeated and aims at or constitutes a violation of dignity, reputation, personal and professional integrity, health, or position of the employee, and which causes fear or creates a hostile, humiliating, or offensive environment, worsens working conditions, or leads to the employee being isolated or induced to terminate the employment relationship or cancel the employment contract or another agreement on their own initiative, as well as encouraging or inducing others to engage in such behavior."

Since repetition is a legal requirement for the existence of bullying, it is important to clarify whether bullying can also be considered in the case of a single act. The answer is that bullying can exist even at the first incident, provided that the following conditions are met:

- that the incident is carried out in the same or a similar manner (pursuant to Article 6 of LPWB and Article 12 of the Rulebook on the Code of Conduct for Employers and Employees in relation to the Prevention and Protection against Workplace Bullying ("Official Gazette of the Republic of Serbia", No. 62/2010, hereinafter: Rulebook)), consciously and with the same intent – analogous to the principle of an extended criminal offense[1]. Specifically, in accordance with the provision of Article 61, paragraph 1 of the Criminal Code ("Official Gazette of the Republic of Serbia", No. 85/2005, 88/2005 – corrigendum, 107/2005 – corrigendum, 72/2009, 111/2009, 121/2012, 104/2013, 108/2014, 94/2016, 35/2019 and 94/2024). This concerns the identity of the victim, the similarity of the acts of bullying, the use of the same situation, unity of place, and a single intent.

The second condition for the existence of bullying is that it is carried out intentionally, which distinguishes bullying from a conflict. Intent can relate to the aim (violation of dignity, creating a hostile and offensive environment, worsening working conditions) and to the consequence (causing the employee to terminate the employment contract), or to both.

In case law, ambiguities arise regarding the question of how many times bullying must be repeated for it to be considered to exist. This issue is of particular importance for the uniformity of judicial practice. In order for employees to decide to even enter the procedure, it is essential that they possess this important information and understand the way courts think and act in such cases.

Positions from case law:

- "Workplace bullying is a manner of behavior in the workplace in which one or more persons, who are other employees and may be superiors or subordinates, systematically psychologically abuse or intimidate another person over a relatively long period, almost daily or periodically for several months, with the intention of undermining the professional reputation and moral integrity of the employee, as well as their professional and human dignity over an extended period, and with the aim of creating unbearable working conditions, whereby the person subjected to bullying is in an almost helpless position, all with the purpose of inducing the employee to resign from the employment relationship".[2]
- "When, in a specific case, the actions of the defendant cannot be assessed as repeated actions, which represents a necessary element for establishing the existence of workplace bullying, but rather constitute an isolated incident, i.e., a conflict, then workplace bullying does not exist within the meaning of the Law on the Prevention of Workplace Bullying".3

[1]"Paragraf Lex", Electronic Legal Database, Journal: Pravnik u privredi 2019 / 188
[2]Judgment of the Court of Appeal in Novi Sad, Gž. 1195/16 of May 13, 2016.
[3]Judgment of the Court of Appeal in Novi Sad, Gž. 255/16 of February 11, 2016.

- "An essential characteristic of bullying is, among other things, the repetition of acts that constitute bullying, whereas occasional differences of opinion, problems, and conflicts related to the performance of tasks and work assignments cannot be considered bullying, unless they are intended to harm or deliberately insult the employee".[4]
- "If an employee does not receive any work assignments and is excluded from the work process and communication with other employees, without factual and active involvement in the work process, all with the aim of inducing the employee to terminate the employment relationship or cancel the employment contract on their own initiative, this constitutes the so-called 'empty desk' mobbing, i.e., a specific form of psychological abuse and harassment at work and the isolation of the employee".[5]

Based on the above-mentioned case law, courts face a significant task, as they must approach such situations with great caution and, above all, assess the results, i.e., the consequences of the alleged bully's behavior on the alleged victim, while the time interval between two or more such acts must not be viewed formally. Specifically, in court proceedings concerning bullying, the focus should be on the duration of the consequences of the act, rather than on the duration of the act itself.

The legal procedure is particularly problematic in situations where an employee enters the procedure, and it is subsequently determined that no bullying occurred. In such cases, if there is suspicion that the right to protection against bullying was abused, the employer is obliged, pursuant to Article 23 of the LPWB, to initiate a procedure for establishing the responsibility of the employee for a violation of work discipline or duty. The same sanctions are provided both for committing bullying and for abusing the right to protection (warning, suspension without pay, permanent reassignment in accordance with the law).

For the existence of abuse, two cumulative conditions are required:

1. that the employee was aware or could have been aware that there was no reasonable grounds to initiate the procedure for protection against workplace bullying, and
2. that they did so with the intention of obtaining a benefit for themselves or causing harm to another.

Based on the above, it can be concluded without a doubt that without a lucrative motive there is no abuse, just as without intent there is no bullying.

Many employers, through a general act – either a collective agreement or a work rulebook – stipulate the abuse of the right to protection against workplace bullying as a justified reason for dismissal, in accordance with the Labor Law ("Official Gazette of the Republic of Serbia", No. 24/2005, 61/2005, 54/2009, 32/2013, 75/2014, 13/2017 – Supreme Court decision, 113/2017, and 95/2018 – authentic interpretation; hereinafter: LL), Article 179, paragraph 3, item 8).

A more recent position of the Supreme Court (Decision of the Supreme Cassation Court Rev2. 1137/21 of 24 February 2022) is that the termination of an employment contract by the employer is lawful if the reason for dismissal is provided for in the employer's general act, the employee has been made aware of it, and the dismissal procedure under LL has been followed. The Supreme Court's position is that it is the employer's autonomous right to decide whether, in the case of a violation of work duties or discipline, to sanction it by dismissal or by a milder measure provided for under LL. Based on this Supreme Court position and the ambiguity of the law, employees may be even more reluctant to initiate a procedure for protection against workplace bullying, because if they fail to prove that they have been bullied, the employer may terminate their employment contract. This is particularly important as it demonstrates how legal uncertainty can discourage employees from protecting their rights.

[4]Judgment of the Court of Appeal in Novi Sad, Gž. 3402/16 of November 21, 2016.

[5]Judgment of the Higher Court in Kragujevac, P1-1/15 of June 8, 2016, and Judgment of the Court of Appeal, Gž1. 2978/16 of September 1, 2016.

1.1. Distinguishing between discrimination and workplace bullying

Discrimination at work, or in relation to work, and workplace bullying are two distinct phenomena. They differ both in terms of motives and in terms of the acts themselves. They also differ in terms of legal regulation, so in all countries (including Serbia) there are separate legal regimes for their prevention and, if necessary, sanctioning.

However, discrimination and bullying can sometimes converge in certain forms, and especially their almost identical consequences can confuse those applying the law. For this reason, it is important to clearly determine which behaviors constitute discrimination and which constitute workplace bullying (Petrović, 2025).

- LPWB introduces confusion in the application of the rules, as Article 3 provides that its provisions also apply to cases of sexual harassment, in accordance with LL. Although it is understandable that sexual harassment is recognized as one form of workplace bullying, referring to LL is not purposeful, since Article 21 of the same law treats sexual harassment as a form of discrimination. Despite this confusion, it is important to point out that for employees who have experienced sexual harassment, it is more effective to initiate a discrimination protection procedure, as the existence of discrimination requires only a single act, whereas workplace bullying is characterized by continuity.

2. Initiating the protection procedure

2.1. Internal or external mediator

One of the less common practical questions is whether to choose an internal or external mediator to conduct the employee protection procedure. Each choice has its advantages and disadvantages. The advantage of an internal mediator is that they know the staff, motives, business policies, and internal regulations. The disadvantage is that there is often doubt about their impartiality, as they might be seen as siding with the employer "because they are on the employer's payroll," and they may not have undergone mediation training, unlike an external mediator who holds a mediation license issued by the Ministry of Justice. In addition, they often do not know the legal framework for mediation, including LPWB, the Rulebook, LL, and other applicable regulations in this area. They also lack mediation skills, as they are not qualified for this role.

An external mediator knows the legal framework and possesses problem-solving and mediation skills, but "does not know how the company functions internally," which can make it more difficult to fully assess the situation.

In practice, the best solution has proven to be an internal mediator who has an affinity for this role. It is important that the employer provides this person with adequate training and that they willingly accept the task, so as not to create fear or resistance. It is also essential that this person is considered fair and incorruptible within the workplace and enjoys the trust of employees. Although the mediator does not decide the outcome of the mediation, they are a key factor in finding a compromise solution. For this reason, it is highly beneficial for individuals designated as mediators to undergo training to acquire the knowledge and skills necessary for successfully conducting the mediation procedure.[6]

2.2. Mediation at the employer – internal procedure

Internal mediation is an informal procedure conducted in accordance with the LPWB, in which the mediator assists the parties in reaching a mutually agreed solution.

Mediation in resolving disputes related to workplace bullying, i.e., the attempt at internal resolution, is mandatory, except when the employer or a responsible person at the employer is accused of bullying

[6]"Paragraf Lex", Electronic Legal Database, Journal: Pravnik u privredi 2023 / 277

(Article 14, LPWB). A person who believes they have been subjected to bullying is obliged, before filing a lawsuit, to submit a Request for Protection against Bullying to the employer (Article 13, LPWB, and Article 22, Rulebook), who is required to initiate the procedure and provide a list of mediators within three days (Article 15, LPWB). If the requester and the person accused of bullying agree on the choice of mediator, the mediator conducts the procedure, which lasts from 8 to 30 days.

The purpose of mediation is not the declarative determination of guilt or the sanctioning of the perpetrator, but rather to regulate the relationship in a manner acceptable to both parties, with the employer's consent being mandatory. For example, the removal of the "bully" cannot be demanded, but the relationship with them can be arranged differently (e.g., tasks may be delegated via email, work duties assigned according to a weekly plan, except in unforeseeable situations). A particular feature of mediation in labor disputes is that the agreement between the parties is limited by the will of a third party—the employer. If the employer does not agree with the settlement the parties wish to reach (because it is not in line with business policy or disrupts workflow), the agreement cannot be concluded.

The success of mediation largely depends on the skills of the mediator. Beyond knowledge of the LPWB and the set of labor laws, it is crucial for the mediator to understand business and workplace relationships beyond the immediate context of the dispute. The mediator must possess emotional intelligence, given that the psychological aspect of workplace bullying is always present, and the process is emotionally charged. Additionally, social intelligence and strong communication skills are essential, as they are the mediator's most effective tools in resolving conflicts.

The procedure is conducted according to the mediator's assessment of what is most appropriate in each case, while respecting the fundamental principles of urgency, voluntariness, secrecy, and confidentiality. The principle of voluntariness is key and can shape the application of other principles—for example, the deadline may be mutually extended if a resolution appears likely. Opinions differ regarding the presence of attorneys in mediation, as the goal is to reach an agreement rather than to prove or establish fault. It is also important to note that any agreement depends in part on the "bargaining" power of the parties, which may derive from available evidence.

2.3. Mediation at the employer – external mediator

One of the prerequisites for conducting the mediation process is the parties' agreement on the choice of mediator. If the parties cannot agree on the selection of a mediator, the employer may issue a notice of termination of the procedure and deliver it to the parties, in accordance with Article 20, paragraph 1, item 1) in connection with Article 15, paragraph 3 of the LPWB. The employer may, but is not obliged to, accept the choice of an external mediator if there is a list of internal mediators, especially if they have been invested in through training, since the external mediator represents a cost borne by the employer under the Law, in accordance with the Rulebook on the Tariff, Fees, and Reimbursements in the Mediation Procedure ("Official Gazette of the Republic of Serbia", No. 35/2015, hereinafter: Tariff Rulebook), which amounts to 13,000 RSD per session, although a fixed fee for the completed work may also be agreed upon with the mediator.

2.3.1. Contract between the employer and the external mediator

The mediator concludes a service contract with the employer, the subject of which is mediation in resolving a workplace bullying dispute, and the fee is regulated by the Tariff Regulation, amounting to 13,000 RSD per session (130 points × 100 RSD). For procedural efficiency, the mediator may hold joint and separate sessions on the same day, which can still be billed at 13,000 RSD. In practice, the most common number of sessions ranges from three to five.

2.4. Conclusion of the procedure – agreement

The resolution of a workplace bullying dispute is successfully concluded through an agreement, or unsuccessfully through termination of the procedure. If the parties fail to reach an agreement on the choice of mediator, the employer terminates the procedure by issuing a notice, from the receipt of which

the 15-day preclusive period for filing a lawsuit (Article 29, paragraph 2, LPWB) begins, which is submitted to the Higher Court. In this situation, the employee has the option to initiate general mediation at any time, either before filing a lawsuit or during the court or appellate proceedings, which is a major advantage of general mediation.

2.4.1. Effect of an agreement on the resolution of the dispute

The effect of a signed agreement is binding, and it is advisable to foresee monitoring of the agreement's implementation by the employer's human resources department.

Mediation is successfully concluded through an agreement, which, upon obtaining the employer's consent, is binding for all participants, while monitoring can be assigned to the human resources department. Article 21 of LPWB states: "The agreement particularly contains measures aimed at ceasing behavior that constitutes workplace bullying, or preventing the possibility of continuation of such behavior – bullying. The effect of an agreement reached in the mediation process depends on the will of the parties to the dispute if the agreement regulates behavior in their mutual relations." Therefore, the provision should be interpreted in such a way that the content of the agreement depends on the parties' will to reach a mutually acceptable solution, while the effect of the concluded and signed agreement is binding – lex contractus – and cannot be modified during its implementation without subsequent consent from the same employer, in accordance with Article 133 of the Law on Obligations ("Official Gazette of the SFRY", Nos. 29/78, 39/85, 45/89 – Supreme Court decision, and 57/89; "Official Gazette of the FRY", No. 31/93; "Official Gazette of Serbia and Montenegro", No. 1/2003 – Constitutional Charter; and "Official Gazette of the Republic of Serbia", No. 18/2020; hereinafter: LO).

The outcome of the previous procedure within the employer's framework is likely its most fragile point. This is primarily due to the aforementioned shortcomings of the procedure, both legal and practical. In the case of internal mediators, it often happens that they do not fully understand their role in the process, so the agreements they ultimately present to the parties resemble records of conducted conversations more than formal resolutions of the issues raised.

Most often, neither the problem nor the solution is properly formulated, and sometimes the agreement includes a general clause stating that both parties will comply with the LPWB and refrain from any actions that could mutually jeopardize each other. Such a formulation appears particularly cynical, as it effectively places both parties on the same footing, treating both the perpetrator and the victim as equally "at fault" for the dispute arising in the first place.

These shortcomings are far from insignificant and they undoubtedly undermine the entire procedure, which, for all three employees as well as the employer, becomes a process without substance and without real effect, while also consuming additional resources. In this way, such an approach further empowers the perpetrator and discourages the victim.[7]

2.5. General mediation

In Serbia, the legal framework recognizes various methods of alternative dispute resolution, among which particular importance is given to mediation (see Petrović & Pejović, 2023). This form of dispute resolution was introduced in response to the slowness and complexity of judicial proceedings, which often involve lengthy and costly processes. Mediation is conducted on a voluntary basis, where the mediator does not impose a solution but assists the parties in achieving mutual understanding and reaching an agreement through dialogue and negotiation (Shram, 2016). The aim of this process is to create an atmosphere of trust in which participants can express their interests and concerns and find compromise solutions acceptable to both parties (Zhomartkyzy, 2023).

In cases of workplace bullying, the procedure may be applied when the employer or a responsible person at the employer is accused of bullying, when internal dispute resolution has failed, or when

[7] "Paragraf Lex", Electronic Legal Database, Journal: Pravni instruktor 2012 / 2

court proceedings are already underway. This mediation, which represents the most effective method of resolving labor disputes, is provided for by the Law on Mediation in Dispute Resolution ("Official Gazette of the Republic of Serbia", No. 55/2014, hereinafter: LMDR), which has been in force since January 1, 2015 (Ministry of Justice of the Republic of Serbia, 2018, hereinafter: MJRS). This law builds upon the earlier 2005 Law on Mediation, and its adoption was motivated by the need to improve the existing framework in accordance with practice, European legal standards, and international treaties (Pavić & Đorđević, 2014). The principle of impartiality is extremely important, as the mediator must act fairly and neutrally, adhere to all the aforementioned principles, and focus solely on procedural aspects of the process, without offering comments or opinions on court decisions, giving advice, or proposing solutions. Interestingly, this principle does not exist in internal mediation under LPWB, meaning that a mediator conducting the procedure may point out legal violations, provide advice, and propose solutions—an important distinction from general mediation. The entire general mediation process is conducted without unnecessary delays, aiming for a swift and efficient resolution of the dispute, and all proposals, statements, and evidence presented during the procedure remain legally inadmissible in other proceedings, unless the parties agree otherwise.

It is important to emphasize that the law allows mediation to be conducted both before the initiation of court proceedings and during their course, regardless of whether it is a first-instance or second-instance procedure. In this way, organizations are given the opportunity to attempt to resolve the dispute amicably even while the proceedings are ongoing. If the parties mutually decide to resolve the dispute through mediation, the court will issue a decision to suspend the proceedings and refer them to mediation, providing all necessary information, including a reference to the Register of Mediators[8]. If the dispute is not resolved within 60 days, the court will resume the proceedings. Conversely, if a settlement agreement is reached, the court will terminate the proceedings by decision, and the case will be considered resolved by the presiding judge. This provision is significant for the evaluation of judges' performance by the High Judicial Council and serves as an additional incentive for judges to refer parties to mediation (MJRS, 2017). The Register contains a list of licensed mediators, including basic information, contact details, and information on completed specialized training.

A particular advantage of mediation, which gives it exceptional value, is the fact that attempting mediation does not result in the loss of the right to judicial protection. This is a significant reason why parties should always attempt mediation, that is, try to resolve the dispute amicably. If, despite all efforts, an amicable resolution is not reached, the parties always have the court and judicial protection available to them.

2.5.1. Effect of the agreement

Article 28 of the LMDR provides that the provisions of the LO governing out-of-court settlements shall apply accordingly to the conclusion, effect, and termination of an agreement reached in the mediation procedure under Article 26 of this law.

However, the key provision is set out in Article 27 of the LMDR. Specifically, this provision stipulates that if the parties wish to make a written agreement on dispute resolution through mediation enforceable as an enforceable instrument, they may do so upon the cumulative fulfillment of the following conditions:

- the agreement contains a declaration by the debtor consenting that the creditor, based on the dispute resolution agreement through mediation, may initiate enforcement proceedings after the claim becomes due (enforceability clause); and
- the signatures of the parties and the mediator are certified by a court or a notary public.

[8]Register of Mediators. Ministry of Justice of the Republic of Serbia. Available at: https://www.mpravde.gov.rs/intermediaries.php

In any case, this legal provision is far superior to what is provided under the LPWB, as it facilitates the enforcement of the reached agreement. Specifically, the measure is intended to relieve the court system, since parties in a dispute no longer need to initiate costly and lengthy enforcement proceedings if the need arises, but can resolve the matter within this procedure, fulfilling the primary purpose of implementing this alternative dispute resolution method within the judicial system of the Republic of Serbia.

Conclusion

The importance of combating workplace bullying lies in raising awareness among all citizens that such behavior is prohibited in every aspect of employment relations.

Although the LPWB has been in force since 2010, it still raises uncertainties and dilemmas in its application, as it contains various contradictions and significant potential for practical difficulties, or in certain cases, renders it impossible to apply. Analyzing the provisions of the LPWB, it is evident that its vagueness generates legal uncertainty, not only for organizations and their employees but also for judges, who consequently face justified apprehension when adjudicating cases related to workplace bullying.

Due to the ambiguities of the LPWB, it cannot be applied when the harassment is carried out by the founder and/or owner of a legal entity who "controls" the employees, nor when multiple legal entities share the same business premises, or when a person is engaged by an employer under a business cooperation agreement, i.e., to perform certain tasks for another legal entity, such as security staff, doormen, cleaners, housekeeping staff, drivers, printing house employees, telephone operators, etc., specifically employees provided by employment agencies. Such individuals, who may be exposed to harassment by the company's employees, would not be able to seek protection under this law, because they cannot sue the harassing employer, as that is not their employer, nor can they sue their own employer, because the harassment is not committed by an employee over whom their employer has any control.

The legal obligation to conduct an internal procedure is not favorable for the victim while they continue to be exposed to harassment, especially when it is quite certain that the procedure will not succeed, yet it constitutes a prerequisite for exercising the right to judicial protection, i.e., filing a lawsuit with the competent court.

For these reasons, it is necessary to improve the law through amendments and supplements, in order to more precisely define the harasser and the standard of repetition—i.e., the continuity of the harassing act. Furthermore, the mediation process at the employer should be an option, rather than an obligation for the victim, taking into account the principle of voluntariness.

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Software Engineering Approach to Component-Based Architecture for Trading Bots

Softversko inženjerstvo kao pristup arhitekturi zasnovanoj na komponentama za trejding botove

Dušan Rajčević[1], Goran Jocić[2], Kristina Jauković Jocić[3]

[1]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, dusan@mef.edu.rs*

[2]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, goran.jocic@mef.edu.rs*

[3]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, kristina.jaukovic@mef.edu.rs*

Abstract: *Rapid growth of algorithmic trading in cryptocurrency and financial markets has led to a proliferation of trading bots, many of which are developed in an ad hoc and monolithic manner. Such implementations often lack scalability, transparency, and reproducibility, limiting their long-term utility. This paper proposes a component-based architecture for trading bots, grounded in principles of component-based software engineering and systems thinking. The model decomposes trading functionality into modular components, including data ingestion, preprocessing, strategy engines, risk management, execution, and monitoring. By treating each module as an independent, interchangeable unit, the architecture enables flexible adaptation to new markets, strategies, and regulatory requirements. A case study demonstrates how the architecture supports rapid prototyping and systematic evaluation of trading strategies.*

Keywords: *Crypto, trading, bots, software engineering, components.*

Apstrakt: *Ubrzan rast algoritamskog trejdovanja u kriptovalutama i finansijskim tržištima doveo je do pojave velikog broja trejding botova, od kojih su mnogi razvijeni primenom ad hok i monolitnog pristupa. Takve implementacije često nisu skalabilne, nedostaje im transparentnost i mogućnost reprodukcije, što ograničava njihovu dugoročnu upotrebljivost. Ovaj rad uvodi arhitekturu zasnovanu na komponentama za trejding botove, utemeljenu na principima komponentno orijentisanog softverskog inženjerstva i sistemskog razmišljanja. Model raščlanjuje funkcije trejdovanja na modularne komponente, uključujući prijem podataka, predobradu, strategijske endžine, upravljanje rizikom, izvršavanje i monitoring. Posmatrajući svaki modul kao nezavisnu, zamenljivu jedinicu, arhitektura omogućava fleksibilno prilagođavanje novim tržištima, strategijama i regulatornim zahtevima. Studija slučaja pokazuje kako ova arhitektura podržava brzo prototipovanje i sistematsku evaluaciju strategija trejdovanja.*

Ključne reči: *Kripto, trejdovanje, botovi, softversko inženjerstvo, komponente.*

Introduction

Algorithmic trading is a defining feature of today's financial and cryptocurrency markets, with trading bots executing a large portion of daily transactions. These systems promise speed, efficiency, and ability to exploit market opportunities that are beyond capabilities of human traders. However, the rapid proliferation of trading bots has also exposed some serious shortcomings in their design and implementation. Many of them have been developed in an ad hoc, monolithic way, where data ingestion, strategy logic, risk controls, and execution are tightly coupled into a single codebase. Such architectures often lack scalability, transparency, and make reproducibility difficult, which limits their long-term application in dynamic and regulated markets.

On the other hand, software engineering research has long recognized the benefits of modularity, separation of concerns, and component reuse (Combemale, Gray, & Rumpe, 2024; Thomas, 2022). Component-Based Software Engineering (CBSE) provides a systematic framework for breaking down complex systems into independent, substitutable modules (Crnkovic, Chaudron, & Larsson, 2016; Shahin, Babar, & Zhu, 2017). Applied to a trading bot, this approach allows developers to decouple functionality into clearly defined components such as data ingestion, preprocessing, strategy engines, risk management, execution, and monitoring. Each component can be developed, tested, and replaced independently, resulting in increased flexibility, adaptability, and maintainability. This paper describes a component-based architecture for trading bots that is underpinned by the principles of CBSE and systems thinking. The architecture is designed to support rapid prototyping, systematic evaluation of trading strategies, and adaptation to evolving market conditions and regulatory requirements. This lays the foundation for scalable, transparent, and reproducible trading systems.

1. Background and related work

Algorithmic trading has rapidly evolved over the past two decades, driven by advances in computational power, data availability, and connectivity to global markets. In traditional finance, trading systems were often developed as tightly integrated platforms, where data feeds, strategy logic, and execution modules were bundled into monolithic applications (Chung & Chuwonganant, 2018; Dragoni et al., 2017). While such systems can achieve high performance in specialized contexts, they often suffer from limited adaptability and high maintenance costs when market conditions, regulatory requirements, or trading strategies change.

In the cryptocurrency domain, the barriers to entry for developing trading bots are lower, leading to a rise of open-source and commercial solutions. Many of these implementations emphasize speed of deployment over architectural rigor, resulting in codebases that are difficult to extend, audit, or reproduce (Huang & Polak, 2020; Victor & Lüders, 2019). This ad hoc development culture mirrors early stages of financial technology adoption, where functionality is prioritized over long-term sustainability.

From a software engineering perspective, modular and component-based approaches have long been recognized as effective strategies for managing complexity in large systems (Crnkovic, Chaudron, & Larsson, 2016; Shahin, Babar, & Zhu, 2017). Component-Based Software Engineering (CBSE) emphasizes the decomposition of systems into reusable, loosely coupled modules with well-defined interfaces. This paradigm has been successfully applied in domains such as enterprise software, embedded systems, and cloud computing, where adaptability and maintainability are critical. However, its systematic application to trading bots remains underexplored.

Several frameworks and libraries for algorithmic trading have introduced partial modularity. For example, back testing platforms often separate data handling from strategy logic, while some broker APIs provide abstractions for order tasks (Huang & Polak, 2020; Krauss, Do, & Huck, 2017). Nonetheless, these solutions typically lack a holistic architectural model that treats all aspects of trading (data ingestion, preprocessing, strategy, risk management, execution, monitoring etc.) as interchangeable components within a unified framework. As a result, developers frequently re-implement common functionality, and strategies are difficult to compare or reproduce across platforms.

Recent research in financial computing has highlighted the importance of transparency and reproducibility in algorithmic trading. Regulatory bodies increasingly require auditability of automated systems, while academic studies emphasize the need for reproducible experiments in evaluating trading strategies (Leal & Nogueira, 2017; Johnson & Zhao, 2020). A component-based architecture directly supports these goals by isolating functionality into discrete modules that can be independently tested and documented.

In summary, while modularity has been partially addressed in existing trading frameworks, there remains a gap in applying the principles of CBSE and systems thinking to design a comprehensive,

component-based architecture for trading bots. This paper builds on prior work in software engineering and financial computing to propose such a model, aiming to balance flexibility, scalability, and reproducibility in both research and industry contexts.

2. Component-based architecture for trading bots

The proposed architecture applies principles of Component-Based Software Engineering (CBSE) and systems thinking to decompose trading bots into modular, interchangeable units. Each component encapsulates a distinct responsibility with well-defined interfaces, enabling independent development, testing, and replacement. This separation of concerns enhances scalability, transparency, and reproducibility, while reducing the risks associated with tightly coupled, monolithic designs.

2.1. Architectural overview

At a high level, the architecture can be conceptualized as a pipeline of interacting components, supported by cross-cutting services such as logging, monitoring, and configuration management. Data flows from ingestion through preprocessing, strategy evaluation, risk management, and execution, with monitoring providing continuous feedback. Each component communicates through standardized interfaces, allowing for substitution or extension without disrupting the overall system. One example of this is shown on Figure 1.

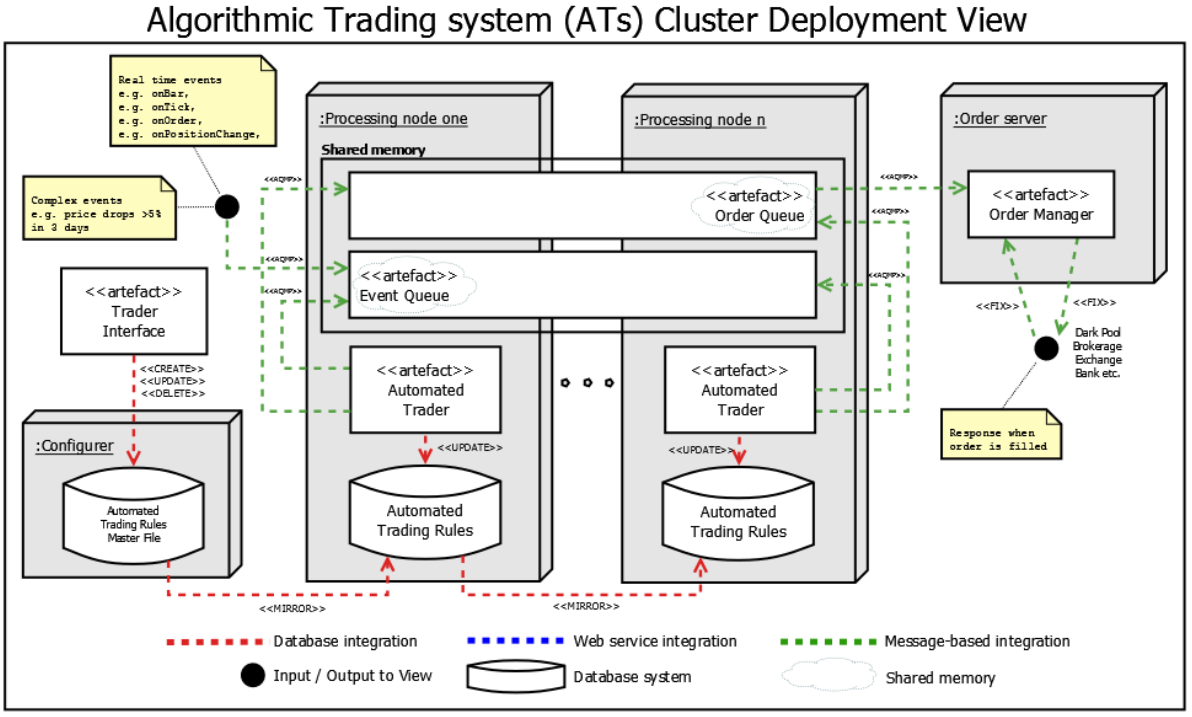


Figure 1. Algorithmic trading system (Ats) cluster deployment view
Source: Algorithmic Trading System Architecture

The diagram illustrates the deployment architecture of an algorithmic trading system (ATS), emphasizing how trading rules, event processing, and order execution are distributed across multiple nodes for scalability and reliability. The system is organized into four main layers:

1. configuration,
2. distributed event processing,
3. order management,
4. and integration mechanisms.

2.1.1. Configuration layer

At the entry point, traders or automated interfaces define complex trading events (e.g., "sell if price drops more than 5% in a day"). These rules are stored in a Trader Master File and linked to a database for persistence. This layer ensures that trading strategies are centrally defined and consistently propagated across the system.

2.1.2. Distributed processing nodes

The system employs a clustered architecture with multiple processing nodes (Node One through Node n). Each node contains:

- An Event Queue for incoming market data or signals.
- A set of Automated Trading Rules that evaluate events against predefined strategies.

Nodes communicate using shared memory for intra-node efficiency and message-based integration for inter-node coordination. This design allows the system to scale horizontally, handling large volumes of market events in parallel while maintaining low latency.

2.1.3. Order management layer

Once a trading decision is made, it is passed to the Order Server, which contains:

- An Order Queue to buffer trade requests.
- An Order Manager that validates, routes, and submits orders to the exchange.

The order server also provides feedback loops, sending confirmations or execution reports back to the trader or interface. This ensures transparency and traceability of all executed trades.

2.1.4. Integration mechanisms

The architecture relies on multiple integration methods, each chosen for its role:

- Database integration (red dashed lines): for persistent storage of trading rules and configurations.
- Message-based integration (green dashed lines): for asynchronous, scalable communication between nodes and the order server.
- Shared memory (grey cloud outline): for high-speed intra-node data exchange.
- Web service integration (blue dashed lines): for external system connectivity not visible on the diagram.
- Direct input/output (black solid lines): for trader interaction with the system.

2.2. Core components

The first stage of the pipeline is **data ingestion**, which connects to market data providers, broker APIs, and historical datasets. Its role is to ensure that information enters the system in a reliable and synchronized manner, regardless of the source or format. Once collected, the data passes into the preprocessing stage, where it is cleaned, normalized, and transformed into standardized structures. This step may also include feature engineering, such as the calculation of moving averages or volatility measures, which enrich the raw data for downstream use.

The strategy engine represents the analytical core of the system. It encapsulates trading logic in the form of plug-in modules, allowing different strategies such as momentum, mean-reversion, or arbitrage to be implemented, tested, and compared under consistent conditions. Crucially, the strategy engine is insulated from the mechanisms of risk control and execution, which ensures that trading ideas can be evaluated independently of operational constraints.

Risk management is handled by a dedicated risk management component, which enforces safeguards such as position sizing, stop-loss thresholds, and portfolio constraints. By decoupling risk management from strategy logic, the architecture guarantees that protective measures remain consistent across all strategies, thus reducing exposure to unpredicted losses and ensuring compliance with regulatory or exchange-specific requirements.

The execution component translates trading signals into actionable orders. It manages the complexities of order routing, slippage control, and latency optimization, while providing a uniform interface across multiple brokers or exchanges. This abstraction allows strategies to be deployed in diverse markets without requiring fundamental changes to their design.

Finally, the **monitoring and logging layer** spans the entire architecture. It records trades, decisions, and system performance, enabling both real-time oversight and retrospective analysis. This layer is essential for transparency and reproducibility, as it provides the evidence needed to audit system behavior and replicate experiments.

Together, these components form a flexible and extensible framework. Strategies or data sources can be swapped without rewriting the entire system, components can be scaled independently across distributed environments, and the modular design supports both academic reproducibility and industrial robustness. By adopting this architecture, trading bots can evolve from ad hoc tools into systematic, sustainable platforms for algorithmic trading.

Beyond the core modules, the architecture incorporates shared services:

- **Configuration Management:** centralizes parameters for strategies, risk thresholds, and execution settings.
- **Persistence Layer:** stores historical trades, logs, and performance metrics.
- **Security and Access Control:** ensures safe handling of API keys, credentials, and sensitive data.

2.3. Benefits of the architecture

- Flexibility: strategies or data sources can be swapped without rewriting the entire system.
- Scalability: components can be distributed across multiple machines or cloud services.
- Transparency: modular logging and monitoring improve auditability.
- Reproducibility: standardized interfaces allow experiments to be replicated across environments.

3. Implementation and case study

3.1. Implementation framework

To illustrate the feasibility of the proposed architecture, a prototype was designed using Python and containerized services. The core modules and their responsibilities are summarized in Table 2.

Table 2. Key components and supporting technologies in the proposed architecture

Component	Description	Representative technologies
Data Ingestion	Collects live and historical market data from exchanges via REST/WebSocket.	CCXT, WebSockets, MySQL
Preprocessing	Cleans, normalizes, and enriches data with indicators and derived features.	pandas, NumPy
Strategy Engine	Hosts pluggable strategy modules implementing various algorithms.	Custom API, Dynamic Imports

Risk Management	Enforces portfolio constraints, stop-losses, and exposure limits.	YAML configuration, Redis cache
Execution	Translates trade signals into market orders, manages latency and slippage.	AsyncIO, Exchange APIs
Monitoring & Logging	Provides dashboards, metrics, and alerting.	Prometheus, Grafana, ELK stack

Source: Author's own proposition (2025)

3.2. Modular momentum strategy

To validate the architecture, a momentum-based trading strategy was implemented as a plug-in within the strategy engine. The strategy relied on moving average crossovers applied to hourly Bitcoin data from Binance. Risk parameters such as position size and stop-loss thresholds were enforced by the risk management component, to make sure that protective measures remain consistent regardless of the strategy logic.

The modularity of the system was further supported by reusing the same framework to test an arbitrage strategy across Binance and Kraken. Only the configuration and strategy plug-in were changed, while all other components remained the same. This highlighted the interchangeability and extensibility of the architecture.

3.3. Evaluation setup

The architecture was conceptually assessed along three dimensions commonly used in prior research to evaluate modular systems: scalability, maintainability, and reproducibility (Dragoni et al., 2017; Crnkovic et al., 2016). These dimensions are commonly used to assess modular systems.

4. Results and discussion

4.1 Performance and scalability

Consistent with findings on modular and microservice architectures (Dragoni et al., 2017), the proposed design is expected to scale more effectively than monolithic baselines. In trading contexts, system design directly influences latency and throughput (Chung & Chuwonganant, 2018). By adopting message queues and asynchronous communication, the proposed architecture aligns with these findings and is expected to mitigate bottlenecks as strategy components increase.

4.2 Maintainability and flexibility

Component-based software engineering emphasizes separation of concerns, which reduces coupling and minimizes regression risks (Crnkovic, Chaudron, & Larsson, 2016; Shahin, Babar, & Zhu, 2017). In practice, this means that introducing a new trading strategy requires only localized changes, rather than modifications to the entire system.

4.3 Transparency and reproducibility

Transparency and reproducibility are increasingly emphasized in both academic research and regulatory contexts (Leal & Nogueira, 2017; Johnson & Zhao, 2020). By isolating monitoring and logging as independent components, the architecture supports reproducible experiments and provides audit trails that align with compliance requirements.

4.4. Limitations

As highlighted in modular systems research, decomposition introduces orchestration overhead and requires robust interface definitions (Dragoni et al., 2017; Combemale, Gray, & Rumpe, 2024). These trade-offs are inherent to modularity and must be managed carefully in financial applications.

5. Future work

Several directions remain open for extending this architecture. One avenue is the use of container orchestration platforms such as Kubernetes to enable elastic scaling of strategy and data components. Another is the development of inter-bot communication frameworks, allowing multiple agents to collaborate on portfolio optimization. Machine learning models could also be integrated as strategy or preprocessing components, while formal interface definitions (e.g., gRPC or OpenAPI) would strengthen interoperability across languages and platforms. Finally, compliance modules could be added to automate audit reporting in line with regulatory standards such as MiFID II or SEC requirements.

Conclusion

This work has proposed and illustrated a component-based architecture for trading bots. While the prototype and case study serve as conceptual demonstrations, the approach is consistent with findings in software engineering and financial computing literature. By decomposing trading functionality into modular, interchangeable units, the architecture aligns with best practices for scalability, transparency, and reproducibility. While modularity has been explored in related domains, its systematic application to trading bots remains underdeveloped; this work contributes by outlining a unified CBSE-based framework tailored to financial and cryptocurrency markets.

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Models for Harmonizing Control and Motivation in the Organizational Management Process

Modeli za usklađivanje kontrole i motivacije u procesu upravljanja organizacijom

Darko Mosić[1], Jelena Kostovski[2]

[1]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, darko.mosic@yahoo.com*
[2]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, jpetrovic75@gmail.com*

***Abstract**: The paper examines the amalgamation of management control systems and motivational methods as a basis for enduring organizational success. The research purpose is to determine the design and implementation of control systems that ensure congruence between individual actions and strategic objectives, while preserving employee engagement and fostering creativity. The research employs a qualitative analytical methodology grounded in a survey of theoretical and empirical literature. The findings emphasize that efficient control systems need explicit objectives, dependable data, equitable performance metrics, and ongoing feedback, bolstered by intrinsic and extrinsic motivating factors. The results indicate that aligning control and incentive converts management systems from oversight mechanisms into dynamic frameworks that promote responsibility, trust, and sustainable growth.*
***Keywords**: Management control systems, motivation, organizational performance, strategic alignment, feedback, innovation.*

***Apstrakt**: Rad ispituje spajanje sistema upravljačke kontrole i motivacionih metoda kao osnovu za trajni organizacioni uspeh. Cilj istraživanja je da se utvrdi dizajn i implementacija sistema kontrole koji obezbeđuju usklađenost između pojedinačnih akcija i strateških ciljeva, uz očuvanje angažovanja zaposlenih i podsticanje kreativnosti. Istraživanje koristi kvalitativnu analitičku metodologiju zasnovanu na pregledu teorijske i empirijske literature. Rezultati naglašavaju da efikasni sistemi kontrole zahtevaju eksplicitne ciljeve, pouzdane podatke, pravedne metrike učinka i kontinuirane povratne informacije, potkrepljene unutrašnjim i spoljašnjim motivacionim faktorima. Rezultati ukazuju na to da usklađivanje kontrole i podsticaja pretvara sisteme upravljanja iz mehanizama nadzora u dinamične okvire koji promovišu odgovornost, poverenje i održivi rast.*
***Ključne reči**: Sistemi menadžerske kontrole, motivacija, organizacione performanse, strateško usklađivanje, povratna informacija, inovacije.*

Introduction

In the competitive landscape of contemporary business, organizational success increasingly relies on the capacity to harmonize structure with flexibility, control with liberty, and efficiency with innovation. Management control systems serve as a fundamental tool for maintaining this equilibrium, ensuring that both individual and collective actions are congruent with strategic objectives, performance benchmarks, and the long-term vision of the business. The efficacy of such systems transcends technical or procedural aspects; it is fundamentally anchored in human behavior, motivation, culture, and the ability of leaders to amalgamate various components into a cohesive framework that fosters responsibility and participation (Ampauleng et al, 2024). The development of management control theory illustrates this paradox. Conventional control techniques generally emphasized performance monitoring, deviation detection, and compliance enforcement. Although these methods provided

stability and predictability, they frequently overlooked the psychological and social factors that influence employee dedication, inventiveness, and initiative. Conversely, modern viewpoints regard control systems as multifaceted tools that not only govern behavior but also facilitate learning, creativity, and incentive. The challenge for contemporary managers is to convert control from a mechanism of oversight into a catalyst for performance, development, and organizational advancement. Motivation, as an adjunct to control, incorporates the human element crucial for enduring success. Control systems offer structure and guidance, whereas motivational tactics stimulate both inner and external factors that encourage individuals to actively engage with corporate objectives. The interaction between control and incentive influences the organizational environment and its ability to sustain high productivity, flexibility, and employee happiness. A control system that integrates motivational concepts is viewed as empowering rather than restricting, promoting ownership, trust, and proactive involvement (Arif & Tahiri, 2025). This paper examines the design, use, and implementation of efficient control systems within the wider framework of organizational management. It analyzes how the incorporation of incentive techniques improves control efficacy and how cultural, technological, and psychological aspects affect implementation results. The initial section examines the essential ideas and structural elements of organizational control systems, emphasizing that they involve objectives, data precision, feedback, and flexibility. The second section emphasizes the use of motivational methods inside control frameworks, including the integration of internal and extrinsic motivators to maintain performance and commitment. The third section examines the obstacles and critical factors for effective implementation, emphasizing concerns pertaining to company culture, resistance to change, data integrity, and long-term strategy alignment.

The primary objective of this debate is to elucidate how businesses may devise and execute control systems that not only ensure compliance but also foster a culture of accountability, involvement, and ongoing enhancement. By synchronizing structure with motivation and performance oversight with empowerment, contemporary management can establish a sustainable framework that fosters both operational excellence and human development, an essential foundation for thriving in an age of swift technological, economic, and social transformation.

1. Design and key components of effective organizational control systems

Any business needs control systems to ensure that activities align with strategic goals and performance criteria. Effective control systems not only assess and analyze performance but also inform decision-making and enable corrective measures (Al-Dhubaibi, 2025). The creation of such systems necessitates meticulous planning and design, considering the specific requirements and conditions of the company. This chapter outlines the essential elements and considerations in the development of effective control systems, based on various theoretical frameworks and empirical research. Several essential components must be present for a control system to operate well. These components guarantee that the system delivers essential feedback and insights to managers for sustaining organizational alignment with objectives:

- Explicit objectives and criteria: The basis of any control system is the establishment of explicit objectives and performance criteria. Objectives must correspond with the organization's overarching mission and vision, while performance criteria should be quantifiable and precise. In the absence of explicit criteria, evaluating whether employees or processes fulfill expectations becomes challenging. Research indicates that ambiguous or inconsistent goals diminish the efficacy of control systems and may even hinder motivation (Merchant & Van der Stede, 2011).
- Precise and prompt information: Control systems rely on the acquisition of precise and prompt data. Increased data reliability enhances the efficacy of the control system. For example, financial controls need real-time information about sales, costs, and profits so that they can make quick changes when needed. Technological advancements have facilitated the real-time collection of substantial data, although guaranteeing its accuracy continues to pose a barrier.

The quality of information is a pivotal element in the efficacy of any control system (Bedford & Malmi, 2015).

- Holistic and equitable assessment: Effective control systems must achieve equilibrium across various measurement kinds, including financial and non-financial, as well as quantitative and qualitative. Excessive focus on financial outcomes may result in short-term decision-making while disregarding crucial non-financial metrics such as staff satisfaction, customer experience, and process efficiency. Balanced scorecards, which amalgamate financial and non-financial metrics, represent a methodology that has demonstrated efficacy in enhancing the effectiveness of control systems (Ahn, Y. 2022).
- Feedback mechanisms: An essential element of control systems is feedback. Consistent feedback guarantees that management and staff recognize performance deficiencies and can implement corrective measures. Research indicates that regular and constructive feedback enhances control and motivates staff. Feedback must be explicit, efficient, and prompt to facilitate swift modifications and enhancements.
- Flexibility and adaptability: Organizations function within changing contexts, necessitating that control systems be flexible and adaptable. Inflexible control systems can inhibit innovation and impede the decision-making process. Efficient systems allow for modification in response to external factors, such as market volatility or emerging technologies, necessitating a change in direction. Creating a versatile control system necessitates forecasting possible alterations and accommodating a spectrum of reactions (Speklé, & Verbeeten, 2014).

In implementing a management control system, managers must consider many internal and external factors that might substantially affect its efficacy (Mahara, 2025). Organizational culture is crucial, as it influences employees' perceptions of authority, communication, and accountability. In businesses characterized by a robust hierarchical culture, formal and organized control methods operate more efficiently, since they correspond with established chains of command and defined procedures. Conversely, businesses characterized by flexible, inventive, or team-oriented cultures gain advantages from informal and decentralized control structures that prioritize collaboration, adaptability, and trust. Aligning the control system with the organization's values and behavioral norms enhances the likelihood of successful implementation and employee acceptance. Employee participation is equally crucial in the formulation of control systems (Zhang et al., 2025). When employees engage in establishing performance goals and indicators, they cultivate a sense of ownership about the process. This engagement converts control from a mandated requirement into a collaborative framework for goal attainment. Studies demonstrate that participatory control systems enhance motivation and provide greater alignment between individual and corporate performance measurements, boosting efficiency and morale. Technological progress constitutes a critical element in contemporary control systems. Automation tools have transformed data gathering, monitoring, and reporting processes, enabling firms to acquire real-time insights and diminish the probability of human error. Integrating technology necessitates meticulous management; excessively complex or inadequately articulated systems may provoke staff hostility or impede data comprehension. Consequently, attaining an optimal equilibrium between human supervision and technological assistance is crucial for preserving both precision and engagement. Organizations must systematically match control systems with their long-term goals. Systems that concentrate solely on short-term operational enhancements may unintentionally hinder the achievement of overarching objectives like innovation, market growth, or organizational learning. A strategically focused control framework guarantees that daily decisions align with the organization’s larger mission and vision. The most effective control systems are those that govern performance while simultaneously motivating and empowering individuals to actively contribute to sustainable organizational success. Developing an efficient control system often entails the following steps (Yan, 2025):

Step 1: Establish objectives and key results: The initial stage is to explicitly delineate the objectives of the control system. Objectives must be specific, measurable, attainable, relevant, and time-bound (SMART). This guarantees that the system prioritizes the most vital aspects of performance (Rahmi et al., 2025).

Step 2: Determine Key Performance Indicators (KPIs): Upon defining objectives, key performance indicators (KPIs) must be established. Key Performance Indicators (KPIs) are measurements employed to monitor progress toward goals. They must be readily quantifiable and closely associated with the organization's objectives (Leitner, 2024).

Step 3: Implement instruments for data gathering and reporting. Efficient control systems necessitate tools for data collection, analysis, and reporting. Selecting appropriate tools is contingent upon the nature of the data being gathered and the intended degree of automation. Data visualization technologies enhance the accessibility and applicability of information.

Step 4: Implement feedback mechanisms: After the system is established, feedback methods must be incorporated. This encompasses routine assessments, reporting protocols, and performance evaluations that furnish employees and managers with pragmatic insights (Globerson, 2023).

Step 5: Observe and modify: Continuous monitoring is essential for the efficacy of control systems. Managers must consistently evaluate the efficacy of control systems and implement modifications as necessary. This may involve recalibrating performance measurements, reassessing objectives, or adopting new technology.

Creating successful control systems is a complex process that includes meticulous evaluation of company objectives, culture, employee involvement, and technology competencies. By harmonizing explicit objectives, precise data acquisition, and adaptable feedback systems, managers may guarantee that control mechanisms not only direct operations but also inspire personnel towards sustained achievement. A well-designed control system links individual performance with organizational goals, offering a foundation for sustainable growth and continuous improvement.

2. Application of motivational strategies with control

An essential component of effective management is the capacity to balance control with incentive. This ability is due to the integration of two complementary factors within organizational behavior: inspiration and discipline. Control mechanisms are responsible for establishing the structural foundation necessary to ensure the achievement of organizational goals through the deployment of measurable standards, accountability, and consistency. During this period, motivational strategies will enhance the psychological and emotional engagement of employees, therefore fostering their creative and significant contributions to the firm's success (Alev, S., 2024). When these two factors are properly harmonized, they do not compete but instead mutually reinforce each other, leading to a work atmosphere characterized by both high performance and efficiency (Pertiwi et al., 2025). This synthesis of control and reward creates a framework that facilitates the coexistence of individual initiative and flexibility with operational discipline, essential for achieving long-term organizational performance.

To prevent the emergence of rigidity, conformity, and bureaucratic inertia, it is crucial to include incentive mechanisms in control systems. This is because control, when used alone, may quickly become rigid and ineffective. Motivation encompasses the emotional and cognitive elements of human conduct that drive discretionary effort, creativity, and dedication. Control systems make sure that performance standards are met and strategic goals are met. A control system lacking components that incentivize employees risks resulting in mere superficial compliance. Employees may meet the minimum criteria; however, they will lack the involvement and enthusiasm essential for continuous improvement and innovation. Conversely, motivation without regulation may generate enthusiasm but can lead to a lack of focus, ultimately undermining both consistency and efficiency. Therefore, to ensure that

psychological engagement underpins behavioral congruence, an effective management framework requires the deliberate integration of these two domains.

The goal of creating motivating strategies is to enhance the effectiveness of control mechanisms by fostering a workplace environment where individuals feel valued, supported, and empowered to excel in their performance. performance.formance. Such approaches create a natural connection between an individual's purpose and the company's performance. aim.ny's aim. Employees' motivation transitions from external compliance to internalized commitment when they perceive control systems as supportive tools that clarify expectations and facilitate achievement rather than as restrictive measures. This constitutes a transformative experience for employees at aim.ny. This internal perspective yields benefits such as proactive conduct, enhanced inventiveness, and a willingness to exceed established performance targets rather than merely meet them.

This integrative framework may include several incentive strategies for control systems. Each of these methodologies targets a distinct facet of engagement and productivity. productivity.uctivity. Intrinsic motivation emphasizes the internal fulfillment achieved through meaningful work, autonomy, and opportunities for professional development. productivity.development.elopment. By cultivating a sense of ownership and transforming control into a collaborative governance process rather than a top-down directive, managers who empower workers to make decisions about their goal attainment may instill a sense of empowerment among their workforce. Conversely, extrinsic motivation depends on tangible rewards such as financial compensation, public recognition, and opportunities for career advancement. Transparently linking incentive systems to specific performance measures enables employees to perceive fairness and accountability, thereby strengthening their commitment to the firm's standards.

A vital element is empowering employees and granting them autonomy, which signifies that they have the authority to make decisions regarding their jobs and advancement processes. Building trust enhances psychological ownership and accountability, which leads to more consistent compliance with control processes. Empirical evidence has revealed that enhancing employees' autonomy elevates their motivation and improves their adherence to company regulations. This occurs when workers internalize the company's expectations as if they were their own. The significance of appreciation and feedback is paramount in employee engagement. Control systems that incorporate mechanisms for consistent, constructive feedback and public recognition of efforts create a positive feedback loop that promotes desirable behavior and enhances morale. This loop is established when control systems include these components.

Nonetheless, the interplay between control and incentive presents some inherent challenges. Excessive reliance on motivational strategies without adequate structure may result in inconsistency and diminished accountability, while an overemphasis on control can inhibit creativity, undermine psychological safety, and curtail employees' willingness to experiment. The art of management involves maintaining proper oversight to ensure goal achievement while also providing sufficient autonomy and psychological freedom to foster creativity and self-determination.

Moreover, for a system to achieve success, it is essential to equilibrate internal and external motivators. Shifting an employee's focus from significant contributions to transactional performance may lead to an overreliance on extrinsic rewards, such as financial incentives, thereby diminishing their inner motivation. Sustainable motivation arises from a dynamic balance where extrinsic incentives recognize success, but intrinsic motivators such as purpose, mastery, and autonomy sustain long-term engagement and commitment among individuals.

The concurrent use of control systems and motivational tactics facilitates the creation of a balanced organizational environment that is psychologically secure and promotes high operational efficiency. The integration of control mechanisms with emotional and cognitive depth transforms motivation, elevating these mechanisms from mere supervisory instruments to catalysts for development and excellence. Companies can cultivate a workforce that is not only compliant with standards but also

genuinely committed to collective success by establishing clear objectives, fostering participatory decision-making, providing regular feedback, and maintaining a judicious balance of accountability and recognition. A system integrated in this manner demonstrates the core of modern management, characterized by flexibility, a human-centric approach, and strategic alignment with the organization's goal of sustainable success.

3. Challenges and considerations for implementation

The development of control systems that combine structural supervision with motivational involvement poses many obstacles that surpass the technical aspects of system design. Theoretical frameworks establish a basis; nevertheless, their actual implementation necessitates an awareness of company culture, leadership approach, human behavior, and technology capability. Control systems must successfully assess and direct performance while also fostering trust, engagement, and commitment throughout all organizational tiers. The implementation of control systems faces a significant obstacle in the cultural environment.

The organizational culture profoundly affects the perception and implementation of control systems. In hierarchical companies, where power and structure are entrenched, formal control systems may be effective yet risk being viewed as coercive mechanisms of oversight (Bariyah et al.,2023). This view frequently results in passive acquiescence instead of active participation. Conversely, in more adaptable and innovation-centric workplaces, too stringent control systems can suppress creativity and impede adaptive decision-making. Aligning the system with current cultural and behavioral norms while progressively guiding people toward enhanced accountability and participation is crucial for effective deployment (Santi et al., 2025). Employee perceptions and reluctance to change constitute another vital factor. The introduction of new performance metrics or feedback systems frequently upsets established patterns and may elicit skepticism, apprehension over evaluation, or a diminished sense of autonomy. Overcoming such opposition hinges on openness and inclusiveness. Employees ought to be involved early in the design process, informed of the aims and advantages, and motivated to provide input. When individuals see that control systems are intended to facilitate rather than restrict them, they start to internalize performance standards and synchronize their behavior with company objectives. The reconciliation of standards and flexibility is a fundamental challenge in implementation. Standardized systems foster uniformity, comparability, and efficiency, yet may unintentionally constrain innovation and contextual adaptation. Conversely, excessive flexibility may erode responsibility and compromise strategy coherence. The solution is in the establishment of adaptive control framework systems that delineate explicit objectives and quantifiable standards while maintaining the flexibility to respond to environmental shifts, emerging technology, or changing organizational tactics. The incorporation of technology presents distinct complications. As enterprises increasingly depend on data-driven control systems, difficulties with data quality, interoperability, and user understanding arise. Automation improves real-time oversight and decision-making but necessitates significant investment in digital infrastructure, data governance, and personnel training. Furthermore, an overreliance on technology may lead to the depersonalization of management in the absence of human discernment. Consequently, control systems ought to enhance, rather than supplant, management acumen and human communication (Upadhyay et al., 2024). Another factor pertains to the maintenance of motivation within a control framework.

Systems that prioritize measurement and compliance excessively may jeopardize intrinsic drive, inventiveness, and commitment. When control techniques are viewed as punitive or bureaucratic, they undermine trust and psychological safety. To avert this, motivating elements must be included in the control system via acknowledgment, constructive feedback, professional growth opportunities, and collaborative goal-setting (Cheng et al., 2023). By prioritizing equity, clarity, and development, companies may guarantee that control systems function as facilitators of performance rather than impediments. The enduring alignment of control systems with corporate strategy is essential. Short-term operational measurements, although essential for efficiency, must not eclipse strategic objectives

such as innovation, knowledge generation, and sustainable development. Control systems must bolster the organization's mission and vision, guaranteeing that everyday decisions and actions align with overarching objectives.

This necessitates regular assessment, adjustment of metrics, and a dedication to ongoing education. In conclusion, the successful application of control systems in contemporary businesses necessitates not just technical accuracy but also cultural awareness, collaborative design, technological flexibility, and psychological understanding. Upon effective integration, these systems guarantee responsibility and performance while enhancing motivation, engagement, and a collective purpose. The genuine difficulty is to convert control from a static supervision mechanism into a dynamic process of empowerment and organizational development.

Conclusion

The integration of control and incentive in organizational management exemplifies a nuanced equilibrium between structure and human involvement. Effective control systems function not just as tools for oversight and adherence but also as dynamic frameworks that direct behavior, promote learning, and maintain alignment with strategic goals. When these systems are constructed with explicit objectives, dependable data channels, and flexible feedback loops, they transform from administrative requirements into facilitators of performance and creativity. Their success is attributed to the ability to maintain a balance between structure and flexibility, ensuring responsibility and consistent performance while being adaptable to contextual changes and individual inventiveness. Motivation, conversely, incorporates the psychological and emotional aspects that convert control from an external obligation into an inner dedication. The amalgamation of motivating tactics with oversight cultivates an organizational environment in which personnel view performance management as a collaboration rather than a limitation. Control systems may foster self-discipline, engagement, and a proactive pursuit of excellence through intrinsic and extrinsic motivators, participatory goal setting, and constant feedback. The effective execution of such systems relies on overcoming cultural, behavioral, and technical obstacles. Aligning control frameworks with business values and employee expectations is essential for their adoption and efficacy. Leadership is thus crucial in articulating purpose, fostering trust, and ensuring that control mechanisms function as developmental instruments rather than punishing frameworks. In modern enterprises, the integration of digital technology with human-centered management strategies creates new chances to improve the balance between control and motivation. Data-driven insights, automation, and real-time feedback enhance accuracy, yet participative management and empowerment maintain flexibility and morale. This dichotomy enables firms to attain operational excellence while preserving creativity and devotion. The integration of control and incentive encapsulates the core of contemporary management: a framework that guarantees performance while fostering significance, engagement, and ongoing development. Organizations that achieve this balance have robust frameworks that support innovation, learning, and enduring success in a constantly evolving environment.

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Forensic Accountants as Detectives in Uncovering Accounting Tricks and Manipulations

Forenzičke računovođe kao detektivi u otkrivanju računovodstvenih trikova i manipulacija

Dragana Petrović[1], Milja Orlandić[2], Marija Mladenović[3]

[1]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, dragana.petrovic@mef.edu.rs*

[2]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, milja.orlandic@mef.edu.rs*

[3]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, marija.mladenovic@mef.edu.rs*

Abstract: *A forensic accountant plays a vital role in conducting investigative procedures aimed at collecting evidence and providing expert opinions in legal proceedings. This paper presents the development and significance of the forensic accounting profession. The authors will trace the origins and early development of the field, as well as its transformation over time, particularly in light of the emergence of digital technologies. It will be emphasized that, in the course of conducting investigations, forensic accountants must adhere to the ethical principles that govern the practice of forensic accounting. The paper will outline the types of services provided and the various stages involved in the investigative process carried out by forensic accountants. Based on the presented findings, the authors conclude that the profession of forensic accounting holds a critical role in the contemporary world of business finance and accounting. Forensic accountants act as financial detectives, conducting investigative procedures to uncover anomalies and irregularities in business operations, thereby contributing to enhanced financial reporting quality.*

Keywords: *Forensic accountant, financial fraud, principles of forensic accounting, ethics, fraud.*

Apstrakt: *Forenzički računovođa ima izuzetno važnu ulogu u vršenju istražnih radnji radi prikupljanja dokaza iskazivanja stručnog mišljenja u sudskim postupcima. U radu će biti prikazan razvoj i značaj profesije forenzičkog računovodstva. Autori će ukazati korene tj. početak razvoja i transformaciju ove oblasti sve do danas sa pojavom digitalne tehnologije. Objasniće se da prilikom pružanja usluga u istragama, forenzički računovođa treba da se pridržava etičkih principa forenzičkog računovodstva. Prikazaće se vrste usluga i faze u procesu istraživanja koje pružaju forenzičke računovođe. Na osnovu iznetih činjenica, autori zaključuju da profesija forenzičkog računovođe ima krucijalan značaj u savremenom svetu poslovnih finansija i računovodstva. Oni imaju ulogu finanijskog detektiva, jer vrše istražne radnje kojima otkrivaju anomalije i nepravilnosti u poslovanju, doprinoseći kvalitetnijem finansijskom izveštavanju.*

Ključne reči: *Forenzički računovođa, finansijske prevare, principi forenzičkog računovodstva, etika, prevare.*

Introduction

Forensic accounting represents a critical profession in the detection of accounting fraud and manipulation within organizations. Fraud has existed as long as human civilization itself. This raises important questions: how can inaccurate estimations be identified, were they made deliberately or unintentionally, and what are the underlying causes of their occurrence? Fraud is a broad concept involving dishonest and greedy individuals seeking to obtain unlawful financial gain (Knežević et al., 2021).

Fraud constitutes a criminal offense that includes tax evasion, fraudulent financial reporting, or the misappropriation of assets, all with the intention of misleading stakeholders and acting in bad faith. The development of the forensic accounting profession has largely been driven by the lack of specialized expertise among traditional accountants in addressing manipulations and embezzlements in financial reports. Accordingly, the scope of forensic accounting encompasses activities related to the investigation of fraud, embezzlement, tax evasion, and money laundering. This field integrates principles of both forensics and accounting, focusing on the investigative analysis of accounting information with the ultimate aim of providing evidence-based reports for judicial proceedings.

Forensic accounting represents a significant instrument in uncovering financial fraud and misconduct within companies, conducted by forensic accountants and auditors. The primary role of a forensic accountant is to investigate financial statements and, through the application of forensic accounting methods, detect manipulations and fraudulent activities. Forensic accountants must possess multidisciplinary knowledge across various fields in order to effectively address complex financial issues. In line with this, to perform their duties responsibly and independently, it is essential to strengthen the feedback loop between professional institutions, the state, and the field of forensic accounting. In many countries, forensic accountants are referred to as forensic experts, investigators, or fraud examiners. They may be employed by government agencies, courts, auditing firms, or law enforcement institutions. Forensic accountants can perform a wide range of tasks, such as uncovering corporate fraud, participating in legal proceedings, or resolving financial aspects of divorce cases. The development of corporations has brought about increased awareness of the importance of fraud detection, which in turn has led to a growing demand for forensic accountants (Chiang, 2013).

In this paper, the authors will first examine the development of forensic accounting, from its early beginnings to the modern era marked by the application of information technologies. Following this, the focus will shift to the application of ethical principles in forensic accounting during the process of conducting investigations and presenting findings in court. The paper will outline the activities encompassed by the forensic accounting profession and, accordingly, present the procedures employed by forensic accountants in the course of investigative work. The objective of this research is to highlight the necessity of continuous advancement in the forensic accounting profession in order to ensure the timely detection of fraud and manipulation in financial reporting.

1. The development of forensic accounting

Forensic accounting is a rapidly growing field focused on the detection of material misstatements in financial reporting. Such misstatements often result in the distortion of financial statements and manipulation of financial outcomes, a practice commonly referred to as “creative accounting.” False financial reporting can lead to a loss of investor confidence, reduced activity in financial markets, and even broader economic consequences, such as a decline in national economic performance (Petrović et al., 2024). Forensic accounting has emerged as the fastest-growing branch within the accounting profession. As an investigative discipline, it involves comprehensive fraud examinations using scientific methods and techniques designed to uncover the risk of criminal activities. The origins of the concept can be traced back to 1946, when renowned accountant Maurice Peloubet published an article titled “Forensic Accounting – Its Place in the Present Economy,” thereby introducing the term "forensic accounting" for the first time. Forensic accounting represents a fusion of forensic science and accounting principles. Forensics involves the collection and preservation of evidence for use in legal proceedings, while accounting pertains to the systematic recording of business transactions and the preparation of financial reports for stakeholders (Devi, 2023).

The emergence of white-collar crime has led to a significant increase in the demand for forensic accountants. White-collar crime refers to non-violent offenses committed by individuals in professional or managerial positions, typically involving embezzlement, fraud, forgery, or bribery. A distinguishing feature of this type of crime is that it often escapes the attention of investigators, as the perpetrators are

frequently connected to individuals in positions of power and authority. Nevertheless, the societal impact of white-collar crime is far more severe than that of conventional crime. In the United States, the FBI has reported that only 5% of white-collar crimes are detected among observed cases, while such crimes account for approximately 95% of financial reporting losses (Manning, 2005). This imbalance has significantly contributed to the growing demand for forensic accountants, whose role is to assess business risks in a timely manner and, based on gathered documentation, provide evidence of fraudulent activities.

The primary motivation for the development of forensic accounting lies in the lack of specialized and practical knowledge required to detect financial fraud and manipulative practices (Petrović et al., 2023). These irregularities are often anomalies in financial statements caused by management with the intent to manipulate the perceived profitability and financial position of the company. Early forms of forensic accounting can be traced back to the distant history of human civilization. This skill evolved throughout the Middle Ages, when nobles and members of the clergy employed early forensic accountants to uncover financial fraud and speculative activities. The earliest historical records date back to around 4,000 BCE, when ancient civilizations documented transactional exchanges (such as goods, property, or money), equitable distribution of communal wealth, and asset inventories. These records were often kept to prevent errors, detect fraud, or provide evidence in legal disputes (Zavyagin & Shirimov, 2013). Some of the oldest known examples originate from ancient Greece, China, and Rome. During the 12th and 13th centuries, rudimentary forms of auditing emerged in France, England, and Scotland, primarily aimed at overseeing the use of public or private funds. Notably, in 17th-century Scotland, the first records of independent audits appeared (Viodorova & Fursova, 2018). By the 19th century, auditors in the United Kingdom were primarily responsible for auditing public sector entities. However, over time, it became evident that auditors were not adequately equipped to detect fraud risks during the course of their audits. This realization further emphasized the need for a more specialized discipline, one that would eventually take shape as forensic accounting.

The first recorded case in which an accountant served as an expert witness in court dates back to 1817, in the case of Meyer vs. Sefton, which is widely considered the origin of forensic accounting (Tucker, 2011). Despite this early example, the first book dedicated to forensic accounting was not published until 1982, indicating that the popularity of forensic accountants gradually increased in parallel with the growth of corporations and the emergence of increasingly sophisticated forms of financial fraud (Dreyer, 2014). The term "forensic accounting" was first formally introduced in the United States in the 1950s, initially referring exclusively to the collection of evidence for use in legal proceedings (Stevenson, 2015). However, following World War II, the scope and importance of forensic accounting began to expand significantly. Its role has since evolved beyond evidence collection to include the identification, analysis, and prevention of fraud-related risks.

In the digital era, the emergence of information technologies has led to a dramatic rise in increasingly sophisticated financial fraud techniques, particularly through digital platforms and online transactions (Prihanto et al., 2024). The development of forensic accounting has been significantly influenced by both social and technological transformations across global economies. Forensic accountants have been required to continuously enhance their skills and adapt to new challenges in order to effectively detect fraudulent activities in financial reporting. Today, in the modern business environment, forensic accounting systems play a critical role in various domains related to the detection of financial crimes and money laundering.

2. Ethical principles and skills of forensic accountants in fraud detection

The concept of forensic accounting is based on the detection of financial fraud and irregularities by forensic accountants through the use of accounting and auditing techniques, as well as legal regulations. The significance of forensic accounting lies in its capacity to assist business entities in strengthening internal controls and detecting fraud by applying ethical standards, with the ultimate goal of promoting

transparent financial reporting. The core responsibilities of a forensic accountant include risk assessment, evidence collection based on obtained documentation, and the preparation of expert reports for use in legal proceedings (Petrović et al., 2023). Accordingly, the profession of forensic accounting plays a crucial role in resolving ethical dilemmas and identifying deceptive accounting practices aimed at concealing complex financial manipulations and criminal activities. To enhance public trust in the forensic accounting profession, a set of ethical rules-i.e., principles of professional conduct-has been developed. Forensic accountants perform various functions by applying analytical skills such as identifying financial irregularities, detecting risks, assessing damages, and providing expert testimony in court proceedings. Through the application of analytical methods and techniques, forensic accountants contribute to improving the quality of financial reporting and enabling the timely detection of fraud and financial misconduct.

Ethics encompasses a set of rules and principles that guide human behavior without compromising societal values and norms. Business entities that adhere to ethical principles contribute to the reduction of irregularities, promote individual accountability, and enhance their reputation within society. However, in many circumstances, ethical dilemmas may arise-situations in which the boundaries between ethical principles and conflicting interests are not clearly defined, thus creating complex decision-making challenges. Ethical principles are established across all professions in modern society, including law, medicine, psychology, and accounting. These principles form the foundational values upon which professional forensic accountants conduct investigations. By adhering to ethical standards, forensic accountants ensure integrity and foster trust within the contemporary business environment. The following section will present the key ethical principles of forensic accounting, which serve as the guiding rules for their role as fraud investigators. These principles include (Isik, 2025):

Independence and Impartiality. Independence and impartiality require forensic accountants to conduct their investigations free from any personal gain, client pressure, or misrepresentation of collected data. The primary objective is to maintain unimpeachable public trust by ensuring that their findings and professional judgments remain unbiased and objective throughout the investigative process.

Accuracy and Trustworthiness. The profession of forensic accounting must be conducted in accordance with legal regulations and principles of fairness to provide accurate and clear information regarding factual circumstances in an impartial manner. The ultimate goal is to facilitate the resolution of legal disputes based on justice. Therefore, forensic accountants must avoid any familial relationships with clients and must not allow management or other external influences to affect the integrity of their investigations.

Conflict of Interest. Forensic accountants must conduct their investigations in alignment with the public interest, free from any influence by individuals working within the examined business entity. In situations where avoiding conflicts of interest is challenging, forensic accountants should consistently strive to maintain their professional reputation and conduct investigations impartially. This entails performing their duties without any additional engagement with the subject company or personal interests that could compromise professional boundaries during the investigation.

Confidentiality Protection. In conducting investigations, forensic accountants must act with discretion, ensuring the confidentiality of data while maintaining transparency in the disclosure of results. This involves handling sensitive information, including business operations data, individuals' private lives, and potentially legally sensitive material. Forensic accountants are prohibited from sharing obtained information with third parties to prevent any damage to the reputation of the company under investigation.

Orientation Towards the Public Interest. Forensic accountants should prioritize the needs of the public interest to ensure the accurate presentation of facts and the smooth functioning of judicial processes. Accordingly, they must refrain from undertaking tasks beyond their competence or engaging in actions

that could damage their professional reputation. They should not mislead the public, present false information, or conceal unethical behavior by individuals.

Based on the APES 215 Forensic Accounting Services standard issued by the Accounting Professional & Ethical Standards Board, members are required to draw conclusions grounded in factual evidence. The following section provides an explanation of each of these conclusions:

Observed Fact: This refers to the layperson's and superficial observations made by the forensic accountant.

Scientific Fact: A fact based on truth, established through accepted scientific methods.

Assumed Fact: A statement or claim for which experts are not fully certain of its accuracy or validity.

Accepted Fact: A basic assertion regarding facts that experts believe to be accurate and likely to be true.

In order for a forensic accountant to effectively carry out investigative procedures, a decision tree serves as a supportive tool in determining the appropriate type of forensic accounting service. The decision tree outlines the initial step from which the process begins—identifying whether the engagement involves consulting, expert witness services, investigative procedures, or testimony.

Following this determination, evidence is collected and an expert opinion is formed, which may then be presented in court. The objective is to provide a professional opinion grounded in experience, legal knowledge, and accounting regulations. Throughout this process, members are required to comply with **APES 215 Forensic Accounting Services.**

The fundamental requirements for an engagement to be in accordance with the APES 215 standard are as follows:

- Must be members of a professional body.
- Must act in accordance with APES 215 and the ethical principles of forensic accounting.
- The professional practice includes accounting, taxation, auditing, and consulting.
- Provides professional opinion in court to assist the client in resolving legal disputes.

A forensic accountant provides a range of services in the course of conducting investigative procedures. The following section presents the most important roles and services performed by forensic accountants.

2.1. Consulting expert

Participation in judicial proceedings. The role of a forensic accountant is to investigate fraud and manipulation that is the subject of litigation. The court relies on the forensic accountant's professional expertise and conclusions, which serve as the basis for conducting investigative procedures.

Mediator in disputes. As a mediator, the forensic accountant utilizes their specialized knowledge to facilitate communication between the conflicting parties regarding financial fraud and malpractice. In this role, the forensic accountant acts as a neutral third party, serving as an intermediary to help opposing sides resolve disagreements without incurring the costs associated with litigation.

Advisor in investigative procedures of government agencies. A forensic accountant may be engaged by government authorities to assist in the investigation of complex transactions. In this capacity, the forensic accountant applies specialized accounting knowledge to examine intricate financial transactions and provide evidence to support ongoing investigative processes.

Provides damage assessment services. The forensic accountant, acting as an authorized appraiser, determines the extent of damage incurred and the amount of compensation due. This involves conducting a detailed damage assessment, identifying the underlying causes, and preparing a comprehensive damage calculation.

2.2. Expert witness

As a member of a government agency, the forensic accountant prepares company reports in dispute cases. During investigative procedures, they determine the nature of the financial manipulation involved and quantify the lost profits. The report is submitted to the court to assist in the resolution of legal proceedings, wherein the forensic accountant's specialized accounting knowledge is utilized throughout the investigation.

As a member of a government agency, the forensic accountant prepares reports for regulatory bodies concerning publicly traded companies. The forensic accountant provides an opinion on whether the analyzed company has complied with International Financial Reporting Standards (IFRS) and legal regulations. This report is submitted to the court, where the forensic accountant is required to testify and provide a professional opinion regarding the conformity of the company's operations with applicable standards and laws.

2.3. Conducting investigative procedures

In the field of family law, the forensic accountant may be appointed to provide evidence and offer a professional opinion. They participate in dispute resolution between parties by supplying specialized knowledge, including evidence during the investigation.

If employed by the tax authority, the forensic accountant is responsible for conducting investigations of taxpayers. Their role includes carrying out the investigation and providing an expert opinion on irregularities related to the management of current accounts and the payment of tax obligations.

2.4. Witness

As an employee of a company under investigation, the forensic accountant acts as a witness. In this capacity, they are required to provide testimony regarding actions and perpetrators of irregularities, such as asset theft or other types of fraud within the company.

Conclusion

This paper emphasizes the crucial role of forensic accountants in establishing the truthfulness and objectivity of information presented in financial statements. Accordingly, continuous education of forensic accountants is essential, as they must possess multidisciplinary knowledge to conduct thorough investigative procedures in addressing various aspects of economic crime. It is imperative that investigative actions are carried out in accordance with the ethical principles of forensic accounting to ensure that opinions are rendered independently and impartially. Consequently, all investigative activities must be performed with accuracy and confidentiality. Forensic accountants must consistently strive to maintain their professional reputation through careful analysis of the collected documentation and by delivering unbiased opinions. Given the sensitive nature of the information involved, forensic accountants are strictly prohibited from disclosing confidential data to third parties to protect the client's reputation.

From the perspective of the contemporary business environment, it is essential to implement digital technologies within the investigative techniques of forensic accounting to enable timely detection of fraudulent activities in financial reporting. Ultimately, the priority lies in upholding ethical standards in the prevention and detection of financial reporting fraud, as adherence to ethical guidelines and standards enhances the accuracy of work and the integrity of forensic accountants. Furthermore, it is necessary to strengthen the collaboration between professional bodies, governmental institutions, and forensic accounting in order to improve legal regulations, build investor confidence, and preserve a healthy financial market.

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Innovation, Skills, and Entrepreneurship: Building an Knowledge Economy in Bosnia and Herzegovina

Inovacije, vještine i preduzetništvo: Izgradnja ekonomije znanja u Bosni i Hercegovini

Vesna Novaković[1], Miloš Grujić[2], Tanja Škorić[3]

[1]*Pan-European University Apeiron, Banja Luka, Republic of Srpska, Bosnia and Herzegovina, vesna.p.novakovic@apeiron-edu.eu*
[2]*Independent university Banja Luka, Economic faculty, Republic of Srpska, Bosnia and Herzegovina, milos.grujic@ba.gt.com*
[3]*Pan-European University Apeiron, Banja Luka, Republic of Srpska, Bosnia and Herzegovina, tanja.l.skoric@apeiron-edu.eu*

Abstract: *Innovation and entrepreneurship are essential components of economic competitiveness and sustainable development. This paper explores the interrelation between innovation, education, and skills development in Bosnia and Herzegovina (BiH) through the lens of the European Union's* Union of Skills *initiative. Drawing upon both theoretical foundations of innovation and recent EU and UNDP policy frameworks, the study argues that innovation and skills must be developed as mutually reinforcing processes. Bosnia and Herzegovina's challenges—such as outdated education curricula, weak university–industry links, and gender inequalities in STEM—hinder its transition to a knowledge-based economy. The paper highlights good practices and concludes with recommendations for integrating innovation ecosystems into skills development strategies to enhance economic resilience and social inclusion.*
Keywords: *Innovation, entrepreneurship, knowledge-based economy.*

***Apstrakt*:** *Inovacije i preduzetništvo su suštinske komponente ekonomske konkurentnosti i održivog razvoja. Ovaj rad istražuje međusobni odnos između inovacija, obrazovanja i razvoja veština u Bosni i Hercegovini (BiH) kroz prizmu inicijative Evropske unije „Unija veština". Oslanjajući se na teorijske osnove inovacija i nedavne okvire politika EU i UNDP-a, studija tvrdi da se inovacije i veštine moraju razvijati kao međusobno jačajući procesi. Izazovi Bosne i Hercegovine – kao što su zastareli obrazovni programi, slabe veze između univerziteta i industrije i rodne nejednakosti u STEM-u – ometaju njen prelazak na ekonomiju zasnovanu na znanju. Rad ističe dobre prakse i zaključuje se preporukama za integrisanje inovacionih ekosistema u strategije razvoja veština kako bi se poboljšala ekonomska otpornost i socijalna inkluzija.*
Ključne reči: *Inovacije, preduzetništvo, ekonomija zasnovana na znanju.*

Introduction

Innovation and entrepreneurship have recognized as the twin pillars of modern economic growth. In an era of rapid technological progress, global competition, and the digital and green transitions, societies that invest in their human capital—through education, research, and innovation—are the ones that secure long-term prosperity. The European Union (EU) has placed these priorities at the heart of its policy agenda. Through initiatives such as the *European Skills Agenda*[1] and the *Union of Skills*[2] the EU aims to strengthen the link between education, employability, and innovation, building a cohesive

[1]https://employment-social-affairs.ec.europa.eu/policies-and-activities/skills-and-qualifications/european-skills-agenda_en
[2]https://commission.europa.eu/topics/eu-competitiveness/union-skills_en

European area of knowledge and competences. These initiatives recognize that economic competitiveness is no longer determined solely by access to natural or financial resources, but by a nation's ability to continuously create, adapt, and apply knowledge. The concept of skills in the European policy framework extends beyond technical proficiency. It includes transversal competences such as digital literacy, critical thinking, problem-solving, and entrepreneurship—attributes essential for innovation and social resilience. Lifelong learning, flexibility, and adaptability are emphasized as fundamental values, while innovation is viewed as a process that transforms skills and knowledge into tangible economic and social outcomes. This dual focus on innovation and skills represents not only a policy goal but also a paradigm shift toward a knowledge-driven, inclusive, and sustainable economy.

Bosnia and Herzegovina (BiH), as a country in transition and an aspirant to EU membership, finds itself at a crossroads where innovation and skills development could determine its future trajectory. Despite having a relatively well-educated population, the country faces persistent structural barriers. Youth unemployment remains among the highest in Europe—35.1% according to recent estimates (Novaković et al., 2025), while the mismatch between education outcomes and labor market needs limits economic competitiveness. Many graduates, particularly those in social sciences and humanities, face difficulties finding employment, while industries struggle to recruit experts in STEM, digital, and engineering fields. This mismatch reflects both the inertia of an outdated education system and the insufficient integration of innovation policies into national development strategies. From a theoretical perspective, innovation acts as a multiplier of skills. Authors (Novaković et al., 2020) argue that innovation is a dynamic process that transforms knowledge into new products, services, and processes, thereby creating new employment opportunities and increasing productivity. In this sense, innovation both demands and generates skills—it requires a workforce capable of creative thinking and problem-solving, while at the same time fostering the need for continuous learning and adaptation. When aligned with skills development, innovation becomes the mechanism that transforms education into economic value. However, BiH's innovation ecosystem remains underdeveloped. Research and development (R&D) investments are low, cooperation between universities and enterprises is limited, and institutional support for start-ups and technological transfer is fragmented. As a result, the country struggles to translate its human capital into innovation-driven growth. The *Union of Skills* framework provides a valuable reference point for addressing these challenges by promoting systemic reform, gender equality, and entrepreneurship as key drivers of transformation. Within this framework, digital and green skills, lifelong learning, and micro-credentials are recognized as essential tools for building inclusive and resilient economies. Entrepreneurship stands out as a critical competence linking innovation and skills. The *European Framework of Key Competences for Lifelong Learning* defines entrepreneurship as one of the eight essential competences that citizens need for personal and professional development. As Novaković (Novaković, 2012) notes, entrepreneurship should not be viewed as an innate ability but as a skill set that can be learned and cultivated. Entrepreneurial education, combined with innovation-focused learning, can empower young people to become active creators of change rather than passive job seekers.

Therefore, the central argument of this paper is that innovation and skills development must be understood as mutually reinforcing processes. The capacity to innovate depends on the ability of individuals and institutions to learn, adapt, and collaborate, while skills development gains purpose and direction when oriented toward creativity, technology, and entrepreneurship. By aligning national education and innovation policies with the EU's *Union of Skills* framework, Bosnia and Herzegovina can lay the foundation for a knowledge-based economy that values inclusivity, gender equality, and social cohesion. The purpose of this study is to analyze how innovation and skills development can jointly serve as drivers of economic and social progress in BiH. It begins by outlining the theoretical basis for innovation as an engine of growth, continues by exploring the role of the *Union of Skills* initiative in shaping European and regional skills policies, and examines BiH's challenges and examples of good practice. The concluding section proposes policy recommendations aimed at integrating innovation and skills strategies into a coherent national framework, capable of transforming human capital into sustainable development

1. Literature review

The theory of innovation, as presented by (Novaković et al., 2020), builds upon Schumpeter's view of innovation as a key mechanism of "creative destruction," through which entrepreneurs generate new combinations of production factors, technologies, and markets. Innovation, in this context, is not merely technological but also organizational, social, and institutional.

According to (Novaković et al., 2020), innovation emerges from multiple sources—research and development, universities, enterprises, and even social practices. It includes:

- **Product innovations** – development of new goods or significant improvements in existing ones.
- **Process innovations** – improvements in production methods and efficiency.
- **Organizational and marketing innovations** – new business models and management practices.

The *Oslo Manual* (OECD & Statistical Office of the European Communities, 2005) similarly categorizes innovations into product, process, organizational, and marketing types. Together, these forms underpin the competitiveness of knowledge-based economies.

From an economic perspective, innovation creates new industries, increases productivity, and enhances global competitiveness. From a social standpoint, it encourages creativity, adaptability, and lifelong learning—skills crucial for sustainable growth. Therefore, innovation and skills development are not parallel processes but deeply interconnected mechanisms that reinforce each other.

Innovation and skills development are central themes in both economic theory and modern policy frameworks. The concept of innovation as the driving force of economic growth was first articulated by **Joseph A. Schumpeter,** who introduced the notion of *creative destruction* — the process through which new combinations of production factors replace old ones, leading to technological advancement and structural transformation. Schumpeter's theory laid the foundation for understanding innovation as the key engine of capitalism and entrepreneurship. Building on this foundation, **Peter F. Drucker** emphasized innovation as a systematic and purposeful activity that can be managed and taught. He argued that entrepreneurship is essentially the practice of innovation — the discipline of turning ideas into value. This idea strongly resonates with recent work by (Novaković et al., 2025) who argue that entrepreneurship is not an innate talent but a skill that can be developed through education and experience.

During the late 20th century, the focus of innovation studies expanded from individual firms to broader systems. Scholars such as **Christopher Freeman** and **Bengt-Åke Lundvall** (Lundvall, 2007) introduced the concept of *National Innovation Systems (NIS)*, highlighting the importance of interactions among universities, industries, and governments. Innovation, in their view, emerges from networks of learning and cooperation, not only from isolated technological discoveries. This systemic perspective aligns closely with the *Union of Skills* initiative, which emphasizes collaboration across institutions to foster continuous learning and innovation. **Michael Porter** further contributed to this discourse through his *Diamond Model* of national competitiveness, asserting that innovation capacity depends on the quality of human capital, the presence of competitive industries, and the ability of firms to upgrade through knowledge and skills. In this framework, skills development becomes a strategic component of innovation policy. Countries that invest in education, training, and research not only improve productivity but also enhance their capacity for technological leadership (Jakupović & Novaković, 2017).

In the 21st century, new paradigms have emerged, focusing on open and collaborative models of innovation. **Henry Chesbrough** introduced the concept of *Open Innovation*, describing how organizations increasingly rely on external sources of knowledge and collaboration with universities, start-ups, and research institutions. This model underscores the importance of skills mobility and knowledge sharing — principles that lie at the core of the EU's *Union of Skills* and *Horizon Europe* frameworks (Novakovic & Jakupovic, 2023). At the same time, **Richard Florida** popularized the notion

of the *creative class*, emphasizing that regions and nations that attract creative, skilled individuals — scientists, engineers, designers, and entrepreneurs — are those that achieve sustainable economic growth. His work demonstrates that skills, innovation, and urban development are deeply interconnected, and that inclusive and diverse societies tend to be more innovative.

Institutional approaches, such as those presented by the **OECD** and **European Commission**, reinforce these theoretical foundations by operationalizing them into policy frameworks. The *Oslo Manual* (OECD & Statistical Office of the European Communities, 2005) provides standardized guidelines for measuring innovation, classifying it into product, process, organizational, and marketing dimensions. The *European Skills Agenda* and the *Union of Skills* build on this foundation by recognizing that innovation is inseparable from continuous skill formation and human development.

In the context of the Western Balkans, studies by the **Regional Cooperation Council** (RCC, 2024) show that while educational attainment is relatively high, innovation output remains limited due to weak institutional linkages and gender disparities in STEM. Science, technology, and innovation (STI) policies in the region are often "gender-blind," missing opportunities to leverage women's significant presence in higher education for innovation and entrepreneurship.

At the national level, the research corpus provides a detailed understanding of how these global theories apply in the BiH context (Новаковић & Бобрек Мацановић, 2020) (Bobrek & Novakovic, 2024) (Milovanovic & Novakovic, 2025) (Novakovic, Milovanovic, & Kondic, 2025) (Novakovic, Milovanovic, & Skoric, 2024) (Mekinjić et al., 2019). **These paper** conceptualize innovation as a systemic economic process that transforms knowledge into value, aligning with the Schumpeterian and Lundvallian frameworks, explores youth entrepreneurship as a strategic entry point for building innovation culture and risk tolerance among young generations, focus on small and medium-sized enterprises (SMEs) as key innovation actors, echoing Porter's argument that competitiveness depends on firm-level upgrading, emphasize digital transformation as a structural force reshaping skills and business models in the era of Industry 4.0., contribute a gender perspective, arguing that inclusive entrepreneurship and equal access to innovation ecosystems are essential for maximizing national human potential.

Together, these contributions bridge the gap between international theory and local practice. They demonstrate that Bosnia and Herzegovina's innovation potential is not limited by human talent but by the lack of systemic integration — a gap that the *Union of Skills* initiative directly seeks to close. Thus, the literature confirms that the combination of skills development, entrepreneurship, and innovation policies can serve as the foundation for a knowledge-based and inclusive economy.

2. Skills development within the EU's Union of skills initiative

The *Union of Skills* initiative, launched by the European Commission in 2023, represents one of the EU's most ambitious frameworks for connecting education, skills development, and innovation. Building upon the *European Skills Agenda* and the *Pact for Skills*, the initiative aims to create a resilient, knowledge-based economy where learning, research, and innovation are integrated into a single, dynamic system. It reflects the understanding that the European Union's long-term competitiveness depends not only on technological advancements but also on its ability to cultivate the human capacities necessary to generate and apply innovation.

From an innovation perspective, the *Union of Skills* marks a paradigm shift. Traditional models of education often focused on the accumulation of knowledge, whereas the new framework emphasizes the *application* and *transformation* of knowledge through creativity, collaboration, and entrepreneurship. Innovation, in this context, is not confined to laboratories or research centers—it becomes a social process that permeates all aspects of education, work, and lifelong learning. The European Commission (2025) explicitly links the development of skills to innovation capacity, asserting that "the future of European competitiveness will be determined by how quickly citizens can acquire, adapt, and apply new competences in response to technological change."

The *Union of Skills* introduces several key mechanisms that directly support innovation-driven skills development:

1. **Integration of innovation into education and training systems**

   Education systems are encouraged to go beyond formal instruction and embed innovation-oriented learning outcomes into curricula. This includes project-based learning, problem-solving, and interdisciplinary collaboration—approaches that mirror the processes of innovation in the real economy. Through initiatives such as *Erasmus+*, *Horizon Europe*, and the *European Education Area*, the EU promotes cooperation between universities, research institutions, and the private sector, fostering an environment where students acquire not only knowledge but also the mindset to innovate.

2. **Micro-credentials and lifelong learning for an innovative workforce**

   Innovation requires adaptability. The EU's micro-credentials framework allows individuals to acquire specific skills quickly, in response to emerging technologies and market needs. This flexible approach supports innovation ecosystems by ensuring a steady flow of skilled professionals who can bridge knowledge gaps in areas such as digitalization, green technologies, and artificial intelligence. It also supports *knowledge diffusion*, a concept central to innovation theory (Lundvall, 1992), where skills circulate across sectors and stimulate cross-fertilization of ideas.

3. **Promotion of digital and green skills as catalysts of innovation**

   The *Union of Skills* recognizes that the digital and green transitions are inseparable from innovation. Digital competences—data literacy, coding, artificial intelligence, and cyber resilience—enable individuals to participate in innovation processes, while green skills foster sustainable production, eco-innovation, and circular economy models. By integrating these priorities, the initiative positions skills development as the foundation for Europe's twin transition and for the emergence of new innovation-driven industries.

4. **Entrepreneurship as an innovation competence**

   The initiative explicitly identifies entrepreneurship as one of the eight key competences for lifelong learning. Entrepreneurship here is not viewed solely as business creation but as the capacity to identify opportunities, take initiative, and turn ideas into value—core elements of the innovation process (Homayoun et al., 2024). In line with the *EntreComp* framework, the EU promotes entrepreneurial education at all levels, linking it to creativity, leadership, and resilience. This focus on entrepreneurship as a learnable skill directly supports the transformation of human potential into innovative outcomes.

5. **Innovation ecosystems and knowledge partnerships**

   The *Union of Skills* operates within a broader European innovation ecosystem that includes *Horizon Europe*, *European Innovation Council (EIC)*, and *European Institute of Innovation and Technology (EIT)*. These initiatives complement skills policies by creating structured pathways between education, research, and industry. For example, *EIT Knowledge and Innovation Communities (KICs)* bring together universities, research centers, and businesses to co-create programs that blend academic learning with real-world innovation challenges. Such cross-sector partnerships represent the operationalization of what Lundvall (1992) called *interactive learning*—the process through which innovation emerges from collaboration.

6. **Gender and inclusion in innovation-oriented skills development**

   n line with the EU Gender Equality Strategy and findings from the *Regional Cooperation Council (2024)*, the *Union of Skills* framework stresses that inclusive participation is critical to innovation. Women and underrepresented groups must have equal access to STEM education,

entrepreneurship support, and digital literacy programs. The inclusion of women in innovation ecosystems has been shown to significantly increase creativity, productivity, and social impact (World Economic Forum, 2025). Thus, gender equality is not only a moral imperative but also an innovation policy.

7. **Regional cooperation and policy alignment**

   For candidate countries such as Bosnia and Herzegovina, the *Union of Skills* provides a strategic framework for aligning national education and innovation systems with EU standards. Participation in programs such as *Horizon Europe* and *Erasmus+* allows BiH to access funding, exchange expertise, and integrate into European research and innovation networks. Aligning national skills strategies with the *Union of Skills* principles can therefore accelerate the country's transition toward a knowledge-based and innovation-driven economy.

From a broader perspective, the *Union of Skills* can be seen as an evolution of the European innovation model. Whereas earlier EU policies treated skills and innovation as separate domains, this initiative merges them into a single, circular process: skills enable innovation, innovation drives demand for new skills, and the cycle continues. This "skills–innovation nexus" is the foundation of what the European Commission calls *a new social contract for learning and competitiveness*.

For Bosnia and Herzegovina, this model offers both inspiration and guidance. It suggests that innovation should not be viewed as a distant outcome of education reform, but as its integral purpose. By fostering skills that are adaptable, creative, and entrepreneurial, BiH can cultivate an environment where innovation becomes a natural product of education, collaboration, and inclusion. The *Union of Skills* therefore represents not only a European policy framework but also a roadmap for national transformation — one in which education and innovation work hand in hand to build sustainable, inclusive, and competitive societies.

Conclusion

The synthesis of research conducted by Novaković and colleagues over the past decade reveals a consistent message: Bosnia and Herzegovina's economic future depends on its ability to align innovation, education, and entrepreneurship into a coherent national development system. Despite significant human capital potential, fragmentation in governance, limited institutional coordination, and outdated educational models prevent the full use of these capacities.

At the European level, the *Union of Skills* initiative and accompanying instruments such as *Erasmus+*, *Horizon Europe*, and the *European Innovation Council* illustrate how education and innovation policies can function as a single system. The EU promotes the idea of a continuous skills loop — where learning, research, and innovation feed into each other. This approach ensures that individuals acquire not only technical expertise but also the creativity, adaptability, and problem-solving skills required for innovation-driven growth.

In Bosnia and Herzegovina, adopting such an integrated approach would mean:

- **Reforming education** to prioritize practical and entrepreneurial competences alongside theoretical knowledge.
- **Institutionalizing lifelong learning**, with flexible pathways such as micro-credentials, reskilling programs, and partnerships between universities and industries.
- **Encouraging applied research and innovation transfer**, using public funding and fiscal incentives to link academic research with SME innovation.
- **Strengthening innovation governance**, through clearer coordination between ministries, development agencies, and local governments.

Novaković et al. (2024) emphasize that SMEs should serve as the backbone of this transformation. Their agility, local knowledge, and ability to innovate on a smaller scale make them ideal vehicles for linking skills development with technological advancement. However, as Novaković et al. (2025) point out, SMEs can only drive growth if their employees continuously develop digital and managerial skills, and if public institutions create an environment conducive to innovation.

The digital transformation agenda — as presented in *Digital Transformation and Industry 4.0 and Its Impact on SME Business* (Novakovic V. , Milovanovic, Skoric, & Supukovic, 2024) further underlines the urgency of aligning skills with technology. Digital skills are no longer optional but essential across all sectors. Embedding digital literacy, data management, and AI-related competences into education systems and professional training would accelerate BiH's integration into European and global value chains.

From a strategic perspective, Bosnia and Herzegovina could leverage existing EU instruments to achieve this integration:

- **Erasmus+** – for mobility, staff training, and curriculum modernization;
- **Horizon Europe** – for research and innovation partnerships;
- **Union of Skills and Pact for Skills** – for reskilling and micro-credential systems;
- **European Social Fund+ (ESF+)** – for inclusion, youth employment, and gender equality projects.

By combining these instruments with domestic programs such as **UNDP's EGG** and **INOVA**, BiH can move from isolated initiatives toward a coherent national innovation and skills ecosystem. The combined analysis of innovation and skills development reveals that Bosnia and Herzegovina stands at a decisive turning point. Its human capital is strong, its academic community dynamic, and its alignment with EU strategies increasingly visible. Yet, the absence of systemic integration between education, innovation, and entrepreneurship continues to hinder progress.

The literature overview provide a theoretical and empirical foundation for addressing these challenges. They collectively argue that innovation is not only a technological process but also a social and educational phenomenon — one that depends on cultivating creativity, entrepreneurial competence, and institutional cooperation. Skills, on the other hand, provide the practical capacity to transform innovation into economic growth.

Therefore, the key to BiH's sustainable development lies in **building an innovation-driven skills ecosystem,** characterized by:

1. **Integrated policy frameworks** that connect innovation, education, and employment;
2. **Continuous investment in human capital**, focusing on digital, green, and entrepreneurial skills;
3. **Gender-inclusive participation** in STEM and entrepreneurship;
4. **Strengthened SME innovation capacity** through technology, training, and financing;
5. **Partnerships between academia, industry, and government**, supported by EU programs and regional cooperation.

In line with the *Union of Skills* philosophy, innovation should not be treated as a final product of education but as an ongoing process that continuously renews the economy. Bosnia and Herzegovina's participation in EU initiatives such as *Horizon Europe* and *Erasmus+* offers both resources and frameworks to achieve this.

The long-term vision must go beyond policy alignment—it must create a **culture of innovation and lifelong learning**, where every individual is empowered to contribute to development through

knowledge and creativity. If BiH successfully integrates innovation and skills strategies, it can transition from a knowledge consumer to a knowledge producer, positioning itself as a competitive, inclusive, and sustainable economy within the European landscape.

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Applying Machine Learning and Big Data Approaches to Predict Future IT Labor Market Needs

Primjena mašinskog učenja i Big Data pristupa za predviđanje budućih potreba IT tržišta rada

Mahir Zajmović[1], Hadžib Salkić[2]

[1]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, mahir.zajmovic@mef.edu.rs*

[2]*University "FINRA", Faculty of Technical Sciences, Tuzla, Bosnia and Herzegovina, hadzib.salkic@finra.edu.ba*

Abstract: *In this paper, we explore the application of advanced machine learning techniques and Big Data infrastructure in predicting future IT labor market needs. Through the analysis of large amounts of data collected from various sources, such as job advertisements, social networks, technical literature, and course platforms, sophisticated models have been developed that enable more precise detection of current trends and identification of areas with growing demand for IT experts. Special attention is paid to the application of artificial intelligence in processing unstructured and heterogeneous data sets, as well as the use of advanced algorithms for identifying the most sought-after skills and competencies in the labor market. The research results show that the integration of machine learning and Big Data technology can significantly improve the decision-making process, enabling the upgrading of educational programs, career plans, and industrial strategies in accordance with dynamic changes in the technological sphere. Such approaches contribute not only to a better understanding of current labor market needs, but also to its future adaptation and development, thereby stimulating the competitiveness of the economy at the global level and supporting the digital transformation of the economy. The paper highlights the potential of these technologies as a key factor in shaping a sustainable and innovative IT sector in the future.*

Keywords: *Machine learning, big data, data analysis, technological development, digital transformation, labor market.*

Apstrakt: *U ovom radu istražujemo primjenu naprednih tehnika mašinskog učenja i Big Data infrastrukture u predviđanju budućih potreba IT tržišta rada. Kroz analizu velike količine podataka prikupljenih iz različitih izvora, kao što su oglasi za posao, socijalne mreže, tehnička literatura i platforme za kurseve, razvijeni su sofisticirani modeli koji omogućavaju preciznije detektovanje trenutnih trendova i identifikaciju oblasti sa rastućom potražnjom za IT stručnjacima. Posebna pažnja posvećena je primjeni veštačke inteligencije u obradi neuređenih i heterogenih skupova podataka, kao i korištenju naprednih algoritama za identifikaciju najtraženijih vještina i kompetencija na tržištu rada. Rezultati istraživanja pokazuju da integracijom mašinskog učenja i Big Data tehnologija može značajno unaprijediti proces donošenja odluka, omogućavajući nadogradnju obrazovnih programa, karijernih planova i industrijskih strategija u skladu sa dinamičnim promjenama u tehnološkoj sferi. Ovakvi pristupi doprinose ne samo boljem razumijevanju trenutnih potreba tržišta rada, već i njegovoj budućoj adaptaciji i razvoju, čime se podstiče konkurentnost privrede na globalnom nivou i podržava digitalna transformacija ekonomije. Rad ističe potencijal ovih tehnologija kao ključnog faktora u oblikovanju održivog i inovativnog IT sektora u budućnosti.*

Ključne riječi: *Mašinsko učenje, Big Data, analiza podatka, tehnološki razvoj, digitalna transformacija, tržište rada.*

Introduction

Data plays a crucial role in our society and enables us to understand the world around us. It is estimated that 80% of all data is unstructured. Big Data must be prepared, filtered, categorized, analyzed, and visualized. Big Data analysis is a technological process of studying large datasets (high-volume, high-velocity, and/or high-variety data) in order to discover information such as hidden patterns, correlations, market trends, and customer preferences. It helps organizations, governments, and institutions study data collections and gain insights that support informed, faster, and more effective decision-making.

Raw data may contain errors or low-quality values (missing values, outliers, redundant or inconsistent data, etc.), which often need to be preprocessed—through data cleaning, integration, transformation, and reduction-to remove unnecessary information, correct inaccuracies, or reduce dataset size. A good example of this is business intelligence, which represents the process of analyzing data to provide concrete information that helps directors, managers, and employees make informed business decisions. Business intelligence focuses on business activities and performance. The data required for business intelligence is varied and complex. Big Data systems contain raw data that must be filtered and prepared before being loaded and analyzed for business intelligence purposes. Banks and insurance companies use Big Data to improve their financial analyses and credit risk assessments, as well as for customer segmentation and similar purposes.

We can see a practical example of Big Data application in the prediction of credit risk in banks. The focus of this paper is a financial dataset related to loans and associated information. It involves predictions for assessing the repayment risk of active loans, the likelihood of payment delays, and the risk associated with granting loans to specific clients. Data analysis and prediction in this research represent a highly important step, since data analysis, cleaning, and transformation are performed with the goal of enabling accurate predictions. The predictions in this study are carried out using the Python programming language, which is an ideal option for machine learning and algorithmic applications.

The dataset used in this research is called Financial (PKDD'99 Financial Dataset). It contains a certain number of successful and unsuccessful loans, along with their related information and transactions. The dataset includes all eight tables in the database, with over 10,000 loan records used for this research and analysis (Berka, 1999).

1. Problem and research subject

Credit risk is one of the key factors in decision-making processes related to loan approval in banking and credit institutions. Accurate risk analysis allows financial institutions to minimize losses and increase profitability. In this paper, we analyze credit risk prediction using three different machine learning algorithms: DecisionTreeClassifier, LogisticRegression, and K-Means, applied to a dataset obtained from the website www.relational.fel.cvut.czu/dataset/Financial. These algorithms are commonly used in business intelligence, financial analysis, marketing, sales, and related fields.

For the purposes of this research, Big Data archived on the aforementioned website will be used to perform data analysis and build predictive models using machine learning algorithms (MLA) and software tools designed for data extraction, analysis, modeling, and visualization.

The graphical representation of the Financial dataset, which contains credit transactions and related tables, is shown in Figure 1.

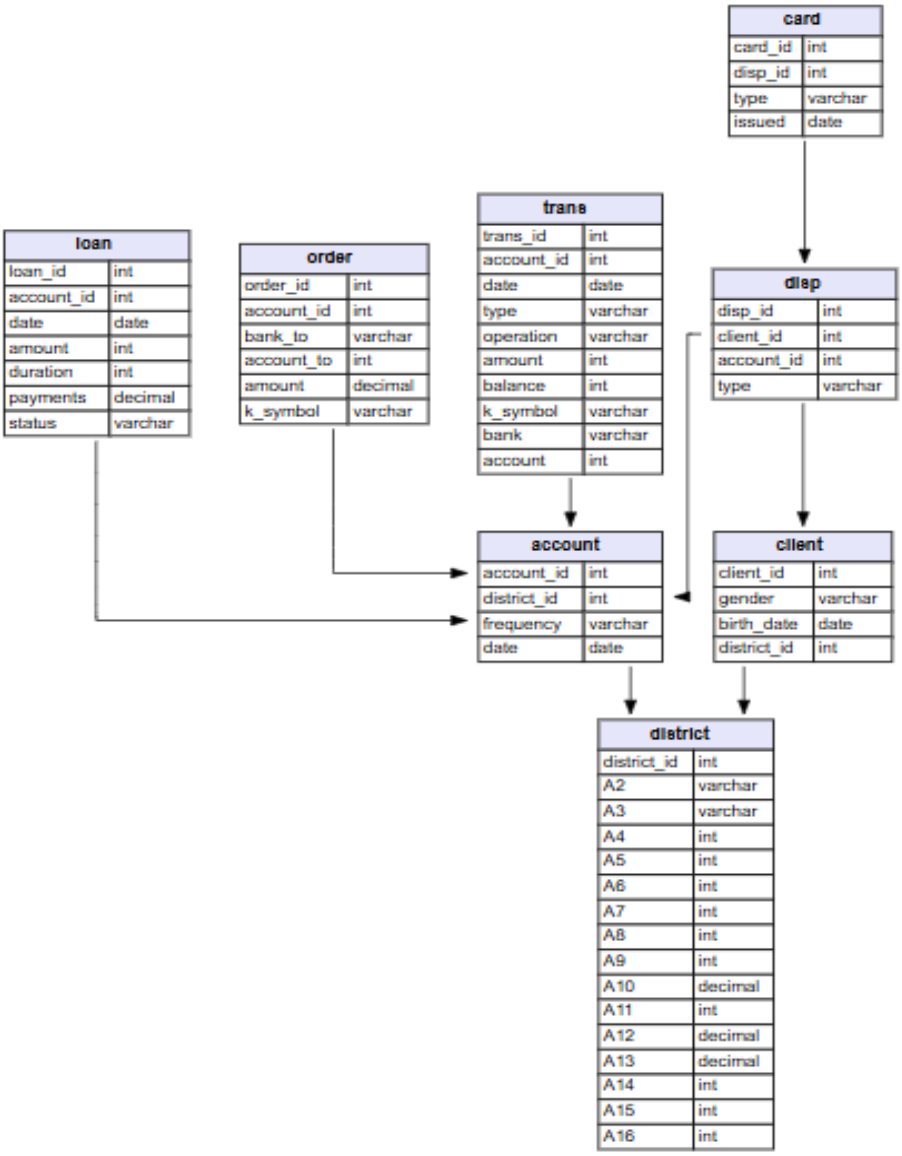


Figure 1. Structure of the Financial dataset showing credit transactions and related tables
Source: Berka, 1999

The database consists of eight (8) tables: loan, order, trans, card, client, account , district and disps.

There are various methods for assessing credit risk, including traditional approaches; however, research has shown that the application of machine learning algorithms in Big Data analysis can provide more accurate predictions compared to classical financial models.

In this study, we analyzed the Financial dataset, which contains more than 10,000 records (8 tables, 55 columns, and 10,908 rows) in a CSV database format. The analyses and predictions (evaluations and predictive models) were performed on credit assessments, repayment risk, loan issuance risk, and payment delay risk. For data analysis and prediction, the Python programming language was used.

2. Data analysis

The structure of the dataset used in this research consists of eight tables. The tables are primarily connected through 1-to-1 or 1-to-many relationships. To access the data, we connected to a publicly available MariaDB database located at: relational.fel.cvut.cz:3306. During the research, several insights were identified within the dataset—for instance, accounts that are unlikely to repay their loans, clients

who do not possess a credit card despite meeting the requirements for one, and clients who have access to payment services but do not use them. Since the dataset needed to be imported into Power BI for further analysis, cleaning, and transformation, an intermediary application was required because Power BI does not support direct connections to this particular database. For that purpose, MySQL Workbench was selected as the intermediary tool. MySQL Workbench is a unified visual tool designed for database architects, developers, and DBAs, enabling efficient data management and integration.

After successfully importing the data, the next step involved manipulating the loaded data. Microsoft Power BI is a data visualization platform frequently used for business intelligence purposes. Once the data was imported, the first task was to organize and clean it. During this process, we identified the available tables and examined the types of relationships between them. In this dataset, the most common relationships were one-to-one (1:1) or one-to-many (1:n). By reviewing the columns within each table, we were able to gain an understanding of the scope and nature of the data contained in the dataset. Figure 2 shows the dataset within Power BI, including all the established relationships between the tables.

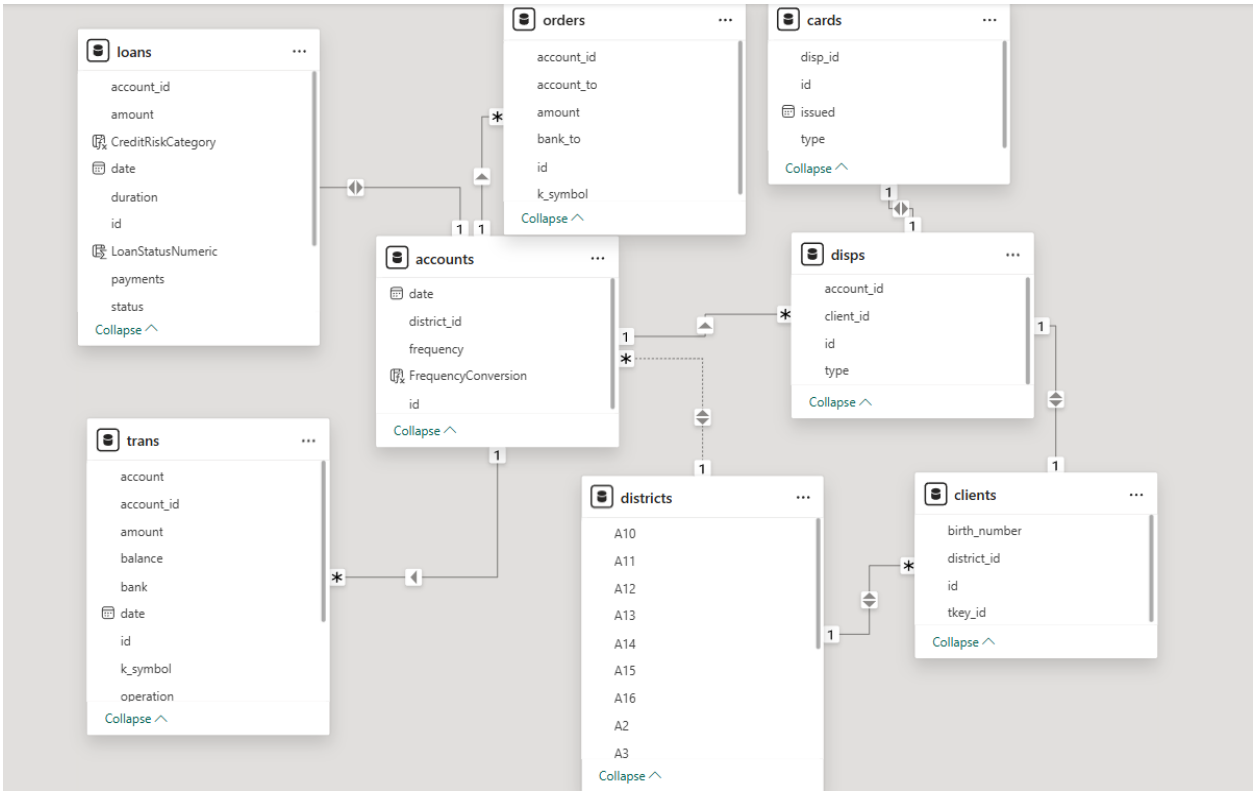


Figure 2. Overview of the dataset with all tables and relationships in the Power BI tool
Source: Author's

Through a more detailed analysis, a clear relationship can be observed between three tables: accounts, loans, and trans. Based on the connections among these three tables, it is possible to extract more detailed information about the loans themselves, as well as the risks and potential delays in loan repayments by clients. These specific tables — or more precisely, selected columns from them — were used to build models for credit risk prediction and repayment delay prediction. The analysis conducted at this stage revealed that it is possible to perform three types of predictions: two directly using the available data, and a third one derived by incorporating the results of one of the previous two predictions.

3. Prediction of loan repayment risk

The assessment of current loan repayment risk was conducted using the Python programming language and the DecisionTreeClassifier from the scikit-learn (sklearn) library. The DecisionTreeClassifier from the sklearn.tree module is an implementation of a Decision Tree, one of the most widely used supervised learning algorithms for data classification.

A decision tree functions by recursively dividing the dataset based on the features that most effectively separate the classes. It starts with all data at the root node and, at each level, selects the best feature for splitting the data using criteria such as the Gini index or entropy. The process continues until a predefined stopping condition is reached (e.g., maximum tree depth).

The classification of a new data point is performed by traversing the tree down to the corresponding leaf node, where the final class decision is made. This algorithm is easy to interpret, as it can be visualized and intuitively understood. It does not require data normalization or scaling and handles nonlinear relationships as well as a mix of numerical and categorical data effectively (Jain, Atishay & Sharma, 2011).

From a machine learning perspective, this algorithm is widely applied in medical diagnostics, credit risk assessment, fraud detection, and speech recognition. For this reason, it was chosen for evaluating credit risk in this study. Additionally, it has been used in numerous similar research works and relevant studies (Jain, Atishay & Sharma, 2011), where this type of algorithm is also applied to financial datasets for prediction purposes. In our case, the achieved accuracy was approximately 82% (0.82) — specifically 0.88 for "Yes" and 0.71 for "No", with the model parameters set to max_depth = 4 and random_state = 42.

The input columns for this prediction were amount and duration from the loans table. Before making predictions, the dataset was divided into 80% training data and 20% testing data to evaluate the model's performance.

During training, the target variable (y) was taken from the status column, where statuses A and B were classified as low-risk loans, while statuses C and D were classified as high-risk loans.

The resulting model produced an additional column named RiskPrediction, containing two possible values:

- 0 – Low risk
- 1 – High risk

The resulting CSV file with predictions was later imported into Power BI and linked with the original dataset for visualization purposes. This visualization process is presented in the later stages of this paper, particularly in the results visualization section. Similar applications of this algorithm can also be found in other studies addressing this problem area (Mu-Yen Chen, 2011).

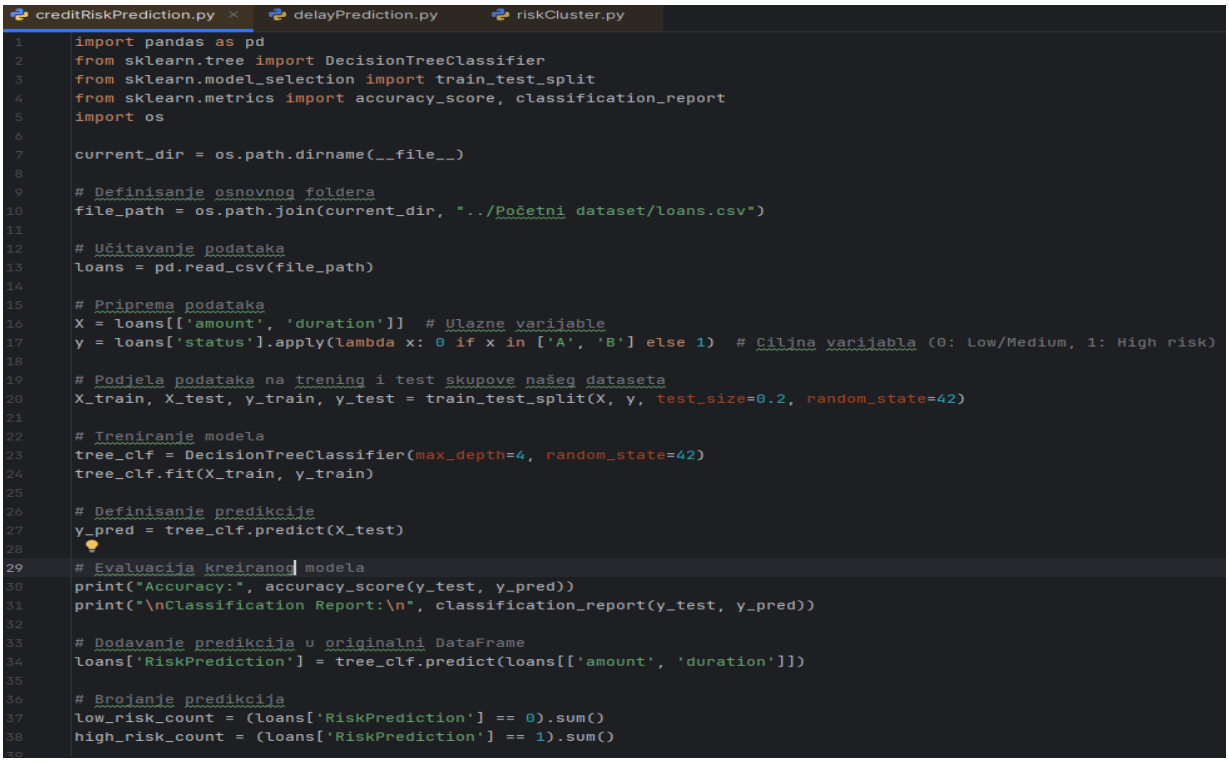


Figure 3. Example of Python source code performing basic credit risk classification using the DecisionTreeClassifier algorithm

Source: Author's

The results obtained from this analysis and prediction using the DecisionTreeClassifier algorithm were quite satisfactory, achieving an accuracy of approximately 82%, which can be considered a solid outcome for this study — especially when compared to other similar research. The Python-generated algorithm performance report is shown in Figure 4.

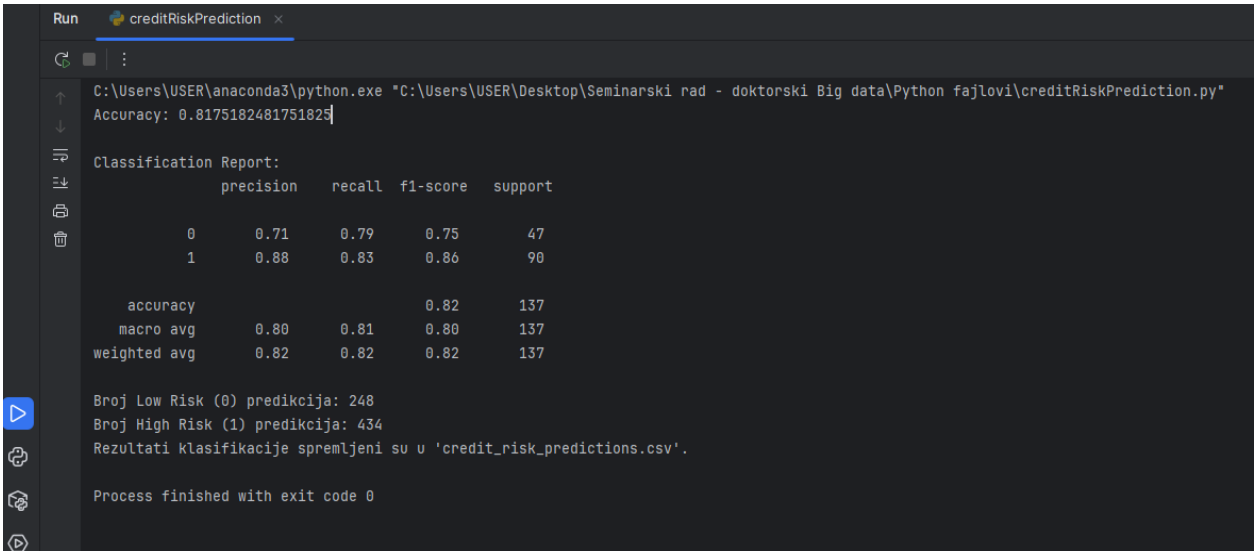


Figure 4. Display of DecisionTreeClassifier algorithm results with a model accuracy of 0.82 (82%)

Source: Author's

The interpretation of the obtained results — for example, 0.82 — indicates that the model correctly classifies 82% of all cases, which represents a strong result for our first model.

In terms of specific performance metrics:

- Precision: 0.71 – When the model predicts "Low Risk," 71% of those predictions are correct.
- Recall: 0.79 – The model correctly identifies 79% of all actual "Low Risk" cases.
- F1-score: 0.75 – This reflects the balance between precision and recall (the higher, the better).

For the High Risk class:

- Precision: 0.88 – This is a very good level of precision, meaning that most "High Risk" predictions are accurate.
- F1-score: 0.86 – Indicates that the model performs very well for this class.

The model proves to be particularly effective in identifying high-risk clients, which is highly beneficial in practice (for example, for banks aiming to reduce lending risks). However, it is slightly weaker in detecting low-risk clients, which could be an area for further data or model optimization.

4. Research results

After importing the data from Python, several transformations had to be performed to make the data easier to interpret. The reason the data was not directly returned in textual format from Python is that additional measures needed to be created in order to effectively present the results. The results were visualized using various charts — including Pie Charts, Bar Charts, and Column Charts — as well as sliders that allow users to interactively manipulate and explore the displayed data. In addition to visualizing the predicted results, the original (initial) data was also displayed, enabling users to compare and track changes before and after the prediction process.

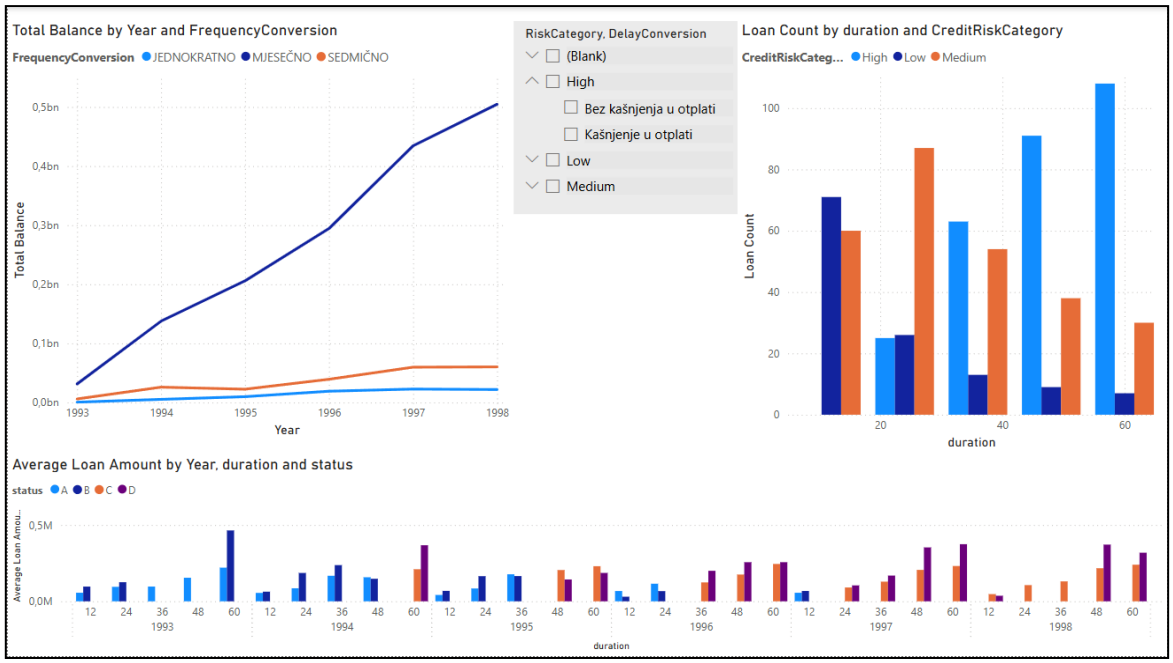


Figure 5. Visualization of dataset results before prediction
Source: Author's

In Figure 5, three charts are shown, representing the distribution of transaction amounts and loan values by year and duration in months. It can be observed that most transactions occur on a monthly basis, and that loans with higher amounts and longer repayment periods are associated with a higher repayment risk, whereas smaller loans with shorter repayment terms tend to have a lower risk.

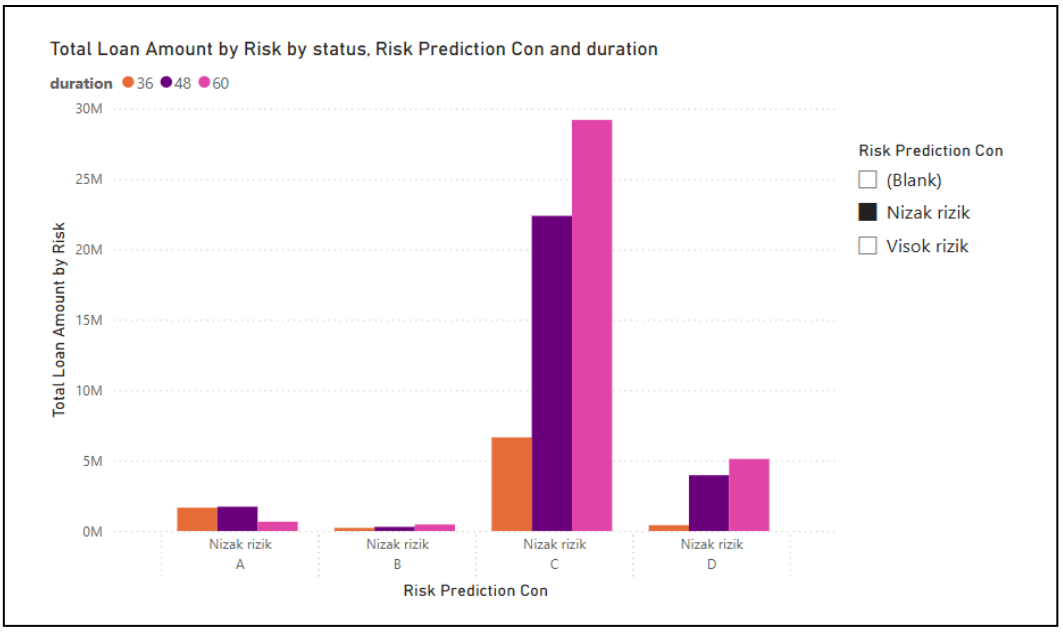


Figure 6. Graphical representation of the predicted low-risk loan repayments
Source: Author's

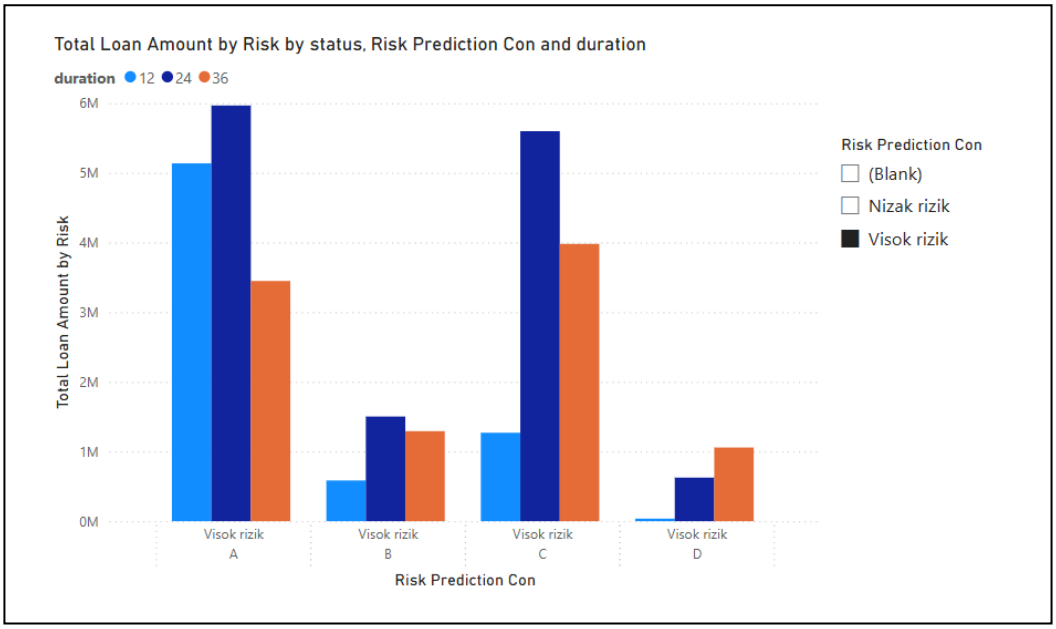


Figure 7. Graphical representation of the predicted high-risk loan repayments
Source: Author's

The chart shows that the highest-risk loans are those with large amounts and a medium number of installments, specifically 24 and 36 months, while loans with 48 and 60 installments are identified as having the lowest repayment risk. The analysis suggests that this is due to the smaller installment amounts, which allow clients with lower incomes to make regular payments more easily. It was determined that, out of a total of 682 input records, 248 were predicted as low-risk loan repayments, while 434 were predicted as high-risk.

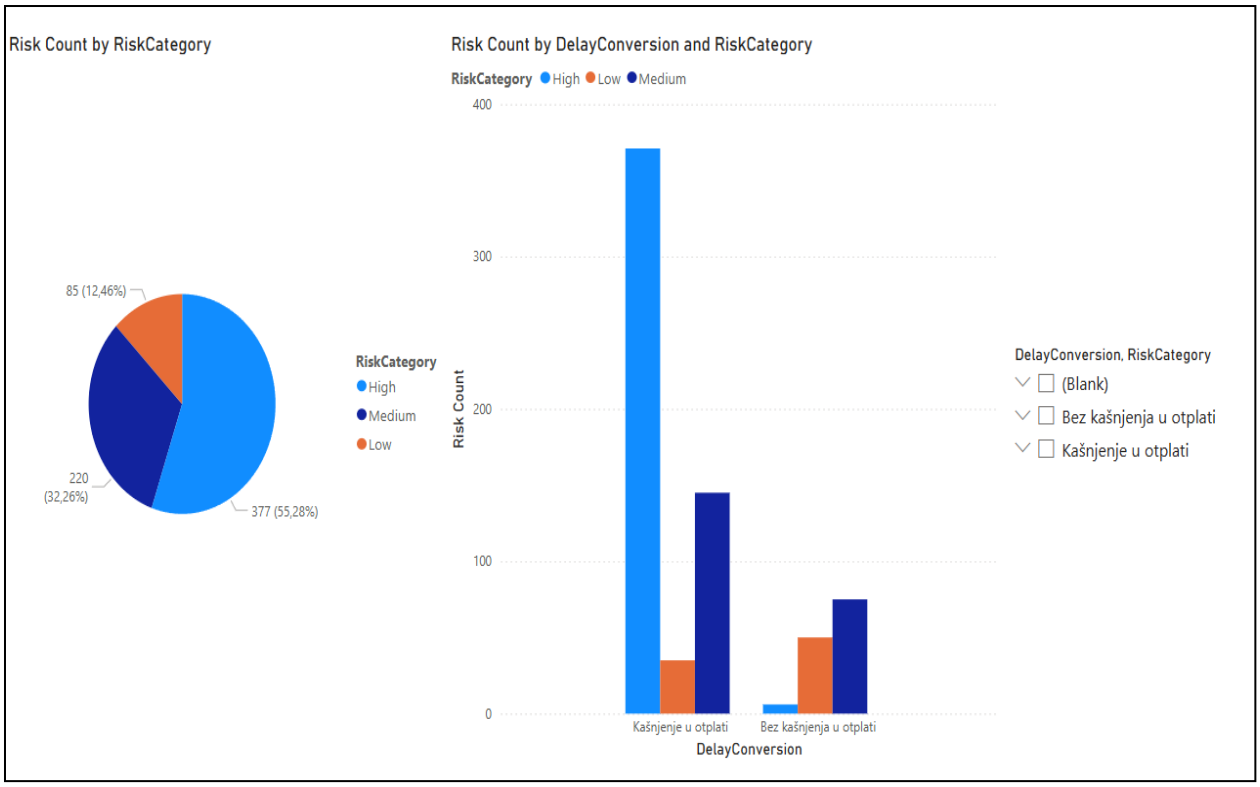


Figure 8. Graphical representation of the predicted loan issuance risk
Source: Author's

In the graphical representation above, it can be observed that when payment delays are taken into account, it is generally best to issue smaller loans, or at most, medium-sized loans. The High, Medium, and Low categories were defined using a custom formula and are distributed as follows: low loans – up to 40,000, medium loans – from 40,000 to 100,000, high loans – above 100,000.

If it is determined that payments are made regularly, meaning there are no expected delays, then it is optimal to issue larger loans. This makes logical sense, as banks benefit from issuing larger loan amounts since higher principal values also generate higher interest income. Based on this analysis, it can be concluded that — depending on a client's income, expenses, and loan duration — it is possible to determine whether a person is a good or risky client, and accordingly, whether a loan should be granted and in what amount. Out of a total of 682 input records, the model predicted: 180 as low-risk loan issuances, 377 as medium-risk loan issuances, and 125 as high-risk loan issuances. From these predictions, a wide range of valuable insights can be drawn — and this represents just one example of their potential applications.

Conclusion

This study highlights the importance of data collected over years of a company's operations. Although such data may initially appear outdated or insignificant, a detailed analysis reveals the opposite — within this information lie key insights essential for understanding business performance. By analyzing historical data, it becomes possible to identify risk points in operations, understand the causes of potential errors, and recognize patterns that influence success or failure.

The study particularly emphasizes the value of using modern software tools such as Power BI, in combination with the Python programming language, which together form a powerful framework for advanced data analysis. This combination enables the efficient utilization of existing data to improve future business decision-making, draw relevant conclusions, and uncover new business insights.

The results obtained from this research can be highly beneficial for financial institutions, as they confirm that valuable lessons can be learned from past mistakes. Through data analysis, prediction, and final outcomes, the study demonstrates which aspects require special attention when addressing issues related to loan issuance and similar financial services.

Furthermore, the research highlighted the importance of high-quality data visualization. Raw data, without appropriate graphical representation, often fails to provide a clear enough basis for informed decision-making. Visual representations, such as charts and interactive dashboards, have proven to be extremely valuable tools—especially for the management of financial institutions (banks, credit organizations, etc.). These visualizations enable decision-makers to more easily interpret complex data, make strategic business decisions, and define future actions toward their clients.

The study successfully demonstrated the use of the Power BI platform for predictive analysis of financial data. By employing various machine learning algorithms—such as Decision Tree Classifier, Logistic Regression, and K-Means clustering analysis—it was possible to assess credit risk and classify clients based on available financial indicators. Power BI proved to be an exceptionally powerful tool, not only enabling advanced data visualization, but also allowing integration with Python scripts, which significantly expands its analytical and modeling capabilities.

The results indicate that such an integration of visual and analytical functionalities provides a comprehensive and clear overview of the financial situation and its associated risks. This represents an extremely valuable resource for making well-informed and high-quality business decisions.

The analysis of the conducted research and the achieved results indicate that this approach can serve as a foundation for the further development of intelligent financial systems. Such systems leverage the power of Big Data and machine learning to enable fast, accurate, and well-informed decision-making within the management processes of financial institutions.

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Innovations in the Architecture of Distributed Computing Systems

Inovacije u arhitekturi distribuiranih računarskih sistema

Ana Veljić[1], Marko Marković[2], Srđan Maričić[3]

[1]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, ana.veljic@mef.edu.rs*

[2]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, marko.markovic@mef.edu.rs*

[3]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, srdjan.maricic@mef.edu.rs*

Abstract: *This paper explores contemporary innovations in the architecture of distributed computing systems, with a particular focus on the changes brought about by the development of Cloud infrastructure, Microservices Architectures, and Containerization. The fundamental principles of transitioning from monolithic structures to flexible microservices and serverless models were analyzed, enabling scalability, efficiency, and easier maintenance of complex applications in dynamic environments. Special attention was given to Hybrid and Multi-cloud architectures that combine the advantages of public and private clouds, ensuring optimal resource utilization, high availability, and reliable system operation. The work also considers the application of artificial intelligence (AI) and machine learning (ML) in flexible distributed systems, thru real-time optimization, correction, and autonomous resource management in areas such as power grids, logistics, and smart infrastructure. By integrating these innovative approaches, distributed systems are becoming more intelligent, efficient, and adaptable to the contemporary demands of digital transformation.*

Keywords: *Distributed systems, cloud architecture, microservices, artificial intelligence, system optimization.*

Apstrakt: *Ovaj rad istražuje savremene inovacije u arhitekturi distribuiranih računarskih sistema, sa posebnim fokusom na promene koje su nastale razvojem Cloud infrastrukture, arhitektura mikroservisa i kontejnerizacije. Analizirani su osnovni principi prelaska sa monolitnih struktura na fleksibilne mikroservise i modele bez servera, omogućavajući skalabilnost, efikasnost i lakše održavanje složenih aplikacija u dinamičnim okruženjima. Posebna pažnja posvećena je hibridnim i multi cloud arhitekturama koje kombinuju prednosti javnih i privatnih oblaka, obezbeđujući optimalno korišćenje resursa, visoku dostupnost i pouzdan rad sistema. Rad takođe razmatra primenu veštačke inteligencije (AI) i mašinskog učenja (ML) u fleksibilnim distribuiranim sistemima, kroz optimizaciju u realnom vremenu, korekciju i autonomno upravljanje resursima u oblastima kao što su elektroenergetske mreže, logistika i pametna infrastruktura. Integrisanjem ovih inovativnih pristupa, distribuirani sistemi postaju inteligentniji, efikasniji i prilagodljiviji savremenim zahtevima digitalne transformacije.*

Ključne reči: *Distribuirani sistemi, cloud arhitektura, mikroservisi, veštačka inteligencija, optimizacija sistema.*

Introduction

Cloud computing represents a significant shift in distributed systems, enabling flexible and scalable technological solutions ready for implementation. It enables the on-demand delivery of computing services over the internet without direct infrastructure management, which provides great flexibility. Distributed computer systems consist of components that are spread across multiple interconnected computer units that communicate and coordinate their work. To users, such systems appear simple, but behind the scenes, this system performs processing that is divided among multiple nodes. This type of

infrastructure offers the possibility of parallel task processing and the ability to reduce downtime during operation. These technical solutions help organizations facilitate data distribution and system load management, indicating the widespread adoption of cloud infrastructure and cloud technology in modern applications (Ramadan et al., 2024). In addition, the use of edge computing significantly improves latency and processor power, enabling the processing of even the most demanding computational tasks (Abirami et al., 2025). Decentralized architecture also represents a key innovation within distributed computing, offering improvements in scalability and fault tolerance. By distributing computational tasks across a network of nodes, such systems can efficiently manage increased workloads without single points of failure, which is characteristic of centralized systems (Maderazo & Teleron, 2024). The development of microservices infrastructure has also transformed the way applications are created and deployed in distributed environments. Microservices enable the development of services that are independent or even minimally connected, meaning that microservices can form a single system but are independent of each other. This represents the principle of modular programming, as each system or application will function independently of other parts, and if one part of the system fails, the others will be able to continue their tasks without interruption (Chandan, 2025). Even this modular approach encourages the use of containerization, which increases the system's resilience and adaptability to various factors that can affect its operation. Even adopting a serverless model within the microservices ecosystem represents a trend toward reducing operational costs while simultaneously increasing the maintainability of distributed applications.

1. Microservice architecture

Microservices architecture stands out for its ability to break down applications into smaller services, which can then be developed, deployed, and updated independently as needed without any concern about disrupting system operation. This approach solves all processes much faster because if one of the services goes down, all the others will continue their processes uninterrupted. As soon as a problem occurs, that service is immediately isolated and security patches are sent out that can resolve the issue. By dividing into smaller components, the practice of agility is utilized in software development, allowing teams to focus on and design specific functionalities or parts of a service, rather than working on the entire application (Hassan et al., 2020). In order for this kind of architecture to meet all the intended requirements, it needs to utilize containerization in its implementation. By placing all microservices and their processes together in portable containers, a convenient working environment is enabled that runs applications across different infrastructures and platforms (Xiang et al., 2021). The most widespread solution is Docker, which offers easy creation and running of container units. This process reduces compatibility issues and significantly simplifies the implementation process. An additional advantage of containers is their rapid startup, which allows for more efficient resource utilization and better overall system performance (Goethals et al., 2022).

Automating microservice configuration using the Kubernetes platform enables greater automation of the process of deploying, scaling, and managing containerized services. Kubernetes, also known as K8s, is a container orchestration system that enables advanced management of microservices architectures thru intelligent runtime resource allocation, load balancing, and automatic service discovery (Xu et al., 2023). With this automation, support for serverless models is expanding, contributing to efficiency when working with dynamic workloads. To distribute resources evenly, machine learning techniques are used, which, with the help of algorithms, increase the overall system performance. Despite all the advantages, there can be problems with network latency and communication overhead between services, which can negatively impact performance. Besides this, problems can arise in creating a microservice architecture, because if systems are divided into very small services, it can lead to issues with system complexity, while an overly broad infrastructure reduces the benefits of using microservice technology.

2. Serverless computing and FaaS

Serverless computing, particularly in the form of the Function-as-a-Service (FaaS) model, represents a significant transformation and advancement in cloud technology. This eliminates the need for direct server infrastructure management, allowing developers to dedicate more time to writing and optimizing code, while all operations related to maintaining the server infrastructure are performed in the background. The economic viability of the FaaS model is its greatest advantage, and along with the "pay-as-you-go" (PAYGO) principle, services are provided to users for a small amount of money. The most common application is in applications that are variable or have an unpredictable load. By this principle, we save significantly, especially if user requirements arise occasionally and not constantly; the application will always be available to users only upon payment for the usage period. If the application is subject to constant load, FaaS technology will not be as cost-effective due to the constant use of resources, and this can exceed the costs compared to traditional cloud services (Lingolu & Dobbala, 2024). Such systems automatically adjust available resources to the application's current needs, without the need for manual configuration or pre-planned capacity reservation. In this way, applications can easily respond to a sudden increase in the number of users or requests. Studies show that the serverless approach provides dynamic scaling, unlike traditional models that require manual intervention. This feature is particularly useful for tasks that require fast data processing and high responsiveness, such as working with APIs (Mathew et al., 2021).

A major problem faced by serverless environments is the cold start, which is also the most well-known issue. This problem arises when a function that is currently inactive needs to be restarted, leading to an extended execution time for the first request. For applications that require real-time processing, such delays can be significant. Therefore, in recent research, increasing attention is being paid to optimizing warm start scenarios, where a portion of the functions remains active to reduce latency. As applications become more complex, coordinating a large number of interconnected functions can make it difficult to track the execution flow and lead to inefficiencies. Therefore, there is increasing research into developing advanced mechanisms for managing and optimizing these workflows, in order to maximize the benefits of the serverless model. The serverless approach has proven particularly useful in the field of machine learning, where it enables the training and deployment of models. Such architectures support distributed learning processes, enabling researchers and engineers to quickly experiment, scale, and reduce data processing time and costs (Liu et al., 2022).

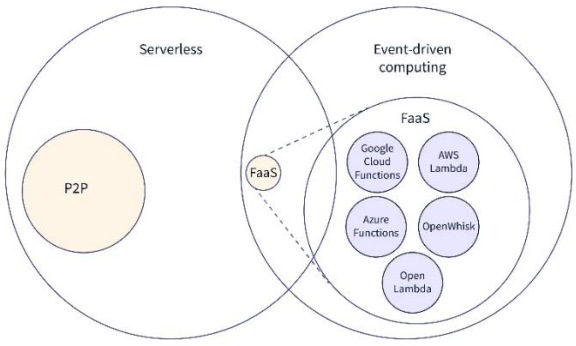


Figure 1. Serverless computing and FaaS
Source: Scaler.com https://www.scaler.com/topics/cloud-computing/faas/

3. Hybrid architecture

Hybrid and Multi-cloud architectures represent one of the key development directions in the field of cloud computing, enabling organizations to simultaneously leverage the benefits of public and private cloud environments. These models offer greater flexibility, resilience, and optimized resource utilization, but they also introduce additional complexities that require advanced management strategies.

A Hybrid cloud architecture is a combination of the advantages of public and private solutions, allowing organizations to securely store and process valuable data in a private environment while directing less critical workloads to the public cloud. Therefore, not only is safety and versatility increased in terms of the law, but cost reduction is also enabled due to the dynamic allocation of resources in accordance with precise dependencies. By adding the introduction of user services like Azure Stack or AWS Outposts, a unified operating model can be achieved across several environments without losing control and flexibility. Similarly, a tool like Azure Arc helps modify and manage resources in hybrid environments, adding extra operational productivity (Ghantous & Gill, 2020).

Multi-cloud architecture, on the other hand, involves using services from multiple different cloud providers simultaneously, thereby avoiding vendor lock-in, increasing system resilience, and leveraging the unique capabilities that each provider offers. This strategy allows organizations to optimize work processes based on the costs, performance, and functionality available to them. According to recent research, a multi-cloud approach improves service quality, business agility, and system availability, as it ensures business continuity even in the event of an outage with a single provider (Kumar & Mala, 2022).

Although they offer numerous advantages, Hybrid and Multi-cloud models face a range of challenges. One of the biggest problems is the complexity of managing different services and platforms. It is necessary to ensure interoperability, secure data transfer, and compliance with standards in order to avoid problems related to management, transparency, and adherence to agreed service levels (SLAs). Additionally, the expanded attack surface in a multi-cloud environment increases the risk of security incidents, necessitating a comprehensive cybersecurity strategy tailored to multi-layered cloud systems. In this context, machine learning techniques are increasingly being applied for threat detection and improving real-time incident response. Another significant challenge relates to workload management. Organizations must develop strategies for automatically balancing workloads across different cloud environments to ensure optimal resource utilization while maintaining high application performance (Voruganti, 2024). Additionally, the literature emphasizes the importance of implementing automated governance frameworks, which enable the monitoring, compliance, and oversight of multi-cloud resources, thereby significantly reducing administrative burden.

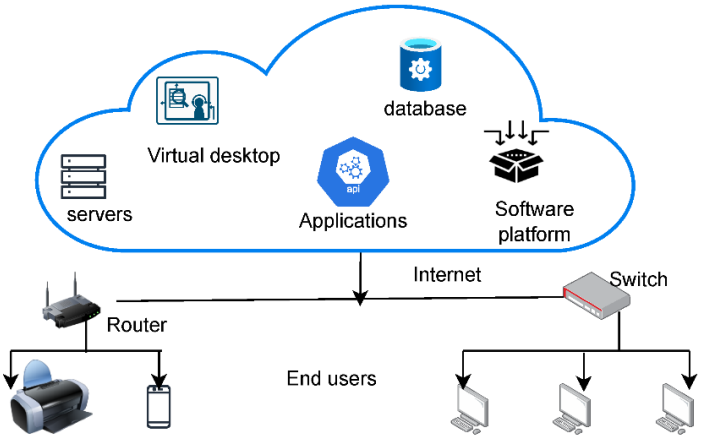


Figure 2. High-level architecture cloud computing
Source: (Donta et al., 2023)

4. Progress in the development of distributed systems

Distributed systems that utilize artificial intelligence represent a new phase in the development of computer architectures. Their main advantage is the ability to dynamically manage performance and optimize operations in real-time. Thanks to this, such systems can adapt to changing environmental conditions and independently respond to various challenges, making them suitable for applications in areas such as energy systems, telecommunications, and smart infrastructure. The key to their

effectiveness lies in the application of machine learning algorithms that enable data analysis, prediction of system behavior, and automatic adjustment of operating parameters without the need for constant human supervision.

One of the most important aspects of these systems is the application of machine learning in management and optimization processes. For example, smart grids use algorithms that combine historical data with real-time data to more accurately predict energy consumption and improve resource allocation. In this way, systems become capable of independently recognizing consumption patterns and optimizing energy distribution according to user needs (Reddy et al., 2023). This approach ensures greater reliability and energy efficiency, especially in environments with distributed energy sources. In the field of distributed systems management, real-time optimization (RTO) and self-optimizing control (SOC) methods are particularly significant, as they enable optimal performance without the need for constant manual adjustments. RTO is based on continuous optimization cycles during system operation, while SOC uses adaptive control that maintains stability by changing key variables without complex calculations, thereby reducing load and increasing efficiency. These methods allow systems to be more autonomous, faster, and less dependent on central control.

Another important characteristic of modern distributed systems is self-healing mechanisms that allow the system to automatically detect and correct operational errors. In smart grids, these mechanisms utilize advanced communication technologies to isolate faults and efficiently manage demand, thereby reducing power outages and increasing system stability. Additionally, contemporary research links these approaches to sustainability and reducing carbon dioxide emissions. For example, methods have been introduced that simultaneously optimize network losses and reduce negative environmental impact, making the operation of distributed systems more environmentally friendly. The development of self-adaptive algorithms forms the basis for creating systems that can continuously optimize without direct human intervention. Such algorithms adjust their parameters according to the current load and requirements, thus maintaining stable and efficient operation even in complex conditions (Litvinchuk, 2023). Thanks to such innovations, distributed systems are becoming increasingly autonomous, resilient, and capable of managing their own performance independently, making them a key element of future digital infrastructures.

5. Security and reliability of distributed systems

The security and reliability of distributed systems are key factors for their successful application, particularly in environments such as industrial applications, healthcare systems, financial services, and critical infrastructures. These systems, which operate without a central authority, rely on various consensus mechanisms to maintain data integrity, availability, and fault tolerance. Consensus algorithms ensure agreement among distributed nodes on the state of a shared ledger or database, thereby increasing system reliability even under partial failures or attacks (Yu et al., 2021). The most well-known consensus algorithms, such as Proof of Work (PoW) and Practical Byzantine Fault Tolerance (PBFT), play a crucial role in maintaining the robustness of decentralized systems. These mechanisms enable tolerance to communication errors and node failures, which is particularly important in environments like the Industrial Internet of Things (IIoT), where stable connectivity cannot always be guaranteed. New algorithms strive to achieve a balance between low latency and high reliability, particularly in wireless distributed networks. Modern approaches introduce and improve consensus models that integrate node credibility assessment into the decision-making process. For example, in an improved PBFT model, node trust evaluation significantly increases data security and traceability which is successfully applied in agricultural product tracking and other sectors requiring a high level of security and transparency.

Progress in the field of distributed systems security is also linked to the development of reputation protocols, which allow for distinguishing between reliable and unreliable nodes. Such approaches significantly increase network integrity and transaction processing speed, studies show an

improvement of up to 19% compared to traditional methods. The application of consensus-based reputation mechanisms increases the system's resilience to attacks such as double-spending and "selfish mining" behavior, thereby improving the overall security profile of the blockchain environment. Today's trends show that development is moving toward adaptive consensus mechanisms, which are capable of functioning even in hostile conditions. By combining new techniques and improving existing algorithms, particularly in the area of Byzantine Fault Tolerance (BFT), systems are becoming more resilient to errors and compromised nodes. In this way, modern distributed systems achieve a high degree of resilience, security, and stability, ensuring their applicability in complex and critical digital environments.

Conclusion

The development of distributed systems within a cloud infrastructure shows a clear trend toward automation, flexibility, and intelligent resource management. By using microservices, containerization, and serverless models, modularity and scalability are achieved, while hybrid and multi-cloud architectures enable optimal utilization of public and private resources with increased security and system resilience. Advances in artificial intelligence further enhance the performance of distributed systems by introducing self-adaptation and autonomous decision-making mechanisms. Given the speed at which technology is advancing, it can be expected that future distributed systems will become even more intelligent, capable of fully autonomous management and learning from their own operation. This will reduce the need for human intervention, increase efficiency, and open up new avenues for development in areas such as smart cities, industry 4.0, and automated digital ecosystems. The key challenges that remain relate to cybersecurity, interoperability, and energy sustainability, but with the right strategic approach, these issues can be overcome, confirming that distributed systems are a cornerstone of the modern digital age.

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The Role and Impact of Digitalization in Modern Library Systems

Uloga i uticaj digitalizacije u modernim bibliotečkim sistemima

Olivera Tot[1]

[1]*University of Defence in Belgrade, University Library, Belgrade, Serbia, olja.tot@gmail.com*

Abstract: *Digitalization has profoundly transformed the purpose and operation of modern libraries. By integrating advanced information technologies, libraries have evolved from static collections of printed materials into dynamic platforms for sharing digital knowledge. This shift has expanded access to information, improved the management of resources, and helped preserve cultural heritage in digital form. Digital technologies make knowledge more accessible and inclusive, allowing users around the world to engage with collections virtually. At the same time, automation, metadata management, and cloud-based systems have made library operations more efficient. However, libraries continue to face challenges related to digital preservation, copyright, and unequal access to technology. Despite these issues, digital transformation ensures that libraries remain vital centers of education, culture, and information literacy in the digital era.*
Keywords: *Digital libraries, digitization, library management.*

Apstrakt: *Digitalizacija je značajno transformisala svrhu i funkcionisanje modernih biblioteka. Integrisanjem naprednih informacionih tehnologija, biblioteke su evoluirale iz statičnih zbirki štampanih materijala u dinamične platforme za deljenje digitalnog znanja. Ova promena je proširila pristup informacijama, poboljšala upravljanje resursima i pomogla očuvanju kulturnog nasleđa u digitalnom obliku. Digitalne tehnologije čine znanje pristupačnijim i inkluzivnijim, omogućavajući korisnicima širom sveta da se virtuelno povežu sa materijalima. Istovremeno, automatizacija, upravljanje metapodacima i sistemi zasnovani na oblaku učinili su rad biblioteka efikasnijim. Ipak, biblioteke i dalje suočavaju sa izazovima vezanim za digitalno očuvanje, autorska prava i nejednak pristup tehnologiji. Uprkos ovim pitanjima, digitalna transformacija osigurava da biblioteke ostanu vitalni centri obrazovanja, kulture i informacione pismenosti u digitalnom dobu.*
Ključne reči: *Digitalne biblioteke, digitizacija, upravljanje bilbiotekama.*

Introduction

The first libraries were created in the 7th century BC. They were called "Treasures of Knowledge", and librarians were called, among other things, the guardians of knowledge and guardians of books. Libraries have existed almost as long as written monuments. The oldest libraries in the world were created where the oldest civilizations were, in Mesopotamia, Egypt and Asia. The first writing system was cuneiform, written on clay tablets. Cuneiform (figure 1) is a writing system first developed by the ancient Sumerians in Mesopotamia around 3500-3000 BC. It is considered the most significant of the many cultural achievements of Sumer.

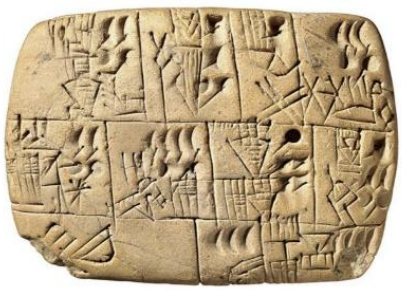


Figure 1. Cuneiform tablet
Source: www.nova-akropola.com

The first libraries were like storehouses of books, and the librarian was there mostly to keep them and provide a book fand. With the improvement of printing technology, books began to be produced in large numbers, and people began to understand their value (Tot, 2025).

The epochal invention of movable type printing in the 15th century (Gutenberg's press and printing house) made book production much easier and faster (figure 2). Books were once very rare and difficult to produce, which is why they were expensive. The first libraries were like warehouses or storehouses of books, and the librarian was there mostly to keep them and provide a book fund. With the improvement of printing technology, books began to be produced in large numbers, and people began to understand their value.

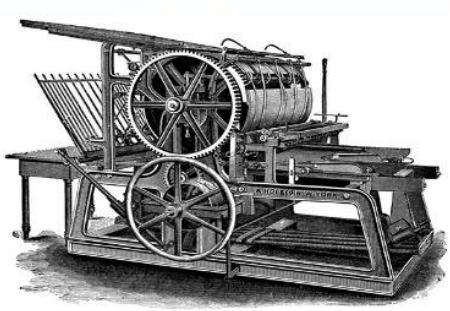


Figure 2. Gutenberg press
Source: www.vrworld.com

The importance of libraries is crucial for the development of civilization and communication between people. Among other things, they are an indicator of the level of development of a community and society.

In the digital age, libraries are undergoing a profound transformation driven by the rapid advancement of information technologies. Digitalization, often referred to as the process of converting analog information into digital formats, has become a cornerstone in reshaping how libraries store, manage, and disseminate knowledge (Piter, 2021). This paper explores the role and impact of digitalization in modern library systems, emphasizing technological, operational, and social aspects that define contemporary information management.

1. Digitization vs digitalization

Digitalization extends beyond mere digitization of physical content; it represents a broader transformation of library processes, services, and user engagement strategies. Digitalization integrates technology into core library operations, enhancing accessibility and efficiency while redefining traditional roles of librarians (Nantale, 2025). The first steps towards digitalizing processes occur when library materials are scanned into the library's digital repository.

Many libraries now use integrated library systems (ILS), online public access catalogs (OPAC), and digital repositories to stay relevant in the digital age. Institutions such as the British Library have digitized millions of manuscripts, making them available to global audiences and ensuring that libraries remain key access points for knowledge

2. Technologies enabling library digitalization

Digitalization in libraries is made possible through a range of technologies that support the collection, preservation, organization, and dissemination of digital content. These technologies provide modern library infrastructure, enabling institutions to provide users with seamless access to digital knowledge resources. Among the most critical technological components are metadata standards, content management systems, digital repositories, cloud computing, and artificial intelligence (Thiruppathi, 2024).

A fundamental aspect of digital library architecture lies in the use of metadata standards. Metadata provides structured descriptions of digital objects, ensuring that materials are discoverable and usable across different systems. By applaying these standards, libraries can ensure the sustainability of digital collections and facilitate integration with global databases such as WorldCat.

Content management and repository systems alos play key role becase they allow storage, indexing, and retrieval of digital assets. Many IT platforms support functions like access control and metadata tagging, while also providing interfaces for researchers and users to interact with stored materials.

Cloud computing can be a huge step forward in how libraries manage their IT infrastructure. Cloud-based solutions support collaborative cataloging, resource sharing, and disaster recovery through geographically distributed backups. Major cloud service providers such as Amazon Web Services (AWS) and Google Cloud offer specialized solutions for libraries that require large-scale data storage and computing capabilities (Urmila, 2025).

AI-powered tools can assist in automated cataloging, optical character recognition (OCR) for digitized texts, and intelligent search systems capable of semantic analysis. Machine learning algorithms enhance the discovery process by predicting user needs and providing personalized content recommendations. Moreover, AI supports automated metadata generation, improving both accuracy and efficiency in information organization (Jesubukade, 2021).

Optical Character Recognition (OCR) technology plays a key role in converting scanned text into machine-readable formats. This allows the creation of searchable databases and supports accessibility features, such as screen reader compatibility. Modern OCR systems, often integrated with AI-based language processing, can recognize complex scripts and historical typefaces with remarkable precision.

Additionally, data analytics and visualization tools can allow libraries to assess usage patterns and optimize services. Through dashboards and statistical models, librarians can monitor how users interact with collections, identify underused resources, and make data-driven policy decisions. These insights are invaluable for strategic planning, collection development, and improving the user experience (Urmila, 2025).

3. Benefits of digitalization in library management

Digitalization has reshaped how libraries function, interact with users, and manage their collections. Among the most evident advantages is the enhanced accessibility of information resources. Users can access digital collections remotely, breaking physical and temporal barriers that once limited access to printed materials. This shift has allowed students, researchers, and the general public to explore vast repositories of information from virtually anywhere in the world (Matthew & Daniela, 2025).

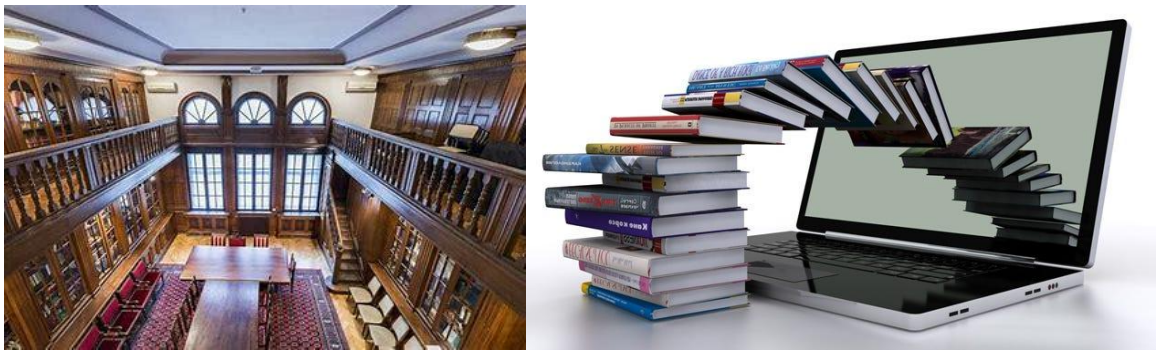


Figure 3. Traditional and modern library
Source: www.medium.com

Another significant benefit is preservation and protection of rare and fragile materials. By digitizing manuscripts, photographs, and historical documents, libraries reduce the need for physical handling, thereby extending the lifespan of original artifacts. Digitization also serves as a disaster recovery strategy, ensuring that valuable content remains accessible even in cases of physical damage or loss. This aspect is especially vital for institutions safeguarding cultural heritage collections.

Integrated Library Systems (ILS) and digital cataloging tools automate numerous administrative tasks—such as acquisitions, circulation, and inventory tracking—allowing staff to focus on user engagement and research support (Urmila, 2025).

A major transformation brought by digitalization is the personalization of user experiences. Through the application of Artificial Intelligence (AI) and data analytics, libraries can analyze user behavior to offer tailored recommendations, reading lists, and research materials (Jesubukade, 2021).

From an educational perspective, digital libraries support collaborative learning and interdisciplinary research. Open-access digital repositories, online archives, and institutional databases allow users to share, cite, and build upon existing research, fostering a more interconnected academic community (Matthew & Daniela, 2025). In many universities, digital platforms have become essential components of e-learning ecosystems, integrating seamlessly with virtual classrooms and course management systems.
Digitalization also enhances library outreach and inclusivity. Through multilingual interfaces, accessibility tools for visually impaired users, and mobile applications, libraries can reach broader and more diverse audiences. These innovations uphold the library's traditional mission of inclusivity while leveraging technology to extend its social role (Nantale, 2025).

4. Challenges and limitations

Despite its numerous advantages, digitalization in libraries also presents significant challenges and limitations that impact technological, financial, ethical, and social dimensions of library operations. One of the primary barriers is the high cost of implementation and maintenance. Developing digital infrastructure-scanners, servers, cloud services, and content management systems-requires substantial initial investment, which can produce problems for smaller institutions or those in developing countries. Additionally, ongoing maintenance, software licensing, and staff training costs continue to grow library budgets over time.

Another major challenge is technological dependence over time. As digital tools evolve rapidly, libraries must continually upgrade their systems to remain compatible with new formats and standards. This often results in a 'technological treadmill' effect, where previously digitized materials risk becoming inaccessible due to outdated hardware or file formats. Preserving digital content over the long term requires robust digital preservation strategies to evolving metadata and archival standards (Thiruppathi, 2024).

Libraries also face serious copyright and intellectual property challenges. Many institutions must navigate complex legal frameworks when digitizing and distributing copyrighted materials. Balancing open access principles with intellectual property rights remains one of the most contentious issues in the digital transformation of libraries. In some cases, restrictive copyright laws can limit the availability of culturally or historically significant materials to the public (Nantale, 2025).

From a human resources perspective, skills gaps and staff resistance pose additional barriers. Many librarians were trained primarily in traditional cataloging and archival methods, and may lack the digital literacy skills needed for advanced systems management or metadata creation. Continuous professional development programs are essential to equip librarians with competencies in cybersecurity and digital content management (Thiruppathi, 2024).

5. Future prospects of library digitalization

As libraries continue to integrate emerging digital technologies, their traditional role as repositories of knowledge is expanding into that of active facilitators of digital scholarship, community engagement, and lifelong learning.

Through natural language processing (NLP), future digital libraries will be able to understand user intent more effectively, delivering precise, context-aware search results. Virtual assistants and chatbots will continue to evolve into intelligent reference systems, providing users with personalized guidance and academic support in real time.

VR environments may allow users to explore reconstructed historical sites or rare manuscripts in 3D, while AR tools could overlay additional information on physical books and exhibits (Urmila, 2025). These technologies will make learning more interactive, experiential, and accessible to diverse audiences, particularly within educational and museum library contexts.

Future digital libraries will increasingly rely on big data analytics to enhance strategic decision-making and resource management. By analyzing user interaction patterns and citation trends, libraries can optimize acquisitions, tailor services to user needs, and assess the long-term impact of digital initiatives (Nantale, 2025). Predictive analytics will also enable proactive planning, allowing institutions to anticipate technological shifts and user demands.

A growing emphasis will also be placed on open science and open access movements. Libraries are likely to play a leading role in developing infrastructures that support the free exchange of scholarly outputs, including open repositories and data-sharing platforms. This will strengthen global collaboration, transparency, and innovation in research, while ensuring that publicly funded knowledge remains publicly accessible.

Furthermore, the future will demand a stronger focus on digital preservation and sustainability. As digital content continues to increase rapidly, ensuring its accessibility for a long time will become more complex. Libraries must invest in long-term preservation strategies, such as format migration, redundant storage, and the use of non-proprietary standards. In parallel, the environmental footprint of digital infrastructure will become an important consideration, prompting the adoption of energy-efficient technologies and green data centers.

Conclusion

Digitalization has redefined what libraries are and how they serve their communities. By embracing technology, libraries have transformed from physical repositories into digital ecosystems that connect people to knowledge on a global scale. They play a vital role in preserving cultural heritage, supporting education, and promoting equality in access to information.

By digitizing rare collections and offering open-access repositories, libraries have made significant steps toward ensuring access to knowledge. Moreover, digital preservation safeguards humanity's collective memory, ensuring that future generations will have access to both historical and contemporary works.

Librarians are no longer mere keepers of books; they have become information architects, digital curators, and educators in digital literacy. This transformation requires continuous professional development and adaptability as new technologies and user expectations emerge. Institutions that invest in staff training and infrastructure will be best positioned to leverage the full potential of digital tools.

However, the transition to digital environments also introduces challenges that cannot be ignored. Issues of copyright, data privacy and technological dependence remain critical obstacles. Libraries must adopt sustainable strategies that address these risks while maintaining their commitment to openness, equity, and intellectual freedom. By collaborating with academic institutions, technology developers, and policy makers, libraries can help build a digital ecosystem that promotes transparency, accessibility, and sustainability.

As libraries continue to embrace digital transformation, they maintain their relevance in a rapidly changing world, serving as vital bridges between the past, present, and future of human knowledge. By accepting innovation while supporting ethical and cultural responsibilities, libraries will continue to serve as vital gateways to knowledge in the evolving digital age.

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Modeling Adaptive Onboarding Flows in Mobile Applications

Modelovanje adaptivnih *onboarding* tokova u mobilnim aplikacijama

Dušan Rajčević[1], Ivona Brajević[2], Francine Niedo[3]

[1]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, dusan@mef.edu.rs*

[2]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, ivona.brajevic@mef.edu.rs*

[3]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, niedofrancine@gmail.com*

Abstract: *Onboarding is a critical factor of user retention and satisfaction in mobile apps, yet many current approaches rely on static, one-size-fits-all flows that fail to account for different contexts and goals. This paper introduces a systems-based framework for modeling adaptive onboarding flows that dynamically adjust to user behavior, device capabilities, and contextual signals. Grounded on systems thinking and UX optimization, the framework introduces decision-tree logic and modular onboarding components that can be combined to suit different user profiles. The approach prioritizes reproducibility, transparency, and ethical considerations ensuring that adaptive mechanisms enhance usability without compromising user autonomy. A case study in a mobile learning app demonstrates measurable improvements in engagement and task completion, highlighting the framework's potential for broader application.*

Keywords: *Mobile apps, UX optimization, onboarding, android.*

Apstrakt: *Onboarding je ključni faktor zadržavanja korisnika i njihovog zadovoljstva u mobilnim aplikacijama, ali mnogi postojeći pristupi i dalje se oslanjaju na statične, uniformne tokove koji ne uzimaju u obzir različite kontekste i ciljeve. Ovaj rad predstavlja sistemski okvir za modelovanje adaptivnih onboarding tokova koji se dinamički prilagođavaju ponašanju korisnika, mogućnostima uređaja i kontekstualnim signalima. Zasnovan na principima sistemskog razmišljanja i optimizacije korisničkog iskustva, okvir uvodi logiku odlučivanja u obliku stabla i modularne komponente za onboarding koje se mogu kombinovati u skladu sa različitim profilima korisnika. Pristup daje prioritet reproduktivnosti, transparentnosti i etičkim razmatranjima, obezbeđujući da adaptivni mehanizmi unapređuju upotrebljivost bez narušavanja autonomije korisnika. Studija slučaja u mobilnoj aplikaciji za učenje pokazuje merljiva poboljšanja u angažovanju i izvršavanju zadataka, naglašavajući potencijal okvira za širu primenu.*

Ključne reči: *Mobilne aplikacije, UX optimizacija, onboarding, android.*

Introduction

Fast growth of mobile apps has transformed how individuals use and interact with digital services, from communication and sales, to education and healthcare. In this competitive environment, the first moments of user interaction are decisive – research consistently shows that poorly designed onboarding experiences lead to high rates of abandonment, while effective onboarding can significantly improve retention and long-term engagement (UX Magazine, 2021). Despite this, many mobile apps continue to rely on static, linear onboarding flows that treat all users equally, overlooking differences in prior knowledge, goals, and contextual needs (UXCam, 2025).

Onboarding, in its broadest sense, is not merely a tutorial or a sequence of introductory screens. It is a structured process of guiding users toward competence, confidence, and value realization within a certain application. Traditional approaches often emphasize feature exposition rather than adaptive guidance, resulting in cognitive overload, user frustration, or premature disengagement (Mockplus, 2023). As mobile ecosystems evolve toward personalization and context-awareness, there is a growing need for onboarding models that are flexible, modular, and responsive to user behavior.

This paper addresses this gap by proposing a systems-based framework for adaptive onboarding flows in mobile applications. Drawing on principles of systems thinking and user experience (UX) optimization, the framework conceptualizes onboarding as a dynamic system of decision points, feedback loops, and modular components. Rather than prescribing a single linear path, the model enables applications to adjust onboarding sequences in real time, based on user interactions, device capabilities, and contextual signals. Such an approach not only enhances usability but also aligns with broader trends in adaptive learning, personalized interfaces, and ethical design.

The contribution of this work is threefold. First, it formalizes onboarding as a system that can be modeled, analyzed, and optimized, moving beyond ad hoc design practices. Second, it introduces a reproducible methodology for constructing adaptive flows using decision-tree logic and modular design principles. Third, it illustrates the application of this model through a case study in a context of a mobile app for learning, demonstrating its potential to improve engagement and task completion. By situating onboarding within a systems framework, this paper seeks to provide both practitioners and researchers with a structured approach to designing mobile experiences that are efficient, user-centered, and ethically grounded.

1. Literature review and background

1.1. Introduction to onboarding in mobile applications

Onboarding has come a long way as a central theme in mobile app design, reflecting the recognition that the first moments of user interaction often determine the long-term satisfaction. Industry reports and academic studies alike, emphasize that poorly designed onboarding experiences correlate with high abandonment rates, while effective onboarding can significantly improve retention, satisfaction, and lifetime value (UX Magazine, 2021). Early conceptualizations of onboarding treated it as a tutorial or walkthrough, primarily focusing on demonstrating features. However, as mobile ecosystems have matured, onboarding is increasingly understood as a strategic process of value delivery, guiding users towards becoming competent and confident enough in achieving meaningful outcomes.

The literature broadly distinguishes between static onboarding flows – linear, one-size-fits-all sequences and adaptive onboarding flows, which adjust to user context, goals, behavior etc. While static flows remain dominant in practice, research in human-computer interaction (HCI), learning sciences, and adaptive systems suggests that personalization and modularity can significantly enhance usability and engagement.

1.2. Systems thinking in UX

Systems thinking provides a conceptual lens for analyzing onboarding as more than a sequence of screens. It emphasizes interconnectedness, feedback loops and emergent behavior. In UX research, systems thinking has been applied to model complex user journeys, where outcomes are shaped not only by interface elements but also by contextual factors such as device capabilities, prior knowledge, and environmental conditions. This perspective aligns with Meadows' (2008) definition of systems as "a set of elements interconnected in such a way that they produce their own pattern of behavior over time." Applying this to onboarding suggests that flows should be designed as dynamic systems rather than static pipelines.

1.3. Cognitive load theory

Cognitive load theory (Sweller, 1988) provides another foundation for adaptive onboarding. Static onboarding often overwhelms users with too much information, leading to excessive cognitive load. On the other hand, adaptive flows can control the way information is delivered based on user behavior, optimizing germane load (Deterding, Dixon, Khaled, & Nacke, 2011). Several studies in educational technology show that adaptive sequencing improves comprehension and task completion, which suggests parallels for mobile onboarding (Rincón-Flores et al., 2024; Kochmar et al., 2023).

1.4. Personalization and adaptive systems

Research in adaptive hypermedia (Brusilovsky, 2001) and recommender systems highlight the benefits of tailoring content to user profiles and contexts. In mobile UX, personalization has been shown to increase engagement, but it raises concerns about privacy, transparency, and autonomy. The challenge is to design adaptive systems that are both effective and ethically grounded. This tension is directly relevant to onboarding, where personalization must balance guidance with user control.

1.5. Onboarding practices in industry

1.5.1. Static and linear approaches

Most commercial mobile apps still implement static onboarding flows – a fixed sequence of welcome screens, feature highlights, permission requests etc. (UXCam, 2025) These flows are easy to implement but often fail to account for user diversity. For example, a novice user may require detailed guidance, while an experienced user may find the same sequence redundant or frustrating. Studies of app abandonment consistently identify friction in onboarding as a leading cause of churn (Clifford & Thorpe, 2020; Khalid et al., 2015).

1.5.2. Progressive disclosure

Progressive disclosure is a widely recommended design principle in UX literature (Nielsen, 2006; Springer & Whittaker, 2020), advocating for the gradual introduction of features as users need them. This approach reduces cognitive overload and aligns with just-in-time learning. However, in practice, progressive disclosure is often implemented in a static manner, without true adaptation to user behavior. The literature suggests that combining progressive disclosure with adaptive logic could yield more effective onboarding (Nielsen, 2006; Brusilovsky, 2001; Springer & Whittaker, 2020; UserOnBoarding Academy, 2023).

1.5.3. Gamification and engagement strategies

Gamification techniques such as badges, progress bars, points, rewards etc. are frequently employed to increase onboarding engagement. While effective in some contexts, gamification can also lead to superficial engagement if not aligned with intrinsic user goals. Research indicates that gamification works best when integrated into a broader adaptive framework that respects user autonomy and provides meaningful value (Deterding et al., 2011; Koivisto & Hamari, 2019; Toda et al., 2018; Alhammad & Moreno, 2018).

1.6. Adaptive onboarding: emerging research

1.6.1. Behavioral adaptation

Some recent studies explore onboarding flows that adapt based on real-time user behavior (Berkovsky, Taib, & Conway, 2015; Kochmar et al., 2023; Xillentech, 2023). For instance, if a user skips explanatory screens, the system may infer prior knowledge and shorten the onboarding sequence. Similarly, if a user struggles or makes errors, the system may provide additional guidance. These adaptive mechanisms draw on decision-tree logic and machine learning models, though reproducibility and transparency remain challenging.

1.6.2. Context-aware onboarding

Context-aware computing has been applied to onboarding in domains such as health and education. For example, onboarding flows may adjust based on device type, connectivity, or environmental conditions. A mobile learning app might offer offline-first guidance in contexts with low bandwidth, or a health app might adapt onboarding based on the availability of a certain sensor. These approaches give potential to contextual signals to enhance usability.

1.6.3. Modular design

Modularity is increasingly recognized as a key principle for adaptive onboarding. By designing onboarding as a set of combined components, developers can construct flows tailored to different user profiles. This aligns with research in component-based software engineering and instructional design, where modularity supports scalability, flexibility, and reuse (Pressman & Maxim, 2014; Merrill, 2002; Qureshi, 2023).

1.7. Ethical and practical considerations

1.7.1. Transparency and user autonomy

Adaptive onboarding raises ethical questions about user autonomy. If flows adapt invisibly, users may feel manipulated or disoriented. Research in persuasive technology warns against "dark patterns" that exploit adaptation for commercial gain (Zagal, Björk, & Lewis, 2013; Gray et al., 2018; Mathur et al., 2019). Ethical frameworks in HCI emphasize the need for transparency, explainability, and user control. In onboarding, this translates to mechanisms that allow users to skip, revisit, or customize their onboarding experience.

1.7.2. Reproducibility and evaluation

A repeating challenge in the research of adaptive systems reproducibility. Many adaptive onboarding implementations are ad hoc, making it difficult to compare results or replicate findings. Scholars call for formal models and methodologies that enable systematic evaluation (Brusilovsky & Millán, 2007; Paramythis & Loidl-Reisinger, 2004; Bauer, 2021). Metrics such as engagement, task completion, and retention are commonly used, but there is also a need for qualitative measures of user trust and satisfaction.

1.7.3. Balancing efficiency and inclusivity

Adaptive onboarding should balance efficiency with inclusivity. While personalization can streamline experiences for the majority, it risks marginalizing users with atypical needs. Accessibility research highlights the importance of designing for edge cases and ensures that adaptive mechanisms do not inadvertently exclude vulnerable populations (Wobbrock & Kane (2019); Anuyah et al., 2023; Shinohara & Wobbrock, 2016). This is relevant in domains such as education and healthcare, where onboarding may serve different user groups.

1.8. Related work in adjacent domains

1.8.1. Adaptive learning systems

The literature on adaptive learning provides valuable insights for onboarding. Systems such as intelligent tutoring systems (ITS) use decision trees, Bayesian networks, and reinforcement learning to tailor instruction. These methods demonstrate the effectiveness of adaptive sequencing and feedback loops, which can be applied to onboarding flows in mobile apps.

1.8.2. Human-computer interaction (HCI)

HCI research has long emphasized the importance of user-centered design and iterative evaluation. Studies of adaptive interfaces show that personalization can improve usability but also introduce complexity (Gajos et al., 2006; Gajos & Weld, 2004; Jameson, 2009). Lessons from HCI suggest that

adaptive onboarding should be tested with diverse user groups and refined through iterative prototyping.

1.8.3. Service design and customer journeys

Onboarding in mobile apps parallels onboarding in service design and customer experience management. Both involve guiding users through initial interactions to build trust and value. Literature in service design emphasizes holistic journey mapping, which aligns with the systems perspective proposed in this paper (FasterCapital, 2024).

1.8.4. Identified gaps in the literature

Despite growing interest in adaptive onboarding, several gaps remain:

- Lack of formal models: Most implementations are ad hoc, lacking reproducible frameworks.
- Limited evaluation: Few studies provide rigorous, comparative evaluations of adaptive vs. static onboarding.
- Ethical concerns: Transparency and autonomy are often overlooked in adaptive designs.
- Cross-domain integration: Insights from adaptive learning, HCI, and service design are underutilized in mobile onboarding research.

These gaps show the need for a systems-based framework that formalizes onboarding as a dynamic, adaptive process, grounded in reproducibility, transparency, and ethical design.

The literature demonstrates that onboarding is critical to user retention and satisfaction, yet current practices remain dominated by static, linear flows. Research in systems thinking, cognitive load theory, adaptive systems, and modular design provide a foundation for more effective approaches. However, gaps in formalization, evaluation, and ethics persist. This paper addresses these gaps by proposing a systems-based framework for adaptive onboarding, illustrated through a case study in mobile learning.

2. Proposed model for adaptive onboarding

2.1. Conceptual foundation

The proposed model conceptualizes onboarding as a dynamic system rather than a static sequence of screens. Drawing on principles of systems thinking, cognitive load theory, and adaptive learning design, the model treats onboarding as a network of interconnected components governed by decision logic and feedback loops. This approach enables onboarding flows to adjust in real time to user behavior, device capabilities, and contextual signals, while maintaining transparency and user autonomy.

2.2. Core principles

The model is grounded in four guiding principles:

- Modularity: Onboarding is decomposed into discrete, reusable components (e.g., welcome, feature introduction, task prompt, contextual help). These modules can be combined together to suit different user profiles.
- Adaptivity: Decision-tree logic and contextual signals determine the sequencing and presentation of modules, ensuring that users receive guidance tailored to their needs.
- Transparency and Autonomy: Users retain control through options to skip, revisit, or customize onboarding steps, preventing manipulative adaptation.
- Reproducibility: The model provides a formalized structure that can be replicated, evaluated, and compared across applications.

2.3. Model architecture

2.3.1. Modular components

The onboarding process is structured as a library of components, each with a defined purpose and input/output conditions. Examples include:

- Welcome & Value Proposition – communicates purpose and benefits.
- Profile Setup – collects essential user data, with optional personalization.
- Feature Introduction – explains core functions through tooltips, walkthroughs, or micro-tasks.
- First Task Prompt – encourages immediate engagement with a meaningful activity.
- Contextual Help – provides just-in-time support when friction is detected.
- Feedback & Motivation – reinforces progress and encourages continued use.

2.3.2 Decision-tree logic

A decision-tree engine governs the sequencing of modules. Branching conditions are based on:

- User Behavior (e.g., skipping, hesitation, repeated errors).
- Device Capabilities (e.g., screen size, connectivity, sensor availability).
- Contextual Signals (e.g., time of day, location, prior app usage).

For example, if a user demonstrates prior knowledge by skipping feature explanations, the system bypasses redundant modules and accelerates progression. Conversely, if hesitation is detected, the system inserts contextual help or simplified alternatives.

2.3.3. Feedback loops

The model incorporates feedback loops to refine onboarding dynamically:

- Immediate Feedback – contextual prompts triggered by user actions.
- Session-Level Feedback – adjustments in subsequent sessions based on prior performance.
- Aggregate Feedback – system-level refinements informed by aggregated user data, ensuring continuous improvement while preserving individual autonomy.

2.4. Ethical and inclusive design

The model explicitly integrates ethical safeguards:

- Transparency – users are informed when adaptation occurs.
- Autonomy – users can override or skip adaptive suggestions.
- Inclusivity – modules are designed with accessibility standards (WCAG) and edge cases in mind, ensuring that adaptation does not exclude vulnerable populations.

2.5. Evaluation framework

To ensure reproducibility, the model includes a structured evaluation methodology:

- Quantitative Metrics – engagement rates, task completion, time-to-competence.
- Qualitative Metrics – user satisfaction, perceived autonomy, trust.
- Comparative Testing – A/B testing against static onboarding flows.

This dual evaluation approach allows both measurable outcomes and subjective experiences to inform iterative refinement.

2.6. Generalizability

Although demonstrated in a mobile learning context, the model is designed for cross-domain application. Its modular and adaptive architecture can be applied to:

- Healthcare apps (personalized onboarding for patients with different conditions).
- Productivity tools (adaptive guidance based on user expertise).
- E-commerce platforms (context-aware onboarding for first-time vs. returning customers).

3. Case study / application example

To illustrate the proposed systems-based framework for adaptive onboarding, we applied it to the design of an Android mobile learning application aimed at classroom students. The app provides short, modular lessons in programming fundamentals, with features such as quizzes, progress tracking, and peer discussion. Like many educational apps, it faced the dual challenge of diverse user profiles (novices vs. advanced learners) and varying device contexts (low-end phones vs. high-performance phones). Traditional static onboarding flows, consisting of a fixed tutorial and feature tour had previously resulted in high abandonment rates during the first session.

The case study was designed to test whether an adaptive onboarding flow, modeled as a dynamic system of decision points and modular components, could improve engagement, task completion, and user satisfaction.

3.1. Framework implementation

3.1.1. Modular components

The onboarding process was decomposed into five modular components, each representing a distinct onboarding function:

- Welcome and Value Proposition: concise explanation of app purpose.
- Account Setup: profile creation, optional personalization.
- Feature Introduction: guided walkthrough of core functions.
- First Task Prompt: invitation to complete a short learning activity.
- Feedback and Support: contextual help, tips, and encouragement.

Each component was designed to be combined with each other or skippable, depending on user behavior and context.

3.1.2. Decision-tree logic

- A decision-tree model governed the sequencing of components. Key decision points included:
- Prior Knowledge: inferred from whether the user skipped or engaged with explanatory screens.
- Device Capabilities: detected automatically (e.g., screen size, connectivity).
- Behavioral Signals: hesitation, repeated errors, or rapid progression.

For example, if a user skipped the feature introduction, the system assumed prior familiarity and redirected them to the first task prompt. Conversely, if a user hesitated during account setup, the system triggered contextual help and simplified options.

3.1.3. Feedback loops

The system incorporated feedback loops to refine onboarding in real time. If a user abandoned a task, the next session began with a simplified version of the same task, accompanied by a motivational message. If the user completed tasks quickly, the system reduced guidance and accelerated progression.

3.1.4. Evaluation design

The adaptive onboarding flow was evaluated against a static control version in a pilot study with 85 participants (undergraduate students). Participants were randomly assigned to either:

- Control Group: static onboarding (linear tutorial + feature tour).
- Experimental Group: adaptive onboarding (decision-tree + modular components).

Metrics collected included:

- Engagement: number of sessions completed in the first week.
- Task Completion: percentage of users completing the first three learning activities.
- Time-to-Competence: average time to complete a task without errors.
- User Satisfaction: self-reported ratings via post-onboarding survey.

3.1.4. Results

Results of the adaptive onboarding experiment are summarized in Table 1.

Table 6. Comparative results of adaptive and control onboarding groups

Metric	Adaptive Onboarding Group	Control Group	Improvement
Engagement	98% returned for a second session	79% returned for a second session	19% improvement
Task Completion	72% completed first three activities	31% completed first three activities	41% improvement
Time-to-Competence	19% faster to reach error-free task completion	Baseline	19% faster
User Satisfaction	Reported appreciation for "flexibility", "clear guidance when needed" and "not being forced through unnecessary steps"	Lower satisfaction, more reports of friction	Qualitative improvement

Source: Author's own research (2025)

Compared to the control group, the adaptive onboarding group demonstrated significantly higher engagement, with 98% of users returning for a second session versus 79% in the control condition. Task completion also improved substantially, as 72% of adaptive users finished the first three activities compared to only 31% of control users. In addition, adaptive users reached error-free task performance 19% faster on average. Beyond these quantitative gains, survey responses emphasized qualitative benefits such as greater flexibility, clearer guidance when needed, and the absence of unnecessary steps. These results suggest that adaptive onboarding can improve both behavioral outcomes (e.g. engagement, completion, efficiency) and perceptual outcomes such as satisfaction and autonomy.

Conclusion and future work

This app example illustrates how a systems-based framework for adaptive onboarding can be operationalized in a real-world context. The results provide evidence that adaptive onboarding not only improves measurable outcomes but also aligns with ethical design principles by respecting user

autonomy. The case study thus validates the framework's potential for broader application in domains where user diversity and contextual variability are high, such as education, healthcare, and productivity apps.

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Integrated Approaches to Developing Digital and Language Competencies in Higher Education: Interdisciplinary Projects Theoretical Framework

Integrisani pristupi razvoju digitalnih i jezičkih kompetencija u visokom obrazovanju: teorijski okvir interdisciplinarnih projekata

Jovana Ljubisavljević[1], Ana Veljić[2], Marko Marković[3]

[1]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, jovana.ljubisavljevic@mef.edu.rs*
[2]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, ana.veljic@mef.edu.rs*
[3]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, marko.markovic@mef.edu.rs*

Abstract: *Digital competencies and proficiency in multiple languages are of paramount importance for graduates in contemporary higher education. This paper examines the development of these competencies in interdisciplinary, integrated projects involving information technology, management, and foreign language education. It presents a theoretical proposition for such integration, demonstrating the effectiveness of such an approach in preparing learners for sophisticated and multifaceted global problems in contrast to siloed education. The discourse presents an evaluation of the advantages, the required institutional approaches to make this work, along with a conceptual plan for implementation. The final remark states the importance of integrating digital and language education in collaborative projects to cultivate a flexible and competitive labor force.*
Keywords: *Digital competencies, interdisciplinary projects, higher education, integrated learning.*

Apstrakt: *Digitalne kompetencije i znanje stranih jezika od izuzetne su važnosti za studente u savremenom visokom obrazovanju. Dati rad ispituje razvoj ovih kompetencija kroz interdisciplinarne, integrisane projekte koji uključuju informacionu tehnologiju, menadžment i nastavu stranih jezika. Iznosi se teorijski predlog za takvu integraciju, pokazujući efikasnost ovakvog pristupa u pripremi studenata za suočavanje sa složenim i višestrukim globalnim izazovima, za razliku od izolovanog obrazovanja. Diskusija prikazuje ocenu prednosti, neophodnih institucionalnih pristupa za njihovu realizaciju, zajedno sa konceptualnim planom za implementaciju. Zaključak ističe značaj integrisanja digitalnog i jezičkog obrazovanja kroz kolaborativne projekte za formiranje fleksibilne i konkurentne radne snage.*
Ključne reči: *Digitalne kompetencije, interdisciplinarni projekti, visoko obrazovanje, integrisano učenje.*

Introduction

In contemporary higher education, digital and language competencies represent the foundation for developing quality teaching and preparing students for a global, technologically-mediated environment. The increased use of virtual platforms and digital tools has fundamentally changed the way teaching and learning occur, leading to a transformation of pedagogical practices and the need for new models of teaching skills (Srivastava & Dangwal, 2021). Effective application of technology in teaching today implies not only technical knowledge of tools but also critical reflection, creativity, and innovative design of the teaching process that encourages active learning and collaboration. Digital

transformation has particularly impacted the field of language teaching, where modern tools based on artificial intelligence, adaptive learning, and virtual reality enable better personalization and more efficient knowledge acquisition. Such approaches not only increase student motivation but also enhance their communication and professional skills, which is especially significant in teaching English as a medium for international cooperation and employment (Cao et al., 2023). The development of these competencies is most effective in interdisciplinary environments that connect technology, language, and management. Interdisciplinary approaches foster critical thinking, complex problem-solving, and collaborative learning, simultaneously merging academic and practical knowledge (Scott & White, 2024). Despite implementation challenges, this approach shows significant potential for developing modern skills and competencies applicable in a global context.

1. Digital competencies in higher education

The integration of digital competencies into higher education is today one of the key prerequisites for successful teaching and research. The European Digital Competence Framework (DigComp) defines five core areas encompassing information and digital literacy, communication and collaboration, content creation, digital safety, and problem-solving (Dou & Huang, 2022). This framework serves not only as a guide for assessing digital skills but also as a strategic instrument for planning institutional development and raising the level of digital literacy in the academic environment. Contemporary research increasingly points to the need to expand existing models. Martynova and colleagues (2023) propose that DigComp include aspects of digital health and well-being, highlighting the connection between technology and other areas of social activity. Such approaches confirm the importance of interdisciplinarity and the need for educational frameworks to adapt to new forms of digital interaction and collaboration. In this sense, the integration of different disciplines-from information technology to social sciences contributes to developing comprehensive digital competencies in students and teachers. Effective collaboration in such environments requires not only technical knowledge but also the ability to communicate across different academic and professional fields (Martynova et al., 2023).

1.1. Key dimensions of digital competence

Information literacy, which encompasses the critical ability to find, evaluate, and use information, is a key dimension of digital competence and a vital skill for higher education. Beyond recognizing relevant sources, it also includes developing the capacity for analysis and critical reflection in the digital environment. Communication and collaboration form the basis for active participation in academic and professional communities. The use of digital tools for sharing information and collaborative work contributes to the development of inclusive and collaborative forms of learning. Digital safety is becoming an increasingly important dimension, especially in the context of heightened risks associated with online communication and data protection. Educational institutions have a responsibility to develop awareness of the ethical use of technology and safe behavior in digital spaces (Tso et al., 2022). Content creation involves the ability to produce and share relevant, creative, and ethically appropriate digital materials. This dimension promotes the development of innovativeness and digital literacy, while simultaneously encouraging students to actively participate in academic and professional communities. All these dimensions together form the basis of the modern understanding of digital competence. Their development among teachers and students not only enhances the quality of educational practices but also equips individuals for active, responsible, and safe participation in the digital society.

2. Language and communication competencies

The Common European Framework of Reference for Languages (CEFR) and models of communicative competence represent the basis of the modern approach to language teaching, as they enable clear definition of proficiency levels and direct teaching methods towards the real use of language. The CEFR

encompasses six levels, from A1 to C2, and emphasizes the importance of applying linguistic, pragmatic, and sociolinguistic skills in real communication situations. Its application ensures the alignment of curricula and assessment systems with international standards, thereby fostering the development of functional communicative abilities (Azman et al., 2021). The concept of communicative competence, which includes grammatical, sociolinguistic, discursive, and strategic components, highlights the need for learners to use language in accordance with the context and purpose of communication (Foley, 2021). This approach is realized through communicative language learning, which encourages interaction and practical application of knowledge. The integration of the CER and communicative competence provides a clear framework for the development and assessment of language abilities. The focus on interactive and meaningful language use enables students to develop the communication skills necessary for successful functioning in academic, professional, and international environments.

2.1. The connection between language skills and professional and digital contexts

In the modern global environment, language skills, particularly in English as an international language of business, have become crucial for professional success and effective communication in digital and multicultural settings (Rahman & Akter, 2023). Contemporary jobs require a combination of verbal, written, and digital literacy, necessitating that foreign language curricula be adapted to the real demands of the labor market. The integration of technology into language teaching has enabled the development of competencies that reflect professional situations from practice.

Strategic competence, i.e., the ability to adapt language to specific professional contexts, is becoming an increasingly important goal of education in higher education (Almazova et al., 2021). Therefore, institutions must develop integrated teaching models that connect language, digital, and professional skills, thereby increasing professional preparedness and graduates' readiness to work in a global digital environment.

2.2. The role of English in the global IT and management environment

In the contemporary business and technological environment, the English language functions as the primary medium of international communication and coordination. As a lingua franca, it enables collaboration among specialists of different languages and cultures, making it essential for the successful functioning of global teams, especially in IT projects and management (Raine, 2023). Clear and precise use of the English language contributes to building trust and efficiency in communication among members of distributed teams. Knowledge of English significantly impacts professional mobility and leadership abilities. In management, language competence forms the basis for effective leadership of multicultural teams, where digital literacy and cultural awareness are key to successful management. The development of digital communication tools has further solidified the status of English as a global business language. Platforms for virtual collaboration require high linguistic and technical competence to ensure clear and adaptable communication in multilingual teams (Ljubisavljević et al., 2024).

3. Interdisciplinarity and competency integration

Interdisciplinary and transdisciplinary education represent contemporary approaches that integrate knowledge, methods, and perspectives from different fields to solve complex real-world problems. While interdisciplinarity implies collaboration between disciplines to achieve common educational goals, transdisciplinarity goes a step further-connecting academic and professional spheres to create new, applicable knowledge (Radakovic et al., 2022). These models are particularly relevant in fields such as IT and management, where innovations are developed through the exchange of expertise and perspectives from different disciplines. Transdisciplinary approaches promote learning through practice, emphasizing reflexivity and open pedagogy, which fosters creativity and collaboration. Institutional support remains crucial for the sustainability of these models. Creating a culture of collaboration and connecting academic and business actors enables the development of programs that

merge theory and practice and prepare students for action in complex, globally-oriented sectors (Mashau, 2023).

3.1. Benefits of an integrated approach

Integrated learning approaches, which connect disciplines through teamwork, are vital for preparing students for complex professional challenges by fostering a broader contextual understanding and the ability to apply theoretical knowledge. Collaboration in interdisciplinary teams develops critical thinking, creativity, and the communication skills necessary for effective work in digital and international environments. Thus, integrated learning develops the flexibility, adaptability, and applicable skills that increase graduates' employability and professional competitiveness (Hirscher et al., 2024).

3.2. Conceptual model for connecting IT, management, and language areas

The conceptual model integrating IT, management, and language is based on the idea that technological, managerial, and communication competencies are interconnected and necessary for contemporary education and professional practice. This integration of management theories and linguistic approaches promotes effective communication and decision-making, while creating a common language between disciplines that enables collaboration and culturally aware solutions (Chew et al., 2020). Such a model fosters collaboration, teamwork, and innovation, preparing students to connect technical knowledge, management strategies, and linguistic precision in solving complex professional tasks.

4. Interdisciplinary projects as a framework for competency development

Interdisciplinary projects represent an effective way to engage students in active, collaborative, and experiential learning that connects theory and practice. Their value is reflected in the integration of different areas of knowledge and the development of competencies needed to solve complex problems of modern society. These projects encourage collaboration and teamwork, enabling students to develop communication and organizational skills essential in professional environments through shared tasks. Active participation in such tasks strengthens the sense of responsibility and motivation for independent learning (Rima & Rodriguez, 2022). The use of digital technologies further enhances the efficiency of interdisciplinary projects. Cloud-based platforms and hybrid environments enable collaboration and knowledge exchange regardless of physical distance, thereby promoting the global dimension of education.

4.1. The role of digital tools and collaborative platforms

Digital tools have become the backbone of interdisciplinary projects as they enable collaborative work and knowledge exchange in virtual environments. This infrastructure increases productivity and transparency while expanding collaboration possibilities through virtual classrooms and hybrid environments for discussion and joint problem-solving (Alturki & Aldraiweesh, 2021). In this way, digital platforms create an environment where theoretical knowledge from different disciplines is connected through interactive practice.

4.2. Benefits for teachers and institutions

Interdisciplinary and innovative approaches in education bring multifaceted benefits—they enrich teaching practice, open space for knowledge exchange, and encourage collaboration among educational institutions. When different perspectives are combined within a common teaching framework, teachers gain the opportunity to learn from each other and develop methods that transcend the boundaries of individual disciplines. Such exchange of experiences leads to the creation of communities of practice that contribute to higher quality and more dynamic education. Innovative teaching methods stem precisely from such collaborations. Projects based on interdisciplinary learning and the use of technology encourage creativity, engagement, and the application of knowledge in real situations

(Fomin et al., 2024). Teachers who connect content from multiple areas develop more flexible teaching models that simultaneously encourage critical thinking and problem-solving (Li, 2024). For the institutions themselves, such approaches open doors to internationalization and connection with educational partners worldwide. Joint projects and the exchange of practices contribute to understanding different educational cultures and developing more inclusive programs. Interdisciplinary collaborations thus become a means through which educational communities strengthen their own capacity for innovation and adaptation to contemporary educational trends.

5. Managerial perspective on implementation

Establishing interdisciplinary projects requires clearly defined strategic frameworks, institutional support, and a culture of collaboration among teachers and students. To build this culture, institutions must overcome barriers like academic silos by encouraging open communication, which can be achieved through workshops, joint training, and professional networks. Finally, a flexible curriculum that combines theory and practice is key, ensuring interdisciplinary projects are an integral part of the program with shared learning outcomes (Kolmos et al., 2025).

5.1. The role of leadership, institutional support, and teacher professional development

Leadership plays a crucial role in the development of interdisciplinary education, as it sets the vision and creates a culture of collaboration among teachers of different profiles. Effective leaders promote innovation and support change through clear communication and practical management models (Walsh et al., 2021). Institutional support must provide resources, infrastructure, and training including investments in digital tools and collaborative spaces. Finally, continuous professional development, fostered through communities of practice, is essential for teachers to apply new methods and technologies, strengthening their digital and pedagogical competencies (Shon et al., 2024).

6. Discussion

The discussion encompasses the consideration of theoretical models and their practical implications in higher education. Although contemporary frameworks offer clear guidelines for the development of digital and language competencies, their application in real institutional conditions is often limited by organizational, technical, and pedagogical challenges. It is therefore necessary to examine the possibilities of adapting existing models to real educational contexts.

6.1. Analysis of theoretical models in relation to the challenges of the higher education system

Comparing contemporary theoretical approaches and real challenges in higher education shows that the development of digital and language competencies requires the simultaneous modernization of teaching methods and institutional support. Models of active and experiential learning emphasize the importance of the student's role as an active participant in the process of knowledge creation, especially in environments where technology is used as a means for collaboration and communication. Such models are particularly significant for IT and management education, where the application of digital tools and business simulations enables learning through practice and authentic tasks.

Modern concepts of networked and project-oriented learning confirm that the use of English as the main language of international communication significantly contributes to connecting teams and knowledge exchange. Precisely the combination of digital literacy and language competence enables students to actively participate in global academic and professional networks, which becomes a key component of graduate employability (Bai & Bai, 2024). Although institutions increasingly recognize the value of interdisciplinary projects, challenges persist —from a lack of infrastructure and teacher training to the slow adaptation of traditional curricula to the digital environment. Therefore, the need for a holistic

model that connects technological competencies, communication skills, and international standards through an integrated educational experience is emphasized.

6.2. Proposal for an original conceptual model of integrated competency development

The proposed conceptual model is based on the idea that digital, language, and professional competencies must be developed simultaneously, by connecting IT, management, and language within a unified educational framework. The model implies five interconnected dimensions: core competencies, interdisciplinary integration, technologization of learning, experimental practices, and teacher professional development. Core Competencies encompass knowledge, skills, values, and ways of thinking that enable students to connect theoretical and practical learning. This forms the basis for developing independence and the ability to adapt to the modern labor market. Interdisciplinary Integration implies teacher collaboration and the connection of fields through joint projects and thematic modules. This encourages creative problem-solving and the formation of professionals capable of working in a global environment. Technologization of Learning emphasizes the importance of digital platforms, hybrid classrooms, and Al tools for personalized and interactive education. Digital technologies connect students of different profiles and enable them to simultaneously develop IT and language competencies through collaborative tasks. Experimental Learning connects academic knowledge with real-world contexts. Participation in practical projects and international teams contributes to the development of critical thinking and communication skills, particularly in English as the working language of global collaboration (Imara & Altinay, 2021). Continuous Professional Development of Teachers is crucial for maintaining quality. Training and communities of practice enable teachers to align their methods with new technologies and multicultural environments. This creates an environment where IT and language are integrated into all segments of teaching, and students acquire competencies that connect technology, communication, and management.

Conclusion

Contemporary higher education faces the challenge of connecting digital and language competencies into a unified, functional framework that meets the needs of global society and the labor market. The integration of information technologies and the English language as key instruments of learning and professional communication has proven to be the most effective way to enhance the quality of teaching and equip a new generation of professionals capable of international collaboration. The analysis of implemented models and theoretical frameworks indicates that interdisciplinary projects represent the most efficient mechanism for developing these competencies. They connect technical knowledge, communication skills, and cultural awareness, enabling students to develop the capacity for critical thinking and adaptation through collaboration and practical work. The key to success lies in systemic support —in institutions that nurture an open academic culture, invest in digital infrastructure, and the continuous professional development of teachers. Only such an environment can enable the integrated approach to education to become a real practice, not a theoretical ideal. Ultimately, the development of digital and language competencies through interdisciplinary approaches represents not only a pedagogical innovation but also a strategic direction for the development of higher education. This builds the foundation for an educational system that does not just follow changes but creates them-connecting knowledge, technology, and language in the service of social and professional progress.

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Improving Service Processes through the Application of Operations Management – FIS d.o.o. Vitez

Unapređenje uslužnih procesa primjenom operacionog menadžmenta – FIS d.o.o. Vitez

Denis Marjanović[1], Nera Akrap[2]

[1]*International University Travnik, Travnik, Bosnia and Herzegovina, marjanovic.denis@yahoo.com*
[2]*International University Travnik, Travnik, Bosnia and Herzegovina, akrapnera5@gmail.com*

Abstract: *This paper explores the role of operational management in improving efficiency and service quality within organizations, with a particular focus on the service industry. Operational management encompasses planning, organizing, leading, and controlling business activities to ensure the effective production and delivery of goods and services. The concept is analyzed through the 5V model—Volume, Variety, Variation in Demand, Visibility, and Value—which defines the key characteristics of operations. While much of the existing literature focuses on production-oriented operations, this study emphasizes the growing importance of service operations in today's economy. The practical part examines FIS d.o.o., where operational challenges were identified and addressed. Through process mapping of the company's kitchen and restaurant, solutions such as space optimization and bottleneck reduction were proposed, demonstrating how small operational adjustments can enhance flexibility, employee satisfaction, and overall performance.*
Keywords: *Operational management, service industry, 5V model.*

Apstrakt: *Ovaj rad istražuje ulogu operativnog menadžmenta u unapređenju efikasnosti i kvaliteta usluge unutar organizacija, sa posebnim fokusom na sektor usluga. Operativni menadžment obuhvata planiranje, organizovanje, vođenje i kontrolu poslovnih aktivnosti kako bi se osigurala efektivna proizvodnja i isporuka dobara i usluga. Koncept je analiziran kroz 5V model – Volumen, Raznovrsnost, Varijacija potražnje, Vidljivost i Vrijednost – koji definiše ključne karakteristike operacija. Dok većina postojeće literature naglašava proizvodno orijentisane operacije, ovo istraživanje ističe sve veću važnost uslužnih operacija u današnjoj ekonomiji. Praktični deo rada ispituje kompaniju FIS d.o.o., gdje su identifikovani i adresirani operativni izazovi. Kroz mapiranje procesa kuhinje i restorana predložena su rješenja kao što su optimizacija prostora i smanjenje uskih grla, što pokazuje kako male operativne prilagodbe mogu poboljšati fleksibilnost, zadovoljstvo zaposlenih i ukupne performanse.*
Ključne reči: *Operativni menadžment, sektor usluga, 5V model.*

Introduction

Management is a universal activity present in all spheres of the economy and society and in all organizations, of all types and sizes, at all levels. Management is focused on efficiency and effectiveness for the most rational use of available human, financial and material resources to achieve organizational goals. Successful organizations are those that do the right things in the right way.

In any organization, we can distinguish at least two levels of management: strategic and operational, and very often we also have a tactical level.

1. The concept of operational management

Operations management is located at a lower level in the hierarchy and is tasked with implementing strategic management plans. Well, we can say that operations management transforms strategies into

tangible tasks of production management, with the ultimate goal of improving the competitive position of the company. Production processes differ significantly from each other in certain types of products and services, but what they all have in common is the transformation of inputs into outputs.

Precisely because of the importance of this issue, operational management and its application in product production and in the processes of service delivery to clients are gaining more and more importance today.

Operations are characterized by five properties that can be explained through the 5V concept:

- Volume
- Variability,
- Variation in demand,
- Visibility,
- Value.

Operations management deals with the outputs of any job, that is, the conversion of outputs to create a certain input. This process is known as transformation, the result of which is a tangible product, an intangible service or a charitable deed. Recently, there has been a growing interest in operations management.

There are at least two reasons for this.

- The first reason lies in the modern approach to business improvement, which focuses on the optimization of business production and service practices by eliminating losses and incorporating the human factor into transformation processes.
- The second reason is the one that today encourages competitiveness in a global market where there is no survival without the best quality of a product or service. Business success depends on whether a company can compete simultaneously in four fields: flexibility, efficiency, quality, and innovation.

2. Operational management model

2.1. Operational strategies

An operational strategy is a vision of the operational functions that set the general direction or direction in the decision-making process. This vision should be integrated with the business strategy. Often, but not always, it is reflected in the formal plan. An operational strategy should result in a consistent decision-making scheme in operations and give the company a competitive advantage.

2.1.1. Types of operational strategies

There is a low-cost manufacturing business strategy that would be typical of mature markets sensitive to the price of products with standardized products. In this case, the operational mission would underline cost as the dominant goal, and operations would seek to reduce costs through such policies as superior process technology, low personnel costs, low inventory levels, a high degree of vertical integration, and cost-reduction quality. Marketing and finance would also follow and support a low-cost business strategy.

The second business strategy is the one that is based on innovation and the introduction of new products. This strategy would be used in markets that are either emerging or in a state of expansion and where a competitive advantage can be gained by bringing out superior products in a short period of time. Price, in this case, would not be the dominant form of competitiveness and could be high, and thus little attention would be paid to low production costs. In this case, operations would particularly emphasize the flexibility to bring new products to market quickly and efficiently and this would be the

dominant goal of their mission. The operational policy should include the use of teams of professional staff for the introduction of new products, flexible automation that could be adapted to new products and a highly skilled workforce of broad education, as well as the possible purchase of some of the key services and materials from outside to maintain flexibility.

Table 1. Strategic alternatives

	Strategy A	**Strategy B**
Business Strategy	Production at a low cost	Innovations in production
Market Conditions	Price sensitive, Mature market Large quantity, standardization	Sensitive Product, Emerging Market, Small Quantities Specialized products
Operational objectives	Emphasized low price in maintenance Acceptable quality and delivery	Emphasis on flexibility with reasonable prices and deliveries
Distinctive Competency Operations	Low cost through superior process Technological and vertical integration	Fast and reliable product introduction
Operational Policies	Superior process Statistical Process Control Central Location Low-growth economy Strict Inventory Control Unskilled Labor High automation	Superior products Flexible automation Quick reaction to changes The Economy of Expansion The use of production teams Trained Workforce Low automation
Marketing strategies	Mass distribution Constant Sales Maximizing Sales Opportunities Nationwide Sales Low cost of advertisements	Selective distribution Development of a new market Product design Selling through an intermediary Expensive advertising
Financial Strategies	Highly invested capital Low risk Low Limited Profit	Low investment of capital, high level of risk. A high level of profit

Source: Bagarić, I., Operational Management, Singidunum University, Belgrade, 2012, p. 24.

3. Application of operations management in the service sector

First of all, we need to define the service. A service is any act or act that one party can offer to another that is completely intangible and does not result in the possession of something. Its production may or may not be tied to a physical product. Service is an activity, i.e. a set of steps that includes the treatment of the customer, providing a certain benefit, and also the customer himself is involved in the process and performs a certain role in the process of serving. Services are "products" that do not represent material goods. With them, a benefit is created for the customer that he cannot store (save in any way). Services must be consumed at the time of their "production".

Services are of increasing importance in the business of entrepreneurs, regardless of the fact that they are only engaged in the production of products. In most cases, services represent what is called added value. Quality of service is a set of activities that act on the satisfaction of human needs (quality of services for humans) and on the return of product quality to the required limits for its further functioning (quality of services for the product).

The importance of services is growing and services are increasingly dominating in various branches of the world's economy. The service has become an indispensable tool in the struggle in the market. Because of this, the need for business research within the service industry has developed. The

simultaneity of production and consumption means that in most cases the user is present or even participates in the creation of the service. More and more in the business of an organization, the importance of the individual within it is emphasized, and the work they are in charge of and the way employees perform it is the key to achieving business results. Employees are also an integral part of the service and a key element of the customer's service experience and satisfaction.

3.1. Kitchen and restaurant mapping process

One of the most complex business processes in the hospitality industry is the kitchen and restaurant. A complete service depends a lot on the quality of their service, but also on their communication. Seemingly simple operations have a lot of hidden and complex business operations that affect the level of service quality and guest satisfaction.

Business processes in the restaurant were not applied in the same way by all employees. That is why we have done a restaurant mapping process that should increase the efficiency of restaurant work, and lead to the standardization of business processes within this business unit. Through the mapping of business processes, the basic elements that are the main processes of serving one guest were taken. This includes all the processes of the waiter and the kitchen from the moment the guest arrives to the moment the bill is collected and the guest leaves.

The image below shows the mapping of the restaurant, with all the important steps and a detailed explanation of each of the mentioned activities. It is also important to note the meaning of abbreviations:

- G – guest
- K – activity performed by the waiter
- KK – activity performed by the kitchen

Based on the mapping of business processes, we have shown the mapping of the restaurant, with all the activities. After mapping and monitoring activities, we can conclude that business processes have accelerated and, most importantly, there has been a systematization of business processes, which are key to establishing standardization and professionalization.

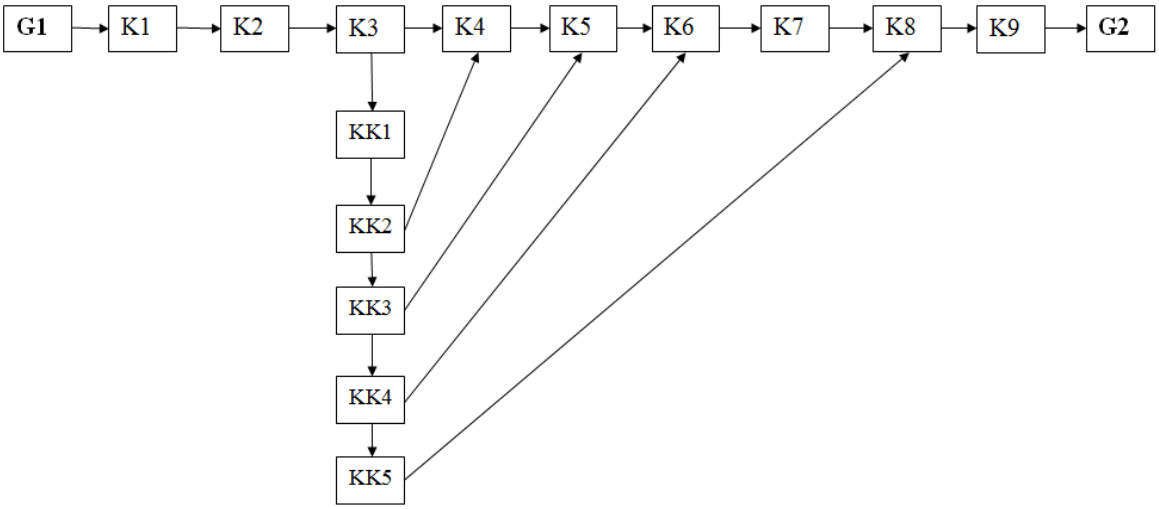


Figure 1. Mapping in the restaurant of the company FIS d.o.o.

G1 = This activity involves the guest's nudge.

K1 = Approaching the guest.

K2 = Bring the guest a menu, so that he can order the appetizer and the main course.

K3 = Serve the guest with the requested drink, and take the order for the main course and appetizer, and hand it over to the kitchen (KK1).

KK1 = Taking an order for an appetizer and a main course. Organization of the preparation of the main course.

KK2 = Preparation and delivery of the compartment to the waiter for activity K4.

K4 = Serving the guest with an appetizer.

KK3 = Preparation and decoration of the salad.

K5 = Serving salad.

KK4 = Final preparation and decoration of the main course.

K6 = Serving the main course.

K7 = Approaching the guest to check if everything was in order. Pick up the free meals. Ask guests if they want dessert.

KK5 = Preparing desserts (if necessary) and/or serving desserts that are already prepared

K8 = Bringing the dessert to the guest

K9 = Bill Collection

G2 = Guest departure

3.2. Impact of operations management on employee satisfaction

The operations that we have previously listed in this paper have resulted in the improvement of business performances, as well as employee satisfaction.

One of the steps of employee satisfaction is a different organization within the company through shifts. With the increase in working hours, there are now more workers in the period when there is the most work. This resulted in less nervousness and conflicts among employees.

By addressing bottlenecks, crowds are reduced, making it easier for staff to work and navigate through the hall while serving guests.

Mapping of business processes has led to the speed and efficiency of business process execution, where waiting times for food have been reduced and service improvements have been improved.

In the end, everything was aimed at satisfied guests, and this resulted in their willingness to leave more tips for the workers. Cash reward is certainly one of the main factors of employee satisfaction within the company.

4. Results obtained from the application of operational management

After the theoretical part of the work, a survey was carried out using a questionnaire. The geographical area in which the research was carried out is Central Bosnia, the company FIS d.o.o.

The number of employees who participated in the survey is 50. In order to make a better analysis of the survey, we analyzed the sample through gender and age structure and by workplace.

Table 2. Gender structure

Sexual structure	Number of employees	Percentage
Men	23	46%
Women	27	54%

Table 3. Age structure

Age group	Number of employees	Percentage
18-22	14	28%
23-27	9	18%
28-32	8	16%
33-37	3	6%
38-42	5	10%
43-47	3	6%
48-52	4	8%
53-57	2	4%
57-62	2	4%
ALTOGETHER	50	100%

Table 4. Structure of employees by job position

Workplace	Number of persons	Percentage
Kitchen	12	24%
Patisseries	7	14%
Bars	25	50%
Restaurant	6	12%
Altogether	50	100%

Survey questionnaire:

Please rate which of the above statements apply to your company: 1 – Strongly disagree; 2 – I disagree; 3 - I neither agree nor disagree; 4 – I agree; 5 – Strongly agree					
1. Employees focus on completing only one part of the work.	1	2	3	4	5
2. The cost per unit of product is high.	1	2	3	4	5
3. Are there standardized procedures in the execution of work?	1	2	3	4	5
4. The company conducts education and sends employees to specialization	1	2	3	4	5
5. The client's requirements are standardized (similar).	1	2	3	4	5
6. Employees possess a high level of flexibility.	1	2	3	4	5
7. Employees generally provide routine knowledge when doing their job.	1	2	3	4	5
8. Customers are provided with a high level of product variety	1	2	3	4	5
9. The demand for products is continuous (unchanging).	1	2	3	4	5
10. Clients have a low tolerance level for waiting for the product?	1	2	3	4	5
11. Employees should possess a high level of communication skills.	1	2	3	4	5

12. Employees have contact with the client on a daily basis.	1	2	3	4	5
13. Employees have time for creativity.	1	2	3	4	5
14. Employees need to be highly efficient	1	2	3	4	5
15. The service provided has a high value for the customer.	1	2	3	4	5

The research has shown that employees within FIS are specialized in performing certain activities, which they routinely perform on a daily basis. The majority of respondents (60% strongly agree, 38% agree) confirmed this statement, indicating a high workload and clearly defined tasks. Given this specialization, the costs per unit of product are low, because the repetition of activities allows the company to use production capacities more efficiently, which was confirmed by employees (60% strongly disagree that costs are high).

Standardization is also an important element of business, which was confirmed by the respondents' answers to the question about the existence of standardized procedures (52% strongly agree, 46% agree). However, the company does not invest significantly in additional employee education, so most rely on formal and informal acquired knowledge (32% strongly disagree, 26% disagree, 40% neither agree nor disagree). Only a small number of employees have acquired additional skills at the company's request, which indicates room for improvement in the development of employee competencies and the improvement of the working environment.

Client requirements in the company are largely standardized (55% strongly agree, 44% agree), which further reduces the need for employee flexibility, which according to the results is low (56% strongly disagree, 40% disagree). Employees apply routine knowledge when performing everyday tasks (40% strongly agree, 58% agree), which is a consequence of the standardization of procedures and insufficient investment in professional development.

Despite the standardization of internal processes, the company provides clients with a wide and diverse range of products and services (54% strongly agree, 44% agree), including cafes, restaurants, express restaurants, pastry shops and fast food. The demand for these products is stable, with the highest volume on weekends (50% strongly agree, 44% agree), and the most sought-after product is coffee. However, clients show a low tolerance for waiting, especially during periods of greater congestion, which further emphasizes the importance of efficiency and visibility of operations.

Employees are in constant contact with clients (56% strongly agree, 38% agree) and therefore must possess high communication skills (54% extremely agree, 40% agree). Their ability to adequately respond to the needs of guests directly affects the quality of service and customer satisfaction. On the other hand, employees spend most of their working time performing routine tasks, so they have little room for creativity (48% strongly disagree, 46% disagree), and high efficiency is especially needed on weekends when the number of visitors is highest (50% strongly disagree, 46% disagree).

In the end, the research showed that the service provided generally has a lower value for customers (64% strongly disagree, 30% disagree), because these are everyday products and services, such as coffee, food and cakes. All of the above indicates that the company functions as a standardized organization with a high volume and clearly defined procedures, while there is room for employee development and increased flexibility and creativity in providing services.

Conclusion

Every business must manage business processes in order to fulfill the set requirements and meet the set goals.

The topic of this paper is business processes in service companies, which are much more sensitive and specific because they are the main factor in the service processes of people and their relationship to the

end consumer. That is why this paper presents business processes in the service part of the company FIS d.o.o. Vitez.

The paper consists of a cargo and an empirical part. In the theoretical part of the paper, the concept of operational management and its characteristics are explained. On the other hand, the theoretical part serves us to understand the role and importance of operational management in the company, as well as what are the tasks of operational managers in the company.

The two basic tasks of operational management are work management and people management, and it is important that they have both technical and behavioral knowledge and skills.

In the empirical part, the mapping of the kitchen is presented. One of the important processes that has contributed to the business processes within the company itself. Of course, this is a model that can also be applied in many restaurants. A process that leads to the standardization of service with the aim of providing the best possible service is presented.

A very important element through the implementation of these operations has visibly borne fruit and has led to more efficient work. The company followed the idea and led to the reduction of bottleneck problems through increased capacity and reorganization of employees. Employee satisfaction is one of the most important elements of any company.

Based on the questionnaire, the 5V model was linked to the improvement of business processes within the company.

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Innovative Financial Instruments for Achieving Social Impact – Development and Perspectives of Social Bonda

Inovativni finansijski instrumenti za podsticanje socijalnog uticaja – razvoj i perspektive socijalnih obveznica

Ana Anufrijev[1], Anđelka Aničić[2]

[1]*University of "Union – Nikola Tesla", Belgrade, Serbia, anufrijevana@hotmail.com*
[2]*Faculty of Business Economics and Entrepreneurship, Belgrade, Serbia, anicican@gmail.com*

Abstract: *In today's financial environment, innovation plays a key role in shaping instruments that go beyond traditional profit-oriented goals and contribute to achieving broader social impact. One of the most significant instruments of this kind is the social bond – a financial tool designed to raise capital for projects with measurable social outcomes, such as improving employment opportunities, access to education, healthcare, and social services. This review paper aims to analyze the development and future perspectives of social bonds as an innovative mechanism for financing socially responsible projects. The paper discusses international standards and guidelines for social bond issuance (ICMA Social Bond Principles), as well as the experiences of countries that have successfully implemented this instrument. Particular attention is given to the role of international institutions and investors in strengthening the social bond market, as well as the potential for their application in Serbia and the Western Balkans region.The paper concludes that social bonds represent an important step toward building sustainable and inclusive financial markets, as they link financial innovation with social needs. Their further development will depend on regulatory support, transparency in measuring social impact, and the readiness of both public and private sectors to participate in socially driven investments.*
Keywords: *Social bonds, innovative financial instruments, social impact, sustainable development, impact investing.*

Sažetak: *U savremenom finansijskom okruženju, inovacije igraju ključnu ulogu u oblikovanju instrumenata koji prevazilaze tradicionalne ciljeve profita i doprinose ostvarivanju šireg društvenog dobra. Jedan od najznačajnijih instrumenata ovog tipa jesu* ***socijalne obveznice (social bonds)*** *– finansijski instrumenti namenjeni prikupljanju kapitala za projekte sa merljivim socijalnim uticajem, poput povećanja zapošljivosti, poboljšanja pristupa obrazovanju, zdravstvenoj zaštiti i socijalnim uslugama. Ovaj pregledni rad ima za cilj da analizira razvoj i perspektive socijalnih obveznica kao inovativnog oblika finansiranja društveno odgovornih projekata. U radu se razmatraju međunarodni standardi i principi izdavanja socijalnih obveznica (ICMA Social Bond Principles), kao i iskustva zemalja koje su ovaj instrument uspešno implementirale. Posebna pažnja posvećena je ulozi međunarodnih institucija i investitora u jačanju tržišta socijalnih obveznica, te mogućnostima njihove primene u Srbiji i regionu Zapadnog Balkana. Zaključuje se da socijalne obveznice predstavljaju važan korak ka razvoju* ***održivih i inkluzivnih finansijskih tržišta****, jer povezuju inovacije u finansijskom sektoru sa društvenim potrebama. Njihov dalji razvoj zavisiće od regulatorne podrške, transparentnosti u merenju socijalnog uticaja i spremnosti javnog i privatnog sektora da učestvuju u investicijama sa društvenim ciljem.*
Ključne reči: *Socijalne obveznice, inovativni finansijski instrumenti, društveni uticaj, održivi razvoj, impact investing.*

Introduction

Contemporary economic trends increasingly emphasize the need for sustainable development and socially responsible business practices, which has led to the emergence and growth of new, innovative financial instruments. Among these, Social Impact Bonds (SIBs) represent one of the most significant

models, connecting the public, private, and civil sectors in achieving measurable social change. Unlike traditional forms of financing, social impact bonds enable investors to fund projects that generate positive social outcomes, with financial returns conditioned on the achievement of predefined social goals.

The concept of social impact bonds emerged in the early second decade of the 21st century as a response to the limited capacity of the public sector to independently address complex social challenges, such as poverty, unemployment, social exclusion, and access to education. Essentially, this instrument combines principles of financial innovation and social responsibility, promoting a new approach to public service financing – the "payment by results" model.

Over the past decade, the development of the social bond market has reflected growing interest from investors and institutions in projects with measurable social impact. While the most notable achievements have occurred in developed economies such as the United Kingdom, the United States, and Australia, the concept is gradually being explored in developing countries as well. In this context, examining the potential application and development perspectives of social impact bonds in Serbia is particularly relevant, given the current challenges in social policy and the need for more efficient models of financing social programs.

The aim of this paper is to analyze the essence, development, and perspectives of social impact bonds as an innovative financial instrument for achieving social impact, with special attention to their potential implementation in the domestic context. The study provides both a theoretical and practical framework, highlighting advantages, challenges, and the potential for further development of the social finance market.

Research Methods - The theoretical foundation of this paper is grounded in the concepts of sustainable development, socially responsible investing, and innovative financial instruments. The underlying premise is that financial markets, in addition to their economic function, can play a significant social role by facilitating investments in projects with measurable social outcomes.

A combination of qualitative and quantitative research methods is employed to comprehensively analyze theoretical frameworks, international experiences, and the feasibility of applying social impact bonds in Serbia. Content analysis is applied through a systematic review of domestic and international literature, legal and strategic documents, and reports from international organizations (OECD, World Bank, UNDP) concerning the development of the social bond market. This allows for the identification of key concepts, models, and trends in innovative financing and social impact.

The comparative method is used to assess experiences from countries that have implemented social impact bonds, such as the United Kingdom, the United States, and Australia, against the institutional and economic framework of Serbia. This approach enables the identification of factors for successful implementation, as well as challenges and opportunities for developing similar instruments domestically.

Descriptive and analytical methods further support the systematic organization of available data on the social finance market and allow for an evaluation of the advantages and limitations of social impact bonds relative to traditional public service financing models.

Preliminary quantitative analysis of selected international SIB projects highlights significant variability in project outcomes. Calculation of the standard deviation across four representative initiatives yields approximately 20.6%, demonstrating notable differences in effectiveness depending on context, target groups, and program design. This analysis underscores the importance of adapting international models to the local Serbian context and provides a foundation for developing tailored evaluation metrics for future implementations.

Finally, the synthesis of the results from these analyses informs conclusions regarding the prospects for developing social impact bonds in Serbia, along with recommendations for improving the regulatory and institutional framework to enable their successful application.

1. Innovative financial instruments in the function of socially responsible investing

Modern financial systems increasingly integrate the principles of sustainable development and socially responsible investing, creating space for innovative financial instruments. These instruments not only provide financial returns but also achieve measurable social and environmental impact. The transformation of markets demonstrates that capital can be used as a tool to address social challenges, promote social inclusion, and protect the environment. In this context, innovative financial instruments become key mechanisms for linking economic and social goals.

1.1. Development and significance of innovative financial instruments

The development of financial markets in recent decades has been marked by an increasing shift toward sustainable and socially responsible business practices. Traditional financing objectives, based solely on profit maximization, have been supplemented by broader social and environmental goals. This process has led to the emergence of new, innovative financial instruments that connect investors' economic interests with the needs of society and the environment (Bugg-Levine & Emerson, 2011).

Innovative financial instruments include various types of investments that aim, in addition to financial returns, to achieve measurable social or environmental impact. Among the most well-known instruments are green bonds, social bonds, sustainability bonds, and microfinance instruments. These forms of financing have become an integral part of the sustainable finance concept, which aims to direct capital toward activities that contribute to achieving the United Nations Sustainable Development Goals (UN, 2015).

According to data from the Global Impact Investing Network (GIIN), the value of the global market for impact investing was estimated at over 1.1 trillion USD in 2022, with a trend of continuous growth (GIIN, 2023). This growth reflects a paradigm shift—from traditional financing to models in which capital is used as a tool to address social and environmental challenges. Innovative instruments allow financial risk and social benefits to be distributed among multiple actors—investors, the state, the private sector, and civil society organizations (OECD, 2020).

Green bonds represent the first significant step in the development of sustainable finance markets. Their primary goal is to raise funds for projects that contribute to reducing carbon emissions, increasing energy efficiency, and preserving natural resources. Social bonds, which followed as the next phase of development, are aimed at projects with positive social effects—employment of vulnerable groups, access to education, healthcare, and social protection (Sachs et al., 2019). By combining these two approaches, sustainability bonds have emerged, financing projects with both environmental and social components.

What makes innovative financial instruments unique is the measurability of social impact. Unlike traditional donations or subsidies, these instruments require clearly defined success indicators and transparent reporting on results, which increases investor confidence and the efficiency of resource use (OECD, 2020). Impact investments play a particularly important role, defined as investments made with the intention of generating a positive, measurable social and/or environmental impact alongside a financial return (GIIN, 2023).

Socially responsible investing (SRI) also provides an important foundation for the development of innovative instruments. It is based on integrating environmental, social, and governance (ESG) criteria into the investment decision-making process. In this way, investors assess not only financial performance but also the ethical, social, and environmental aspects of business operations (Friede, Busch, & Bassen, 2015).

The role of the state and regulatory bodies is also crucial in this process. Public policies that encourage sustainable financing and create a legal framework for the application of innovative instruments contribute to greater investment attractiveness and risk reduction. For example, the European Union, through the EU Sustainable Finance Framework, actively promotes standardization and transparency of green and social bond markets (European Commission, 2022).

In domestic professional literature, particular attention is given to the research by Dašić and Anufrijev (2024), which analyzes the role of innovative financial instruments in developing circular business models and sustainable economic systems. The authors highlight that innovative strategic instruments, such as green and social bonds, have the potential to connect the financial sector with sustainable development goals by supporting projects that generate economic, environmental, and social benefits. According to their conclusion, the success of these instruments depends on clearly defined objectives, measurable impact indicators, and an established institutional framework that promotes transparency and accountability among all actors involved in the financing process (Dašić & Anufrijev, 2024).

2. Concept and mechanism of social impact bonds

Social Impact Bonds (SIBs) are an innovative financial instrument that enables the financing of projects with measurable social outcomes, where the financial return for investors is directly linked to the results achieved. Unlike traditional public investments, the risk in SIBs is not borne solely by the state but is shared among investors, service providers, and the public sector (Fraser et al., 2018). This "pay-for-success" model motivates all actors to improve service quality and efficiently use resources while enabling transparent monitoring and impact evaluation.

Social impact bonds have emerged as a response to the limited capacity of the public sector to independently finance complex social programs, such as reducing unemployment, including vulnerable groups, and improving education and healthcare. Their main advantage lies in combining financial innovation with social responsibility, allowing investment capital to be directed toward real social impact, with risk and benefit shared among all actors.

2.1. Structure and functioning mechanism of social impact bonds

The basic structure of a social impact bond involves four key actors: investors, who provide the capital; service providers, who implement the programs; government or public institutions, which guarantee repayment of returns if the defined objectives are achieved; and independent evaluators, who assess the outcomes (Nicholls et al., 2012). The effectiveness of SIBs depends on clearly defined success indicators, reliable impact measurement methodology, and timely reporting.

Practical application of SIBs demonstrates that these instruments enable innovative financing of social programs in areas such as education, employment of vulnerable groups, and reducing recidivism (Fraser et al., 2018; OECD, 2020). However, international experiences also highlight certain challenges: high evaluation costs, contract complexity, the need for long-term engagement of all actors, and regulatory misalignment in some countries (Sachs et al., 2019).

Similar challenges regarding the issuance of innovative financial instruments are emphasized by Anufrijev (2024) in the analysis of green bonds in the domestic context. The author notes that while green bonds encourage investment in clean production and sustainable development projects, there are difficulties in standardizing success indicators, measuring environmental impact, and regulatory implementation. These observations are directly applicable to social impact bonds, as both instruments require measurability, reliable evaluation, and clear procedures for distributing risk and returns among participants. Integrating lessons learned from green bonds can contribute to the development of a more efficient social impact bond system in Serbia (Anufrijev, 2024).

The functioning mechanism of SIBs also involves a clear definition of project objectives and success indicators. For example, in projects aimed at employing young people or vulnerable groups, measurable

indicators can include the number of people employed, job retention rates, or reduction in social transfers. The financial return for investors is then linked to the achievement of these goals, ensuring that capital is directed toward actual social impact rather than merely fulfilling contractual obligations (OECD, 2020).

Finally, the success of SIBs depends on a combination of institutional capacity, regulatory support, and transparent outcome measurement. Considering both domestic and international experience, including lessons from green bond issuance (Anufrijev, 2024), it can be concluded that social impact bonds represent a promising instrument for enhancing social policy, but they require comprehensive coordination and a strategic approach from all actors involved in the financing process.

2.2. International experiences and practices in the implementation of social impact bonds

Social Impact Bonds (SIBs) first emerged in the early 2010s in the United Kingdom and have since been implemented in various developed and developing countries. Their application covers a wide range of social programs, including reducing recidivism, employment of vulnerable groups, education, and healthcare (Fraser et al., 2018; Nicholls et al., 2012). A key feature of SIBs is linking the financial return for investors to the social value achieved through pre-defined success indicators, enabling transparent monitoring and evaluation of results.

Analysis of international experiences shows that the success of SIBs depends on several key factors: clearly defined objectives and success indicators, reliable evaluation methodology, an adequate institutional framework, and the involvement of independent evaluators. For example, the Peterborough Prison Social Impact Bond in the United Kingdom was the first major SIB project focused on reducing recidivism. The project evaluation demonstrated a significant reduction in the reoffending rate compared to the control group, allowing investors to be paid based on the results achieved (Fraser et al., 2018).

To systematize the experiences of different countries and facilitate comparison, Table 1 presents selected examples of SIB projects with their main characteristics, areas of application, and achieved results. This overview allows for the identification of factors contributing to the successful implementation of SIBs and provides insight into the challenges faced by various implementation models in international practice.

Table 7. Selected international examples of Social Impact Bond (SIB) projects

Country	Project	Target Group	Measurable Success Indicator	Results (Notes)	Investment (USD)	Duration
United Kingdom	Peterborough Prison SIB	Prisoners	Reduction in recidivism (%)	7.5% reduction in reoffending	5.0 million	6 years
USA	Rikers Island Education SIB	Youth in prison	Number graduated / employed	65% of youth completed programs	8.2 million	4 years
Australia	Newpin SIB	Children at risk of abuse	Stabilization of family environment	30% improvement in child safety	7.5 million	3 years
Netherlands	Employment SIB	Long-term unemployed	Number employed after 12 months	40% returned to work	6.0 million	2 years

Source: Author's compilation based on Fraser et al., 2018; Nicholls et al., 2012; OECD, 2020

The graph below illustrates the efficiency of selected Social Impact Bond (SIB) projects in terms of measurable outcomes. It highlights the variation in performance across different target groups and social objectives, showing how SIBs can achieve significant impact in reducing recidivism, improving

youth education, enhancing child safety, and increasing employment among the long-term unemployed.

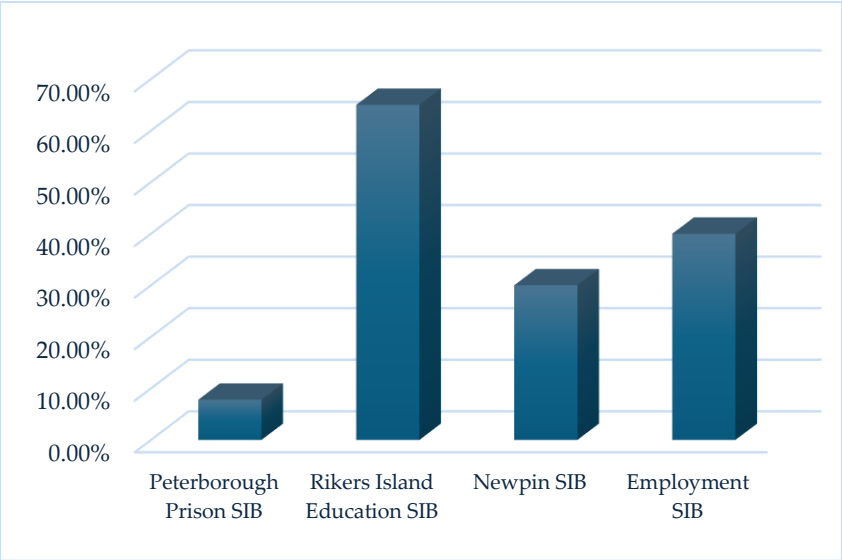


Figure 1. Effectiveness of Social Impact Bonds by Project (%)
Source: authors

This table illustrates the diversity of SIB initiatives, as well as the different indicators used to measure social impact. It can be observed that, although contexts and target groups vary, all projects share the principle of "pay-for-success."

For additional rigor, the standard deviation can be applied to assess the variability of project success:

$$\sigma = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n}} \quad (1)$$

where $x_i$is the success percentage of each project, and $\bar{x} = 35.625\%$.

Calculation:

$$(7.5 - 35.625)^2 = 785.16$$
$$(65 - 35.625)^2 = 864.39$$
$$(30 - 35.625)^2 = 31.64$$
$$(40 - 35.625)^2 = 19.14$$

Sum = 1700.33

$$\sigma = \sqrt{1700.33/4} = \sqrt{425.08} \approx 20.62\%$$

Conclusion: The variability of success across projects is approximately ±20.6%, indicating significant differences in the effectiveness of SIB initiatives across countries and social sectors.

Results from international research also confirm the findings presented in the introduction and methodological framework of this study. Literature reviews and reports from organizations such as the OECD and GIIN indicate that SIBs contribute to improved social outcomes in high-risk areas, while simultaneously providing financial incentives for investors and a tool for more efficient resource allocation for the state (OECD, 2020; GIIN, 2023).

Further analysis shows that challenges remain, including high evaluation costs, contractual complexity, and the need for long-term stakeholder engagement. These challenges, however, also present

opportunities to improve SIB models and adapt them to the local context, which is particularly relevant for developing countries, including Serbia.

3. Perspectives on the development of social bonds in Serbia

Social Impact Bonds (SIBs) have not yet been implemented in Serbia, but international experience demonstrates their potential to improve social programs through a "pay-for-success" mechanism (OECD, 2020; Nicholls, Lawlor, Neitzert, & Goodspeed, 2012). Currently, there is no legislation in Serbia that directly regulates SIBs, nor is there a specific legal framework for this type of financial instrument. However, existing laws, such as the Public Finance Law (*Official Gazette*, Nos. 62/2006, 31/2011, 94/2012, 93/2014, 142/2014, 68/2015, 103/2017, 95/2018, 86/2019, 44/2021, 67/2022, 94/2022) and the Law on Associations (*Official Gazette*, Nos. 51/2009, 99/2011, 44/2018), allow partnerships between the state, private investors, and non-governmental organizations, which can serve as a basis for implementing SIBs (Fraser, Tan, Lagarde, & Mays, 2018).

In Serbia, several areas have been identified where SIBs could have a significant social impact. For example:

- Youth and long-term unemployment: Projects could include training and programs to improve the employability of young people in urban and rural areas, particularly in cities with high unemployment rates such as Novi Sad, Niš, and Kragujevac (OECD, 2020).
- Education and social inclusion: SIBs could support programs for children and youth at risk of dropping out of school, including supplementary education and mentoring projects in primary and secondary schools (GIIN, 2023).
- Support for vulnerable groups: Social Impact Bond projects could target the social inclusion of people with disabilities, the elderly, or Roma communities, through inclusive employment programs and community empowerment initiatives (Fraser et al., 2018).
- Healthcare and prevention: Initiatives could focus on the prevention of chronic diseases or mental health support, especially in areas with limited access to healthcare services.

Although SIBs are not formally regulated by law in Serbia, pilot projects could be developed in cooperation with local NGOs and international partners, using the existing legal frameworks for public-private partnerships. Key success factors include clearly defining social impact indicators, standardizing evaluation methodologies, and educating all stakeholders involved, including investors, the state, and the civil sector (OECD, 2020; Fraser et al., 2018).

In conclusion, Serbia has significant potential for the development of Social Impact Bonds, particularly in areas of high social risk. However, it is necessary to adapt international models to the local context and to develop regulatory and institutional mechanisms that would enable the safe and sustainable application of these innovative instruments.

Conclusion

This paper analyzed the development and perspectives of social impact bonds (SIBs) as an innovative financial instrument aimed at achieving measurable social outcomes. Through a theoretical review, the study examined the basic characteristics of social bonds, their structure, and operating mechanisms, including key actors – investors, service providers, public institutions, and evaluators. International experiences, particularly from the United Kingdom, the United States, Australia, and the Netherlands, were presented to illustrate different approaches to SIB implementation in areas such as reducing recidivism, employing vulnerable groups, education, and healthcare.

By analyzing literature and reports from international organizations, the study identified the key factors for SIB success: clearly defined social impact indicators, standardized evaluation methodologies, and

active involvement of all relevant stakeholders. Analyzing the variability in project outcomes highlighted significant differences in the effectiveness of SIB initiatives depending on context, target group, and local characteristics.

The research employed a combination of qualitative and quantitative methods, including content analysis of relevant literature and reports, comparative analysis of international experiences, and descriptive analysis of the social bond market. This approach provided a comprehensive understanding of SIB potential and opportunities for their application in Serbia, as well as the challenges that may arise during implementation, including regulatory and institutional barriers, evaluation costs, and the need for long-term engagement of all actors.

It is concluded that Serbia has significant potential for the development of social impact bonds, especially in high social risk areas such as youth and long-term unemployment, education, support for vulnerable groups, and health prevention. Successful implementation requires a strategic framework that combines adaptation of international models to the local context, establishment of regulatory and institutional mechanisms, stakeholder education, and collaboration with international partners.

Properly implemented SIBs could become a powerful tool for improving social policy, enhancing social cohesion, and enabling more efficient resource allocation, linking financial innovation with real societal needs and measurable results. At the same time, the development and application of SIBs present a challenge for future research, as it is necessary to further investigate evaluation mechanisms, financing models, and local specificities, as well as a challenge for the community and society as a whole, since their implementation requires active participation of all actors and a readiness to adopt innovative approaches to solving social problems.

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Digital Reputation: A New Currency of Success in Contemporary Society

Digitalna reputacija: nova valuta uspjeha u savremenom društvu

Minel Duvnjak[1]

[1]*International University of Travnik, Travnik, Bosnia and Herzegovina, duvnjakminel455@gmail.com*

Abstract: *In today's hyperconnected world, digital reputation has become one of the most valuable assets of individuals, organizations, and brands. The perception shaped through online presence directly influences professional success, credibility, and social influence. This paper explores the concept of digital reputation as a new form of social and economic currency, examining how it is built, maintained, and sometimes destroyed in the digital environment. The research analyzes the role of social media, online reviews, and algorithms in shaping digital identity and the trust of online communities. Furthermore, the paper highlights the challenges of reputation management in the age of misinformation and the importance of authenticity as a foundation of long-term success. The goal is to emphasize the growing need for digital literacy and strategic communication in creating a positive and sustainable online image.*

Keywords: *Digital reputation, social media, online identity, trust, authenticity, communication strategy.*

Apstrakt: *Digitalna reputacija postala je ključni faktor koji utiče na profesionalni uspjeh, društvenu vjerodostojnost i lični razvoj u digitalnom dobu. Ovaj rad istražuje kako digitalni tragovi, aktivnost na društvenim mrežama i algoritamska vidljivost oblikuju javnu percepciju i povjerenje. Istraživanje analizira metode izgradnje, održavanja i zaštite digitalne reputacije, s fokusom na ponašanje mladih i strategije online prisustva. Kombinacijom pregleda literature i analize anketa, rad identifikuje obrasce digitalnog predstavljanja i procjenjuje utjecaj autentičnosti i online interakcije na percipiranu društvenu vrijednost. Rezultati pokazuju da digitalna reputacija funkcioniše kao nova forma društvene valute, utičući i na karijerne prilike i lični utjecaj u savremenom društvu.*

Ključne riječi: *Digitalna reputacija, društvene mreže, online identitet, povjerenje, autentičnost, komunikacijska strategija.*

Introduction

The digital era has fundamentally transformed the way people communicate, work, and present themselves. Social media platforms, artificial intelligence, and algorithm-driven systems have reshaped not only personal interactions but also professional opportunities and public perception. In this context, the concept of "reputation" is no longer limited to personal experiences and direct social interactions; it now extends to digital footprints that can influence one's credibility, social influence, and career prospects.

The central question guiding this research is: why has digital reputation become a crucial factor for success in contemporary society? This paper aims to explore how young people perceive, construct, and maintain their digital reputation, analyzing both the opportunities and challenges inherent in a highly connected, algorithm-driven world. The hypothesis of this study posits that digital reputation today carries equal or greater weight than traditional reputation in both professional and social contexts. By examining behavioral patterns, online practices, and attitudes toward digital identity, the paper seeks

to provide a comprehensive understanding of the mechanisms through which digital reputation shapes modern success.

The digital era has transformed not only communication patterns but also the very foundations of social trust and credibility. Today, individuals are increasingly judged based on their online presence, often even before personal interactions occur. The influence of algorithms and social media metrics means that visibility can sometimes outweigh traditional indicators of competence, making online behaviors—ranging from shared content to comments—crucial in shaping a person's digital identity and perceived value. Consequently, managing digital reputation has become an essential skill for both personal and professional development. Unlike traditional reputation, digital reputation is dynamic, evolving continuously in response to interactions, engagement, and societal trends. Young adults, in particular, navigate a complex landscape where social validation and professional opportunities are closely intertwined. The growing prominence of influencers and the practice of personal branding illustrate how strategic digital presence can translate into tangible social and economic capital. At the same time, ethical considerations, authenticity, and transparency remain central to sustaining a credible and respected online persona. This research therefore aims to investigate how young people perceive, construct, and safeguard their digital reputation, providing insights into its significance as a new currency of success in contemporary society.

In an era where online presence can shape first impressions even before personal interactions, managing digital reputation has become a strategic necessity. Individuals are increasingly aware that every post, comment, or shared content contributes to their perceived credibility and social value. Moreover, technological innovations such as AI-driven content recommendations and data analytics make digital visibility more measurable and influential than ever before. By understanding these dynamics, this research contributes to a broader discussion on how digital reputation functions as a form of social currency, influencing both personal growth and professional opportunities.

1. The concept of reputation over time

Reputation has long been recognized as one of the most important social assets an individual or organization can possess. In pre-digital societies, reputation was predominantly built through face-to-face interactions, personal achievements, and communal evaluations. Individuals gained recognition and trust through consistent behavior, ethical conduct, and demonstrated competence. Social networks were limited to local communities, and word-of-mouth served as the primary mechanism for reputation dissemination. In this context, social status, integrity, and reliability were the main indicators of a person's credibility, and even minor lapses could have long-lasting consequences for one's personal and professional life. With the emergence of the digital era, the mechanisms through which reputation is constructed have shifted dramatically. The rise of the internet, social media platforms, and digital communication channels has transformed reputation from a localized, community-driven concept into a global, highly visible, and constantly monitored phenomenon. No longer confined to personal interactions, reputation is now influenced by online activity, digital footprints, and the perception formed by both peers and broader audiences. Every post, comment, review, or shared content contributes to an individual's or organization's digital identity. Technological innovations, such as social media algorithms and artificial intelligence, have further amplified the visibility and impact of digital reputation. Metrics like the number of followers, likes, shares, and engagement rates have emerged as tangible indicators of status, influence, and credibility. As a result, traditional markers of reputation—such as personal integrity and professional competence—are increasingly evaluated through digital proxies. This shift has created a new hierarchy of social validation, where visibility and perceived popularity often play a decisive role in shaping public opinion. Digital reputation now functions as a form of social currency. It can open doors to professional opportunities, partnerships, and social influence, but it also exposes individuals to scrutiny, reputational risks, and the potential for rapid damage in the event of negative exposure. The transition from traditional to digital reputation

underscores the need for strategic online presence management and a deeper understanding of how digital behaviors are interpreted by others.

2. Digital reputation – a new social currency

In the contemporary digital landscape, reputation has transcended its traditional meaning to become a form of social currency. The metaphor of "currency of success" emphasizes that trust, credibility, and influence have acquired measurable value in both professional and social contexts. Just as money facilitates transactions in the economic sphere, digital reputation enables individuals and organizations to access opportunities, build networks, and gain recognition. The more positive and visible one's digital presence is, the greater the potential "capital" that can be leveraged for personal or professional advancement. Digital reputation profoundly influences employment prospects. Recruiters and employers increasingly evaluate candidates not only based on their qualifications but also by scrutinizing their online profiles, social media activity, and professional digital footprint. A strong digital reputation can enhance employability, while negative online behavior or poorly managed profiles can limit opportunities, regardless of offline achievements. Similarly, social relationships are shaped by perceived digital credibility; individuals are more likely to trust, engage, and collaborate with those who maintain a consistent and positive online presence.

Beyond professional implications, digital reputation impacts self-confidence and societal perception. A person's online visibility and the feedback they receive contribute to their self-image, social influence, and overall standing within virtual and real-world communities. In this context, the role of influencers and personal branding becomes critical. Influencers demonstrate how curated digital identities can translate into social capital, business opportunities, and authority within specific niches. Personal branding strategies—such as content creation, audience engagement, and consistent messaging—allow individuals to actively manage their reputation and convert digital visibility into tangible advantages. Ultimately, digital reputation functions as a measurable form of social currency, shaping interactions, career trajectories, and personal identity. Understanding its dynamics is essential for navigating the modern, digitally connected society and for leveraging online presence in ways that maximize credibility, trust, and influence.

3. Mechanisms of building digital reputation

Digital reputation is not created passively; it is the result of deliberate actions, interactions, and the broader dynamics of online platforms. Several key factors influence the construction of one's digital reputation. First, the content individuals publish—posts, photos, videos, and articles—serves as the primary reflection of their values, interests, and expertise. Second, interactions such as comments, shares, and likes contribute to social validation, signaling approval and engagement from others. Third, the network of connections plays a crucial role: the credibility and influence of peers can enhance or diminish the perceived reputation of an individual within digital communities. Together, these elements create a complex web of social cues that inform how others perceive a person online. Algorithms play a central role in determining visibility and shaping digital reputation. Social media platforms, search engines, and other online services rely on algorithmic mechanisms to decide which content is promoted and which remains hidden. Metrics such as engagement rates, follower counts, and interaction histories guide these decisions, effectively "rewarding" certain users with greater exposure while limiting reach for others. Consequently, mastering the dynamics of platform algorithms becomes an essential skill for those seeking to cultivate a positive digital reputation. Despite its potential benefits, the creation of digital reputation carries inherent risks. Many individuals may present an exaggerated or false image, deliberately crafting identities that do not reflect reality. Manipulation, misinformation, and the phenomenon known as "cancel culture" illustrate the fragility and volatility of online reputations. A single misstep or controversy can rapidly diminish trust and influence, often with long-

lasting consequences. Therefore, individuals must balance strategic self-presentation with authenticity, ethical behavior, and awareness of the broader social implications of their digital actions.

4. Results of the research

The research was conducted through an online survey, which was made accessible to adults aged 16–50. The aim was to explore their perceptions, behaviors, and attitudes towards digital reputation. A total of over 150 respondents participated in the survey. The questions focused on the awareness, management, and perceived importance of digital reputation in both social and professional contexts.

1. Do you regularly think about the impression you leave on social media?

Approximately 72% of respondents indicated that they regularly consider the impression they make online. This highlights a high level of self-awareness among young people regarding their digital presence and suggests that online behavior is increasingly intentional and strategic.

2. Would you delete a post if it could harm your reputation?

Around 65% of participants stated that they would remove a post that might negatively impact their reputation. This result underscores the proactive measures taken by individuals to protect and maintain their digital identity.

3. Do you believe that digital reputation can help in employment?

A significant majority, 81% of respondents, agreed that a positive digital reputation can enhance career opportunities. This finding supports the idea that online presence is now an integral component of employability and professional growth.

4. Do you trust someone's online image more than their personal impression in real life?

Only 28% of respondents reported trusting someone's online image more than in-person interactions, while 72% valued direct personal impressions higher. This indicates that while digital reputation is influential, face-to-face interactions still carry considerable weight in trust formation.

5. How important is authenticity in digital self-presentation?

About 78% of participants considered authenticity to be very important in online self-presentation. Respondents emphasized that genuine behavior and transparency are critical in building trust and long-term credibility.

Overall, the results reveal that young adults are highly conscious of their digital reputation and actively manage their online presence. Digital reputation is perceived as an important factor in career prospects, social relationships, and self-image, but authenticity and real-life interactions continue to play a decisive role.

Key Insight: Digital reputation functions as both a personal and professional asset, and young individuals are increasingly treating online presence strategically, balancing visibility with authenticity.

5. Digital reputation and ethics

The expansion of digital presence has brought ethical considerations to the forefront of reputation management. One of the central issues is the boundary between authenticity and misrepresentation. While individuals strive to present themselves positively online, there is a fine line between showcasing one's strengths and creating a false or exaggerated image. Deliberate misrepresentation can lead to short-term social or professional gains, but it carries significant long-term risks, including loss of trust, credibility, and opportunities. Maintaining authenticity is therefore not only a moral choice but also a strategic necessity for sustainable digital reputation. Responsibility for online content—posts, comments, shares, and other interactions—cannot be overstated. Each digital action contributes to an

individual's or organization's reputation, and careless or harmful behavior can result in reputational damage. Ethical digital behavior involves critical reflection on the potential consequences of publishing content, awareness of cultural and social sensitivities, and respect for the rights and dignity of others. Media literacy plays a crucial role in navigating the ethical landscape of digital reputation. Users must develop the ability to discern between authentic content and digitally constructed narratives, understanding how algorithms and platform design can amplify misinformation. By cultivating critical thinking and responsible engagement, individuals can protect both their own reputation and the integrity of the online communities they participate in.

Conclusion

This paper has explored the evolving concept of reputation in the digital era, examining both theoretical frameworks and empirical findings. Historically, reputation was rooted in personal integrity, social interactions, and professional achievements. The digital transformation has shifted these dynamics, placing online presence, visibility, and engagement at the center of social and professional evaluation. Social media, algorithms, and digital networks have created new mechanisms for building and measuring reputation, while the rise of influencers and personal branding illustrates the strategic value of curated digital identities. The survey results further highlight that young adults are highly aware of their digital reputation and actively manage it. Most respondents recognize the importance of authenticity, the impact of online behavior on professional opportunities, and the role of strategic self-presentation in shaping social perception. The findings support the hypothesis that digital reputation today carries equal or greater weight than traditional offline reputation in determining social and professional success. In conclusion, managing digital reputation is no longer optional—it is a central aspect of navigating modern society. Individuals must balance authenticity, ethical responsibility, and strategic engagement to protect and enhance their online presence.

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The Role of Organizational Benefits in Shaping Employee Motivation and Satisfaction

Uloga organizacionih benefita u oblikovanju motivacije i zadovoljstva zaposlenih

Snežana Mirković[1], Verica Gluvakov[2], Sanja Stanisavljev[3], Sanja Stankov[4] , Mila Kavalić[5]

[1]*BB Trade doo, Zrenjanin, Serbia, snezana.mirkovic@tfzr.rs*
[2]*University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia, verica.gluvakov@uns.ac.rs*
[3]*University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia, sanja.stanisavljev@uns.ac.rs*
[4]*College of Academic Studies „Dositej", Belgrade, Serbia, sssanja89@gmail.com*
[5]*University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia, mila.kavalic@uns.ac.rs*

Abstract: *The aim of this paper is to examine how organizational benefits affect the motivation and satisfaction of employees, as well as to identify which benefits are the most important for employees. By analyzing survey results collected from 130 middle management employees in the trading company BB Trade doo, it was confirmed that not all benefits have the same importance and impact on employee satisfaction. The results of the research showed that the most important benefits for employees are flexible work arrangements, additional time off and additional days off, education and training for the development of employee knowledge and benefit packages related to the health of employees and their families, as well as cash-based bonuses of different types. The obtained results confirm that organizations should invest in benefits that enable the well-being of employees and create strategies that integrate economic and psychological aspects, in order to achieve greater satisfaction and long-term motivation of employees.*
Keywords: *Benefits, satisfaction, motivation, flexible work arrangements.*

Apstrakt: *Cilj ovog rada je da ispita na koji način organizacioni benefiti utiču na motivaciju i zadovoljstvo zaposlenih, kao i da identifikuje koji benefiti su za zaposlene najvažniji. Analizom rezultata ankete, koja obuhvata odgovore 130 zaposlenih u srednjem menadžmentu u trgovačkoj kompaniji BB Trade doo, potvrđeno je da nemaju svi benefiti isti značaj i uticaj na zadovoljstvo zaposlenih. Rezultati istraživanja su pokazali da su najznačajniji benefiti za zaposlene fleksibilni aranžmani rada, dodatan odmor i dodatni slobodni dani, edukacija i obuka za razvoj znanja zaposlenih i paketi beneficija koji se odnose na zdravlje zaposlenih i njihovih porodica, kao i novčani bonusi po osnovu različitih osnova. Dobijeni rezultati potvrđuju da organizacije treba da ulažu u benefite koje omogućavaju blagostanje zaposlenih i da kreiraju strategije koje integrišu ekonomske i psihološke aspekte, kako bi postigle veće zadovoljstvo i dugoročnu motivaciju zaposlenih.*
Ključne reči: *Benefiti, zadovoljstvo, motivacija, fleksibilni aranžmani rada.*

Introduction

Organizations have recognized the importance of benefits and their impact on satisfaction, motivation, loyalty and commitment of employees, as a key instrument of human resource management. There is an increasing emphasis on broader concepts of organizational benefits, which include various employee support programs, such as flexible working hours, working from home, the possibility of professional development, work-life balance and extended vacation time. It becomes a key question which benefits organizations can provide, which are meaningful to employees and affect their satisfaction and motivation. Some research suggests that flexible work arrangements and well-being initiatives should be prioritized (Orkisz & Beck-Krala, 2025).

Organizations must focus on the needs of their employees in order to achieve success (Barbu et al., 2025). Increasing employee benefits is key to improving employee engagement levels (Klein & Ben-Hador, 2025). Benefits strengthen the bond between employees and the company, which is then reflected in responsibility and quality of service to customers (Lee, 2025). It is necessary for organizations to communicate transparently when introducing certain benefits and for employees to perceive the benefits as fair, especially if due to certain job characteristics the benefits cannot apply to all employees (Laundon, 2019).

Employee benefits are one of the key points in human resources strategies. The paper discusses the perception and ranking of benefits among employees, in order to identify those benefits that contribute the most to their satisfaction.

1. Theoretical background

Benefits are very important for improving the level of employee engagement and organizations should work to improve them (Nikisi et al., 2024). It is very important to choose appropriate benefits for employees that will be meaningful and useful to them. In addition to practices and benefits that are introduced to improve employee performance, it is necessary to take care of employee well-being and a positive working relationship, which can also bring mutual benefit to both the organization and the employee (Guest, 2017). Organizations that provide their employees with a balance between private life and work and have organized and accessible programs in this area, affect the reduction of employee stress (Zheng et al., 2015). Given that the concept of work-life balance has shifted towards work-life integration, the role of flexible arrangements is significant (Kumar et al., 2023). For Millennials and Generation Z, working time flexibility, vacation and working from home are extremely important, in order to establish a work-life balance (Waworuntu et al., 2022).

Education and training of employees appear as significant benefits, which influence the commitment of employees (Jaworski et al., 2018). Training and development programs increase the skills, abilities and intellectuality of employees (Kumar & Siddika, 2017). Training indirectly affects the increase of economic growth by improving human capital through the education of individuals and teams (Janev et al., 2018). Also, training and engagement significantly affect employee performance (Sendawula et al., 2018). Through skill development and increased satisfaction, employee retention is also affected, which is very important for organizations (Kalyanamitra et al., 2020). There is a direct link between compensation, benefits, training and development, motivation and empowerment (Leonova et al., 2021). Therefore, continuous education and training of employees is a very important and competitive strategy in the market, in addition to being a significant benefit for employees (Madavi et al., 2022).

Flexible working arrangements have positive impacts on employees, including working from home, which positively affects job satisfaction (Wheatley, 2016). In those organizations that implemented flexible work arrangements, greater employee commitment occurred (Sajjad et al., 2024). On the other hand, it is necessary to regulate the frequency and structure of working from home, in order to maintain clarity and relationships with colleagues (Ahmad, 2025). Organizations also have an interest in working from home, because they influence the reduction of business costs (Nguyen et al., 2025). Research indicates that one in every 5 jobs can be done from home, and in low-income countries, this ratio is one in every 26 jobs (Garrote et al., 2021). Therefore, organizations have an interest in improving training and capacities in the field of information technology, in order to facilitate and promote working from home as a work model (Anakpo et al., 2023).

Flexible working hours have many benefits in improving employee performance, as employees have a greater level of control over their commute and time, which also improves organizational behavior (Gan et al., 2024). Flexible work strategies can help employees with high stress to better distance themselves from work and reduce the need for recovery (Edvinsson et al., 2025). Therefore, flexibility in working hours leads to greater job satisfaction and improved quality of life among employees (Abid & Barech, 2017). Flexible work arrangements are significant in reducing employee turnover, absenteeism and

productivity (Berkery et al., 2017) and have an impact on physical health (Shifrin & Michel, 2021). A distinction should be made between flexible work arrangements that are established through formal and informal means and have different impacts on employees (De Menezes & Kelliher, 2017). Also, research indicates that those who work flexibly generate more work for others and have less chance of promotion (Chung, 2020). The use of flexible arrangements is highly negatively related to work engagement (Timms et al., 2015).

Organizations that decide to provide their employees with more vacation days than the legal minimum have the effect of mitigating burnout at work (Yildirim & Aydemir-Karadag, 2022). Employees have a need for rest, protection of health and safety at work (Panomarioviene & Wrocławska, 2021). More vacation days and leave policies motivate employees to complete their work tasks efficiently and effectively, thus affecting work-life balance (Orogbu et al., 2015).

Another benefit, which is very important for employees, is an organized meal within the organization. Research has shown that colleagues who eat together are more productive at work, demonstrating the social and economic benefits of shared employee meals (O'Neil & Fullilove, 2025). Positive health and well-being of the employee can be ensured in the workplace by providing an organized meal by the employer (Rahman, 2017). Lunch breaks increase employee productivity (DiPilato, 2016), as well as health, efficiency and reduced stress at work (Hakro et al., 2021). Organized lunch not only provides nutritional benefits but also increases social interactions, strengthens workplace relationships, and positively affects organizational culture (Levison, 2022) and well-being at work (Corvo et al., 2020).

In addition to intangible benefits, organizations also use material benefits to increase employee motivation and satisfaction. Material benefits that include different types of bonuses and monetary rewards have an impact on the commitment and productivity of employees (Koo et al., 2019). Bonuses have a long-term impact on employee motivation (Van der Stede et al., 2020). In addition to providing material satisfaction to the employee, bonuses also provide positive feedback to employees in the form of recognition for their work (Law, 2016). Most employees respond to bonuses with increased productivity (Reddy, 2020).

2. Methodology

2.1. Research problem

Most companies invest a lot of money in employee benefits. However, it is equally important whether the benefits provided by the company are important for employees and whether they use them. Through benefits, companies try to increase employee loyalty, motivation and satisfaction. The research problem is reflected in the need to determine how employees rank different benefits and to what extent they contribute to their satisfaction. If companies do not have the right information, they may spend funds on benefits, which will not be significant for employees and whose expected effect will be absent.

2.2. Research subject

The subject of the research is the importance and role of various material and intangible benefits on employee motivation and satisfaction.

2.3. Research goal

The main goal of the research is to determine which benefits affect the satisfaction and motivation of employees and to rank them according to their importance for employees. In this way, an effort is made to identify which forms of benefits have the greatest impact on employee satisfaction and loyalty. A special goal is to identify the relationship between flexible forms of work and employees' perception of the work-life balance, as well as the importance of education and training, in order to better understand the role of material and intangible incentives in human resource management.

2.4. Research hypotheses

The research is based on a main hypothesis, from which several auxiliary hypotheses are derived, which will be examined:

H_0: Not all benefits in the company have the same importance and impact on employee motivation and satisfaction.

H_1: Intangible benefits that include flexible work arrangements are significant for employees.

H_2: Intangible benefits that are closely related to the development of employees' competencies and knowledge have an impact on employee motivation.

H_3: Benefits that contribute to the work-life balance affect the well-being of employees.

H_4: Bonuses are the most significant material benefit for employees.

2.5. Research sample

The research was conducted in June 2024 on a sample of 130 respondents, who are employed in a trading company in middle management positions. Out of a total of 130 respondents, 31% are male and 69% are female. The youngest employee included in the survey is 22 years old, and the oldest respondent is 63 years old.

2.6. Research methods, techniques and instruments

An anonymous survey was used to collect data, and appropriate quantitative and qualitative statistical methods were used to process and interpret the results, with the aim of testing the set hypotheses. The data were analyzed using the methods of descriptive statistics, while the percentage distribution of respondents' answers was used to rank the benefits according to importance. The questions in the survey are divided into 2 dimensions. The first part of the survey refers to the evaluation of the existing benefits in the company based on the criteria of the most significant benefit for the employee. The second part of the survey includes open-ended questions related to the benefits that the company should provide, which should be significant for employees and contribute to their satisfaction.

3. Research results

In this section of the paper, the results of research related to the importance and impact of benefits for employees in middle management will be presented.

Figure 1 shows the most significant existing benefits for employees in middle management based on their answers from the survey. Employees were asked to choose one of the existing benefits in the company, which is the most important for them.

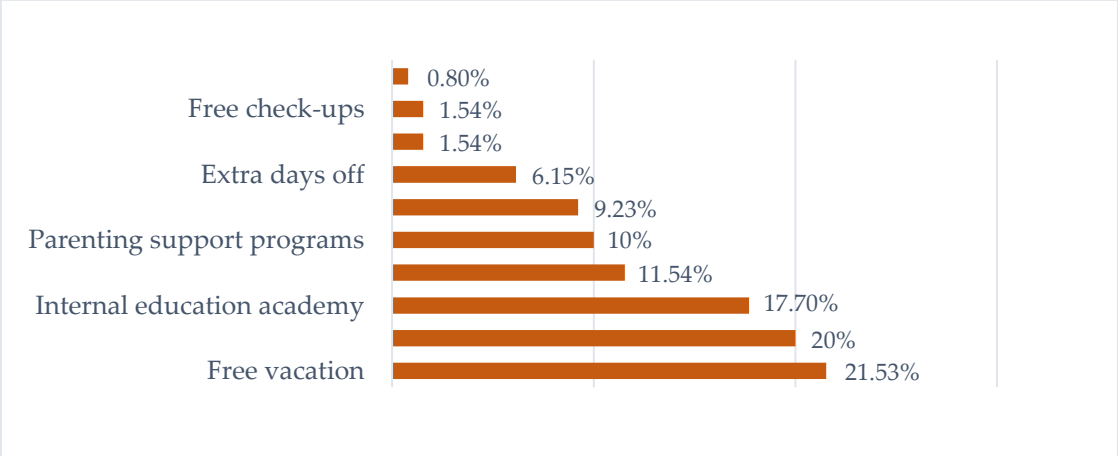


Figure 1. Perception of the importance of existing benefits for employees

The most important benefit for employees in middle management is a free family vacation lasting five days, which indicates the importance of the work-life balance and the need for rest. Second ranked is the material benefit related to performance-based bonuses, which in this company amount to 5%-40% of net earnings and are realized on a quarterly and annual basis. The corporate academy, where trainings and educations are held, is extremely important for employees and is recognized in the first three benefits. Private health insurance in fourth place indicates the importance of health and well-being of employees. That family benefits are of great importance for employees is also indicated by parenting support programs, within which funds and gifts are allocated for newborn babies. Jubilee awards are recognized as an important material benefit and are paid in this company for 10, 20 and 30 years of service. Loyalty is rewarded because it is extremely important for organizations. Additional free days, such as days for employees whose children start first grade, are important for 6.15% of employees. Intangible benefits include New Year's packages for employees' children, free examinations and fruit snacks.

In addition to these benefits, the company also provides other benefits for employees in middle management, which were not listed among the most important for employees: social entertainment activities - team building, company celebrations, sports activities, free swimming pool, theater, gym and fitpass, administrative bans and solidarity fund.

The results of the survey in Figure 2 show which benefits employees would like to have available to them.

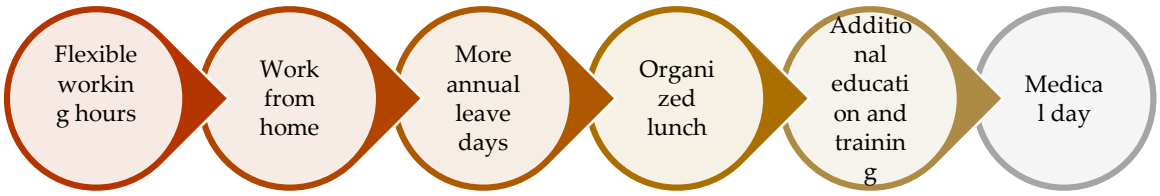


Figure 2. Additional benefits that are important for employees

The results of the research show that benefits that contribute to the work-life balance are extremely important to employees. The most important benefits for employees are flexible working hours and working from home. This is followed by a greater number of annual vacation days, which is important for employees' rest and health, while the possibility of additional education and training is associated with the development and long-term satisfaction of employees. The organized lunch and the "medical day", i.e. a day off for health care purposes, proved to be less significant, but essential benefits for employees.

The research results confirm the basic hypothesis H_0: *Not all benefits in the company have the same importance and influence on the motivation and satisfaction of employees.* Auxiliary hypotheses H_1, H_2, *H3, H4* were also confirmed, which indicate that flexible work arrangements, benefits focused on the development of employees' competencies and knowledge, as well as benefits that contribute to the work-life balance, together with bonuses, have an impact and importance for employees.

4. Discussion

The importance of benefits for employees and organizations is shown by the fact that they have been researched in applied psychology since the 1900s (Bell et al., 2017). The results of the research confirm that it is very important for employees in modern dynamic business to achieve a balance between private and business life, and that flexible work arrangements and additional free days and vacation days enable them to do so. This form of flexibility gained particular importance after the global

pandemic of COVID-19, when many organizations realized that the productivity of employees does not depend on their physical presence in the office. Hybrid work models offer benefits for both employees and organizations, it is only necessary to take into account the possibility of using them for the majority of employees when introducing flexible work arrangements. Frontline employees are often unable to use flexible working hours and work from home due to the nature of their work, and reduced working hours harm them due to loss of income and benefits (Kossek & Lautsch, 2018).

Working from home has exceptional advantages due to the organization of employees' lives and time savings, but it also brings with it certain disadvantages, such as balancing roles amid increased flexibility and blurred boundaries between work and private life (Ahmad, 2025), and it can also affect well-being by exacerbating the conflict between family and work (Dong et al., 2025). Findings also indicate that working from home can negatively affect collaboration and reduce innovation in the long run (Gibbs et al., 2024).

The opportunity for education contributes to the development of employees and gives them the opportunity for personal progress and advancement in the company, and it is extremely important for the company because it increases the satisfaction and knowledge of employees. It is very important that employees acquire the knowledge they have received through training and education and that they are used in the workplace and after training (Hughes et al., 2018). In addition to choosing the appropriate training, research shows that a small number of hours of training, as well as more than 166 hours of training have a negative or no effect on employee performance (Flegl et al., 2022). Such initiatives should be tailored to employees and contribute to strengthening the employee's sense of competence and self-confidence on the one hand and increasing the value and competitiveness of the organization on the other.

Additional days off, as well as additional days of annual leave based on different legal bases, which companies can apply, stand out as significant intangible benefits. This benefit is based on the previous benefits, highlighting the importance of rest for employees, so that they can return more dedicated and motivated to work tasks.

In addition to intangible benefits, material benefits also play a very important role, from bonuses based on various bases to jubilee and other awards. Material benefits require a different approach compared to intangible benefits and are used in a different context to motivate employees. They are very important for employees in the operational level compared to employees in higher positions, due to the amount of salary, which is significantly different.

These findings point to the need for organizations to adapt their benefit policies to employee expectations, in order to improve their satisfaction, engagement and long-term retention in the company. It is recommended that employers implement flexible work models and professional development programs to a greater extent, because these benefits have the greatest impact on employee satisfaction and motivation.

Conclusion

By combining various forms of benefits, of which work from home and flexible working hours, investment in education and additional vacations stand out, organizations create a strong framework that supports the overall well-being of employees and enables them to balance work and private life. When introducing benefits for employees, it is necessary to recognize the needs of employees and to enable the use of those benefits that are important to them. Such benefits encourage employees to be more productive, innovative, more engaged and loyal to the company. In this way, organizational benefits are not a cost, but a strategic investment. Organizations must take care of transparency, perception of fairness and availability of benefits for all or most employees, so that they can contribute to improving efficiency and commitment and be useful for employees. In future research, it is necessary to examine in more detail the differences in the perception of benefits among generational groups and

sectors of activity, including other differences among employees, in order to develop optimal benefit models.

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Smart AI-Based Energy Optimization: A Self-Learning System for Economical Energy Consumption

Pametna energetska optimizacija temeljena na AI: sustav koji sam sebe uči za ekonomičnu potrošnju energije

Selena Kurtić[1], Mahir Zajmović[2]

[1]IPI Academy, Tuzla, Bosnia and Herzegovina, selena.kurtic@yahoo.com
[2]University of Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, mahir.zajmovic@mef.edu.rs

Abstract: *As global concerns about climate change and energy efficiency intensify, countries are exploring smarter ways to manage and optimize energy consumption. Traditional energy systems often rely on fixed rules, outdated infrastructure, and reactive management strategies. This paper builds on previous research analyzing energy data from Bosnia and Herzegovina, with a particular focus on identifying inefficiencies and opportunities for smart system interventions. Using data provided by FERK—including historical load trends, electricity losses, smart meter penetration, and customer segmentation—this research models a smart energy optimization system suitable for local application. Ultimately, the paper demonstrates that self-learning AI models offer a viable, scalable path toward achieving economic energy consumption and sustainable development goals in Bosnia and Herzegovina and similar contexts.*
Keywords: *Energy efficiency, energy consumption optimization, amart system, AI.*

Apstrakt: *Kako se globalna zabrinutost zbog klimatskih promjena i energetske učinkovitosti pojačava, zemlje istražuju pametnije načine upravljanja i optimizacije potrošnje energije. Tradicionalni energetski sustavi često se oslanjaju na fiksna pravila, zastarjelu infrastrukturu i reaktivne strategije upravljanja. Ovaj rad se nadovezuje na ranija istraživanja koja analiziraju energetske podatke iz Bosne i Hercegovine, s posebnim naglaskom na identificiranje neučinkovitosti i mogućnosti za intervencije pametnih sustava. Koristeći podatke koje pruža FERK - uključujući povijesne trendove opterećenja, gubitke električne energije, penetraciju pametnih brojila i segmentaciju kupaca - ovo istraživanje modelira pametni sustav optimizacije energije prikladan za lokalnu primjenu. U konačnici, rad pokazuje da samoučeći modeli umjetne inteligencije nude održiv, skalabilan put prema postizanju ekonomske potrošnje energije i ciljeva održivog razvoja u Bosni i Hercegovini i sličnim kontekstima.*
Ključne reči: *Energetske učinkovitost, optimizacije potrošnje energije, pametni sustav, AI.*

Introduction

The integration of artificial intelligence (AI) into energy management systems has gained increasing momentum in the last decade. With the proliferation of smart grids, renewable energy sources and advanced metering infrastructure, the energy sector is undergoing a digital transformation that requires adaptable, scalable and intelligent solutions (Escobar et al., 2021).

1. Smart energy management systems (SEMS)

Smart Energy Management Systems (SEMS) are platforms designed to monitor, analyze and control energy consumption in real time. These systems typically incorporate data from smart meters, environmental sensors and grid health indicators to optimize energy flow. SEMS aim to reduce operational costs, improve energy efficiency and contribute to decarbonisation (Mohsenian-Rad & Leon-Garcia, 2010).

Many SEMS today rely on rule-based or model-based approaches. Although effective, these methods often lack the flexibility and autonomy needed for dynamic environments with high uncertainty, such as those involving intermittent renewable energy sources or fluctuating market prices (Zhao & Magoulès, 2012).

1.1. The role of artificial intelligence in SEMS

Artificial intelligence, specifically machine learning (ML) and deep learning (DL), enables systems to learn patterns from data without explicit programming. In the energy domain, artificial intelligence techniques have been applied to:

- Load forecasting (eg LSTM, XGBoost, Gradient Boosting) to predict energy demand with high temporal resolution (Ryu, Noh & Kim, 2017).
- Forecasting of renewable energy sources, using historical meteorological data to estimate the production of solar and wind power plants (Voyant et al., 2017).
- Demand response systems, where reinforcement learning can autonomously schedule device usage based on price signals (Wei et al., 2017).
- Recognizing energy consumption patterns, which allows utility companies to detect anomalies, theft or inefficiencies (Deb et al., 2016).

These applications demonstrate the versatility and potential of artificial intelligence to make energy systems more efficient, resilient and user-centric.

1.2. Self-learning systems in energy

Self-learning systems differ from traditional AI in their ability to continuously adapt. These systems can be retrained based on new data, user behavior, or changes in the environment - without human intervention. Such approaches are particularly relevant in smart grids, where real-time conditions vary significantly (Heidarinejad et al., 2020).

Examples include autonomous energy controllers in buildings that optimize HVAC system usage through feedback loops or dynamic pricing mechanisms that adjust tariffs based on predictive demand models (Hao et al., 2020).

1.3. Challenges in AI-driven energy systems

Despite the promise of AI, several challenges remain:

- Data scarcity and fragmentation, especially in developing regions.
- Integration complexity, especially with legacy infrastructure.
- Computational costs and latency when deploying real-time models on edge devices.
- Regulatory and privacy concerns, which limit data sharing and user profiling (Ma et al., 2017).

However, ongoing research seeks to address these limitations by developing federated learning techniques, edge-based AI hardware, and privacy-preserving algorithms.

2. Research problem and objectives

2.1. Research problem

The growing complexity of energy systems – driven by the integration of renewable energy sources, decentralized generation, dynamic pricing and changing consumption behavior – requires intelligent, adaptive and scalable management mechanisms. While traditional energy management strategies rely on static rules or deterministic models, these approaches often fail in unstable or data-limited

environments such as Bosnia and Herzegovina, where infrastructural and regulatory constraints persist (Gungor et al., 2013).

The central problem addressed by this research is:

How can artificial intelligence, in particular self-learning systems, be used to economically and autonomously optimize energy consumption in a localized context in real time?

Current smart grid implementations in the Federation of BiH have introduced smart metering and digitalized infrastructure, but lack advanced optimization layers capable of proactive decision-making. There is a gap between data collection (e.g., smart meter readings) and intelligent action (e.g., load shifting, predictive scheduling), which this study aims to bridge by developing and validating an AI-based self-learning framework.

2.1. Research objectives

The main objective of this paper is to design and propose a prototype of a self-learning energy management system capable of optimizing energy consumption in response to real-time data, price fluctuations, and user demand profiles.

3. Prototype design

3.1. Conceptual overview

The prototype design focuses on simulating a self-learning energy optimization system that integrates IoT-based monitoring, AI-based prediction, and automated control mechanisms. Instead of relying on physical sensors and hardware, the system uses historical consumption and tariff data as a proxy for real-time sensor input. This approach allows for testing and validating the system's predictive and optimization capabilities in a controlled environment.

The conceptual prototype is divided into three layers:

- Data Simulation Layer – emulates sensor readings using historical data sets.
- Prediction and Optimization Layer – applies AI models to predict consumption and determine optimal operating schedules.
- Interface Layer – provides a user interface for visualizing predictions, optimization results, and simulated device controls.

The prototype design is based on a simulated hardware architecture that mimics the functionality of a self-learning energy optimization system in the real world. At its core, a microcontroller unit (MCU), such as an Arduino or ESP32, acts as a processing hub. It collects real-time data from current and voltage sensors connected to household appliances. A smart energy meter module provides aggregated consumption data, while Wi-Fi connectivity ensures seamless data transfer to a cloud server for storage and further processing. The server houses artificial intelligence (AI) models responsible for predicting energy demand and suggesting optimal usage patterns. This layered design allows for modular testing and component replacement without the need to build a physical prototype.

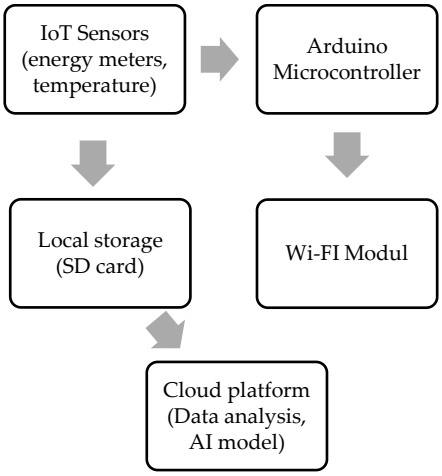


Figure 1. Simulated hardware architecture for smart energy optimization prototype
Source: authors

3.2. Data simulation layer

Instead of physical IoT devices, the prototype uses structured datasets from the Energy Regulatory Authority (FERK) to replicate sensor outputs. Each dataset record corresponds to:

- Household electricity consumption.
- Time-of-use tariffs (peak and off-peak loads).
- Forecasted demand trends.

The dataset acts as the primary input stream, simulating the continuous data stream that would otherwise be collected from smart meters or embedded IoT sensors.

In terms of software, a simulation-based dashboard has been developed to visualize and test the system's operation. The interface allows users to monitor household energy consumption in real time, analyze historical data trends, and view AI-based future demand forecasts.

Furthermore, the dashboard includes control functionalities that allow for simulated activation and deactivation of high-energy-consuming devices (e.g. water heaters) based on AI recommendations and time-of-use tariffs. This provides a user environment for evaluating system performance in different consumption scenarios, without the need to deploy actual physical devices. The simulated environment therefore serves as a proof of concept for testing predictive models and validating energy saving strategies.

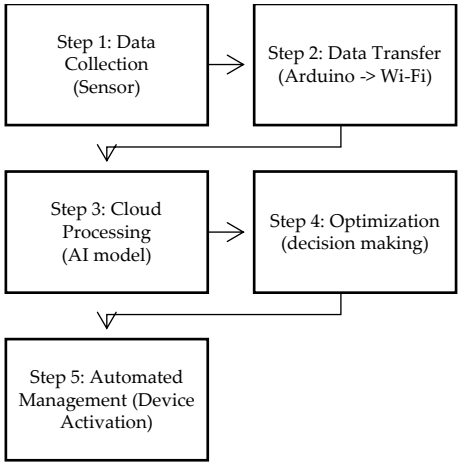


Figure 2. Simulation of a working process prototype
Source: authors

3.3. Prediction and optimization layer

For demonstration purposes, a regression-based model is used to predict hourly consumption, while a reinforcement learning model simulates decisions to turn on or off high-energy devices (e.g., water heaters).

Prediction functionality: Estimates energy consumption for the next 24 hours.

Optimization functionality: Identifies cost-effective schedules based on tariff periods.

The logic can be summarized as:

$$Optimized\ decision = \arg\min_{t} C_t . E_t \quad (1)$$

where C_t represents the cost of the tariff at time t_1 and E_t the expected consumption at that time.

4. Results and discussion

The results present an analysis of household electricity consumption data collected over a one-year period, for the year 2023. The dataset contains monthly values of electricity consumption during the periods of cheap and expensive tariffs, together with calculated costs, net compensation and final bill amounts. The aim of this analysis is to provide insight into consumption patterns, highlight the impact of tariff differences and assess the financial implications for end-users. The simulations were implemented in Python using the PyCharm environment, which enabled systematic data analysis and visualization of the results.

4.1. Actual household consumption patterns

The dataset covers monthly electricity consumption in kilowatt-hours (kWh) by households for the year 2023. It is divided into two categories: cheap tariff (off-peak hours) and expensive tariff (peak hours). For each month, the total cost is derived using the applicable tariff rates. A net billing fee is applied to take into account distribution and regulation costs, resulting in the final bill that households have to pay. This calculation follows the formula:

$$Bill\ Amount\ = Electricity + Network \quad (2)$$

Charge Including the net billing fee is crucial as it ensures that cost estimates accurately reflect the actual expenditure of households, thus providing more realistic and policy-relevant insights. The dataset consists of household consumption divided into cheap hours (off-peak hours) and expensive hours (peak hours), with the corresponding tariff values. The cheap tariff was constant at 0.0415 KM/kWh, while the expensive tariff was 0.0829 KM/kWh. Consumption patterns fluctuated over the months, reflecting seasonal changes in energy demand, such as heating in winter or cooling in summer.

Table 8. Monthly energy costs according to TOU (including net billing fee)

Month	Cheap tariff kWh	Expensive tariff kWh	Price of cheap tariff	Price of expensive tariff	Amount of electricity (BAM)	Network fee (BAM)	Total bill (BAM)
I	261	129	0.0415	0.0829	21.5256	21.5256	43.0512
II	262	131	0.0415	0.0829	21.7329	21.7329	43.4658
III	217	136	0.0415	0.0829	20.2799	20.2799	40.5598
IV	240	150	0.0415	0.0829	22.395	22.395	44.79
V	207	158	0.0415	0.0829	21.6887	21.6887	43.3774
VI	261	142	0.0415	0.0829	22.6033	22.6033	45.2066
VII	237	129	0.0415	0.0829	20.5296	20.5296	41.0592

VIII	171	147	0.0415	0.0829	19.2828	19.2828	38.5656
IX	210	130	0.0415	0.0829	19.492	19.492	38.984
X	219	118	0.0415	0.0829	18.8707	18.8707	37.7414
XI	250	147	0.0415	0.0829	22.5613	22.5613	45.1226
XII	243	146	0.0415	0.0829	22.1879	22.1879	44.3758

Source: authors

Table 1 shows the monthly consumption in kilowatt-hours (kWh), the corresponding tariff multipliers, the calculated sum of tariffs, the net fee and the final bill. It is important to note that the net fee is equal to the sum of tariffs, which means that the final bill is equal to twice the sum of tariffs.

4.2. Predicting potential savings based on artificial intelligence

To better understand the data, visualizations were created using Python in PyCharm. The first visualization (Figure 3) shows the monthly electricity consumption divided between periods of cheap and expensive tariffs. This figure clearly highlights the seasonal variations in electricity demand, with peak consumption during the winter months, mainly due to increased heating needs.

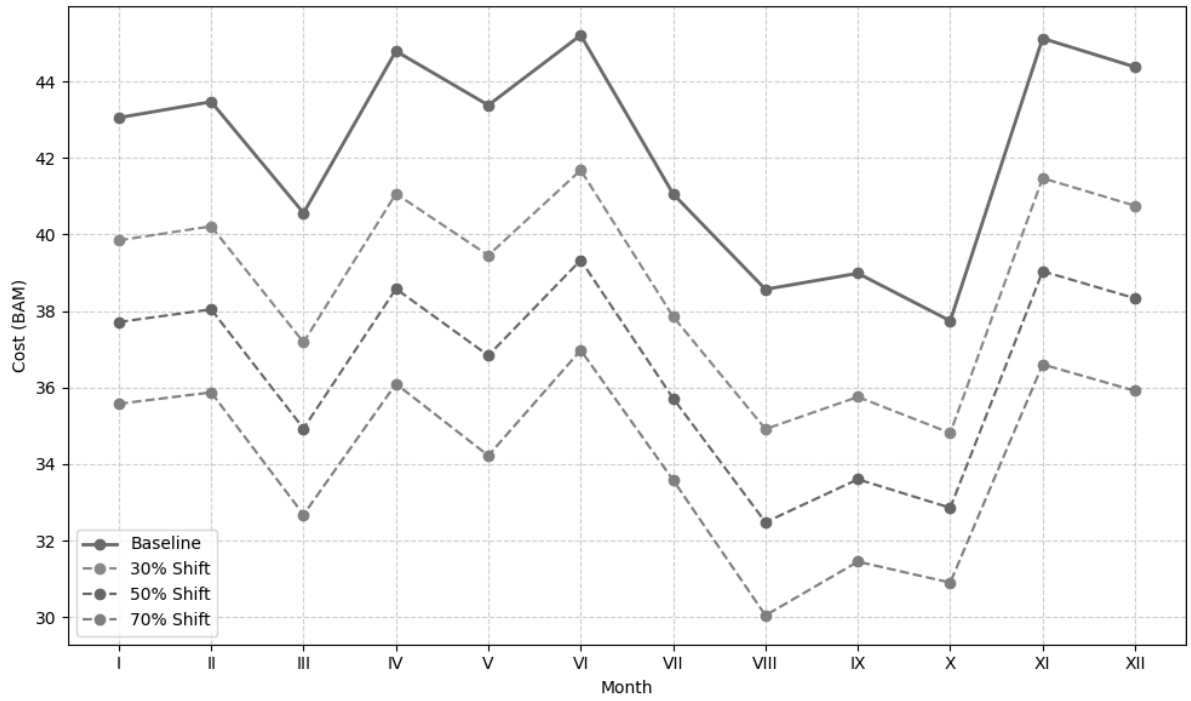


Figure 3. Monthly electricity cost: Basic vs. load shifting
Source: authors

Figure 3, compares the baseline monthly electricity costs with three AI-driven load shifting scenarios (30%, 50% and 70%). The baseline curve shows consistently higher costs, as a significant share of demand is allocated to the more expensive tariff. In contrast, load shifting scenarios show progressively lower monthly costs, with the magnitude of savings increasing proportionally to the share of consumption shifted to cheaper tariff periods. It is particularly important to note that during high-consumption months, such as December to February, the benefits of shifting are amplified, as a larger volume of energy can be shifted to low-cost hours.

This finding supports established research in demand-side management (DSM), which emphasizes the role of time-of-use pricing and intelligent scheduling in reducing household energy bills. Studies show that even partial demand shifting (20–30%) can significantly reduce costs, especially in regions with high seasonal load variability (Gyamfi & Krumdieck, 2011). Similarly, experiments in Europe have

shown that smart device scheduling and tariff-responsive automation can reduce winter peak electricity costs by 10–20%, depending on flexibility levels (Faruqui et al., 2010).

In this way, we confirm that AI-driven load shifting is particularly impactful in months with higher electricity demand, where even moderate changes (30%) can yield significant financial benefits, while more aggressive strategies (50–70%) provide proportionally higher savings.

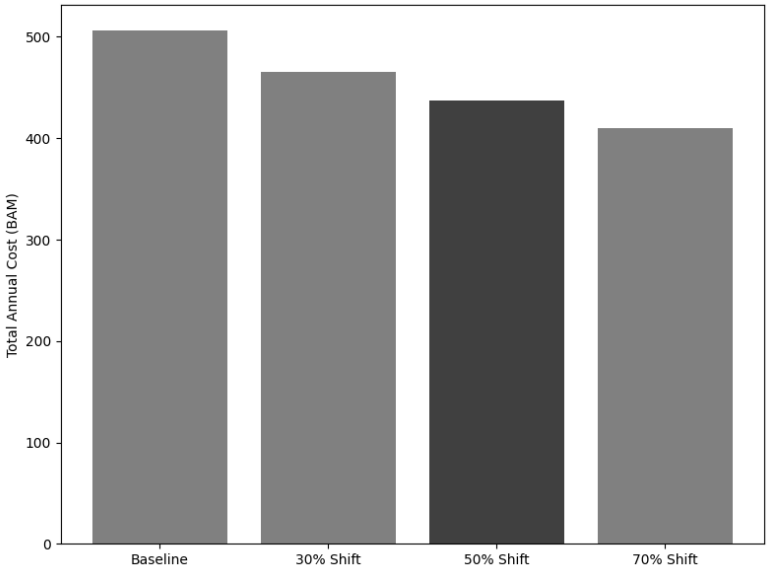


Figure 4. Comparison of annual electricity costs
Source: authors

Figure 4 shows the total annual electricity costs of households based on their baseline consumption patterns, compared to three AI-inspired load shifting scenarios: shifting 30%, 50% and 70% of energy from expensive tariff hours to cheaper ones. The cost reductions are significant: a 30% shift yields savings of around 10%, a 50% shift around 17% and a 70% shift around 23% per year. These results are consistent with broader findings in the demand-side management (DSM) literature. For example, a study in the International Journal of Energy Sector Management shows that device shifting can effectively reduce household energy consumption and bills (Avordeh et al., 2022). The Danfoss paper predicts that demand-side flexibility technologies could deliver savings of up to 7% on household electricity bills across Europe and the UK (Danfoss, 2023). Similarly, research shows that combining dynamic pricing with smart devices achieves a ~14% reduction in peak demand, highlighting how automation improves DSM efficiency.

We see that AI-driven load shifting can reduce household energy bills by double-digit percentages. When applied nationally, such savings could reduce strain on the electricity grid, reduce infrastructure costs, and contribute significantly to energy sustainability goals.

4.3. Implications for smart energy systems

The findings show that real-time energy monitoring combined with AI-driven automation can provide measurable benefits for households. These benefits include:

- Reduced electricity bills by shifting consumption to off-peak periods.
- Improved grid stability, as peak loads are mitigated.
- Lower carbon footprint, as more efficient consumption reduces reliance on high-emission energy generation during peak times.

These results align with current trends in the development of smart grids and demand-side management (DSM), where consumer engagement and intelligent systems play a central role in energy efficiency (Albadi & El-Saadany, 2008).

In practice, the integration of IoT devices - such as smart plugs and energy meters - paired with machine learning algorithms offers households actionable insights into their energy consumption and automates changes in consumption. This technological combination not only benefits consumers, but also contributes to the long-term sustainability of the energy system (Gungor et al., 2013).

Conclusion

In this research paper, we aimed to address a critical gap in energy management in residential buildings by developing an integrated monitoring and optimization system. An interdisciplinary approach to the project that combines IoT, machine learning, and automation shows promise, demonstrating both theoretical and practical progress in the field of energy efficiency.

With very little funding, we reduced the costs of the average household, thereby contributing to a better quality of life. In addition to individual savings, such systems can support broader sustainability goals by reducing peak demand and reducing overall energy consumption, which in turn reduces environmental impact.

Although the prototype shows promising results, the study faced limitations in terms of data set size, real-time implementation, and scalability across households. Addressing these challenges in future research will be key to ensuring reliability and broader applicability.

Future work may include integrating renewable energy sources, incorporating more advanced predictive models, and testing the system in large, real-world environments. In this way, this research can be developed into a comprehensive framework for smart, sustainable and user-friendly energy management.

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An MCDM-Based Assessment of Online English Learning Platforms Using the PSI Method

Procena onlajn platformi za učenje engleskog jezika korišćenjem PSI metode: MCDM pristup

Jovana Ljubisavljević[1]

[1]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, jovana.ljubisavljevic@mef.edu.rs*

Abstract: *With the expansion of language learning platforms, it has become increasingly difficult for users to opt for a particular one, especially when it comes to learning the English language. This study applies the multi-criteria decision making technique, the Preference Selection Index (PSI), to carry out a more objective analysis of the five leading providers: Duolingo, Babbel, Coursera, Preply, and Cambly. This analysis centers on User Satisfaction, Content Quality, Cost-Effectiveness, and Accessibility. The objective weights established according to the PSI method indicate User Satisfaction is the most dominant criterion. The results indicate that Duolingo performs best overall, followed by Coursera in the second place. This method aids learners in making a more knowledgeable decision.*
Keywords: *Online English learning, platform assessment, PSI, MCDM.*

Apstrakt: *Sa ekspanzijom platformi za učenje jezika, korisnicima postaje sve teže da se opredele za neku određenu, posebno kada je reč o učenju engleskog jezika. Ovo istraživanje primenjuje tehniku višekriterijumskog odlučivanja, Indeks preferencijalnog izbora (PSI), kako bi se sprovela objektivnija analiza pet vodećih provajdera: Duolingo, Babbel, Coursera, Preply i Cambly. Analiza se fokusira na zadovoljstvo korisnika, kvalitet sadržaja, isplativost i dostupnost. Objektivne težine utvđene prema PSI metodi pokazuju da je zadovoljstvo korisnika najdominantniji kriterijum. Rezultati ukazuju da Duolingo ostvaruje najbolje ukupne performanse, dok je Coursera na drugom mestu. Ova metoda pomaže učenicima da donesu promišljeniju odluku.*
Ključne reči: *Onlajn učenje engleskog jezika, procena platformi, PSI, MCDM.*

Introduction

The advancements in education technology have resulted in an abundance of platforms for learning languages online, particularly English. These platforms boast a variety of features, such as gamified activities, live instruction, and personalized learning. For students and teachers, however, the issue becomes how to choose the best and most appropriate one among the plethora of options, each excelling in some aspect of engagement, material, or cost effectiveness (Godwin-Jones, 2018). Popular applications result in tangible benefits in a number of areas, such as vocabulary and receptive skills, though these do vary considerably in usability, interaction, and retention, and other metrics (Vesselinov & Grego, 2012; Smith et al., 2024). These empirical studies, though mixed, do raise a tactical dilemma to institutions, teachers, and students alike. How do they evaluate and distinguish between platforms that offer different but valuable outcomes?

At the core of the issue is Multi-Criteria Decision-Making (MCDM), which can advance a systematic approach to trade-off analyses to evaluate the competing dimensions. Multi-criteria decision making (MCDM) offers the decision maker an organized way to evaluate the platform because the problems MCDM attempts to solve involve several criteria that conflict with each other (Hwang & Yoon, 1981). Systems like AHP, TOPSIS, and ELECTRE rely heavily on MCDM. These systems have found MCDM

useful in making decisions in engineering, business, and education (Zavadskas & Turskis, 2011). For the e-learning context, systematic reviews indicate the growing appreciation of MCDM for system selection, platform features, and technology stacks; these studies also develop taxonomies of frequently used criteria (strategic usability, pedagogical alignment, interaction, assessment, pricing, and accessibility, and so on) that are directly relevant for the evaluation of English learning platforms (Zare et al., 2016; Abdullateef et al., 2016).

Among existing MCDM approaches, the Preference Selection Index (PSI) method becomes most suitable in this context, as it provides a clear advantage with its objective criterion weighting which is critical for this context (Ulutas et al., 2021). Rather than relying on subjective estimates of value from the so-called experts, PSI derives the scores by assessing the variability of the data, which adds a layer of impartiality and consistency to the results (Maniya & Bhatt, 2010). This is especially valuable in educational technology assessments, as the differences in value from various stakeholders (teachers, students, etc.) can be extreme. In addition, the attributes of transparency and PSI's reproducibility aids to the fact that its procedure is computationally simple (or economical). Such attributes can be necessary to produce far-reaching recommendations that the grade academics and procurement committees of institutions would wish to have something to defend (Attri & Grover, 2015)

However, PSI is not a panacea. For example, the fact that PSI weights are dependent on empirical samples and phenomenon with importance weighting tends to punishment (e.g. Equal Pricing Strategy). Furthermore, the equilibrium choices within a sample, missing data, and the methodology employed are vital to the PSI attributes (Obeidat et al., 2023; Rao, 2013). Best practice thus incorporates the PSI with alternative normalizations and robustness checks like cross-method validation (e.g., PSI rankings vs. TOPSIS or SAW), and scenario analyses where stakeholder weights are imposed to see how rankings shift. This study positions itself in that methodological gap by applying PSI to the popular online English teaching platforms, using literature-supported pedagogical and technical criteria, and performing cross-validation and sensitivity analyses. The primary purpose is practical and academic in nature: to propose a transparent and reproducible trade-off analysis on the ranked platforms while demonstrating the reliable application of PSI in educational technology evaluation to discuss wide-ranging implications for instructors and procurement decisions. In this way, the analysis not only examines the performance of different platforms but also tests the robustness of the PSI method in real educational settings.

Consequently, this work considers the PSI approach for the first time to provide objective value to five selected, well-known platforms for learning English online: Duolingo, Babbel, Coursera, Preply, and Cambly. The evaluation focuses on four important customer-centric aspects: User Satisfaction & Engagement, Content Quality & Depth, Cost-Effectiveness, and Accessibility & Usability. The goal is to obtain a clear, data-based ranking that eliminates the noise of marketing and aids users in decision-making while showcasing the practical use of PSI in educational technology. The next chapter synthesizes the theoretical underpinnings of MCDM and PSI with the methods of data collection, scoring rubrics, and sensitivity protocols used in the study.

1. Methodology

The Preference Selection Index (PSI) method, introduced by Maniya and Bhatt (2010), is until today one of the few systematic approaches to multi-criteria problems. The approach is interesting because it relies on weights generated from the data (as opposed to potentially biased pre-set weights), and the relative preference of all the data available for each criterion. In other words, the approach allows data to tell what really matters to a decision maker. The data-driven foundation is what makes the approach practical in decision making.

Computational procedures in the PSI method are simple and the approach to them can be broken into the following steps:

Step 1. The decision-maker must first define the set of alternatives and the criteria that will be used to evaluate the alternatives. The criteria should be chosen based on their relevance to the decision-making problem, and the decision-maker should assign a relative importance or weight to each criterion.

Step 2. Evaluate the alternatives and construct initial decision-making matrix D, as follows:

$$D = \left[x_{ij}\right]_{mxn}, \tag{1}$$

where xij denotes ratings of the alternative I in relation to criterion j, m is the number of alternatives and n is the number of criteria.

Step 3. Construct the normalized decision matrix in which the elements of the matrix are calculated as follows:

$$r_{ij} = \frac{x_{ij}}{x_{ij}} \text{ for maximization criteria,} \tag{2}$$

$$r_{ij} = \frac{x_{ij}}{x_{ij}} \text{ for minimization criteria.} \tag{3}$$

Step 4. Calculate preference variation value in relation to each criterion as follows:

$$\chi_j = \sum_{i=1}^{m}\left(r_{ij} - \bar{r}_j\right)^2, \tag{4}$$

where $\bar{r}_j$ denotes the mean value of normalized ratings of criterion j and it is determined as follows:

$$\bar{r}_j = \frac{1}{m}\sum_{i=1}^{m} r_{ij} \tag{5}$$

Step 5. Calculate deviation in the preference variation value as follows:

$$\Omega_j = 1 - X_j. \tag{6}$$

Step 6. Determine the criteria weights using the following equation:

$$w_j = \frac{\Omega}{\sum_{i=1}^{n}\Omega_j}. \tag{7}$$

Step 7. Calculate the preference selection index of alternatives as follows:

$$S_i = \sum_{j=1}^{n} r_{ij} w_j. \tag{8}$$

Based on the preference selection index values of the alternatives, determine the complete ranking order of alternatives. The alternative which has the largest preference selection index represents the best ranked alternative.

2. Results

Based on the proposed methodology for the PSI method, a systematic evaluation of five prominent online English learning platforms is presented below. The platforms were chosen for their relevance to today's learners and were evaluated so as to determine the most suitable and beneficial option. Using the PSI approach gives an unbiased and evidence-based ranking, and simultaneously solves the main problem concerning the decision of which platform to opt for. The platforms under consideration are listed in Table 1.

Table 1. Alternative English language learning platforms

Alternative	Platform name
A_1	Duolingo
A_2	Babbel
A_3	Coursera
A_4	Preply
A_5	Cambly

Source: author

The given alternative English language learning platforms were evaluated against four benefit-type criteria presented in Table 2.

Table 2. Evaluation criteria

Alternative	Criteria	Explanation
C_1	User Satisfaction and Engagement	Determines the level of user approval and their active engagement with the platform, based on the app store ratings and reviews.
C_2	Content Quality and Depth	Determines the educational rigor, organization, and general comprehensiveness of the provided learning materials.
C_3	Cost-Effectiveness	Determines the value and usefulness users feel they receive based on the price of the platform's services.
C_4	Accessibility and Usability	Determines the overall ease of use, interface intuitiveness, and accessibility across multiple devices.

Source: author

Table 3 contains the initial data about chosen alternatives referred to the considered criteria. The data used in the original construction of the decision matrix was collected using a robust process which consisted of data that was publicly available, and therefore objective and transparent with the possibility of being replicated, for each of the platforms. Performance measures for the four established criteria was collected through triangulation methods for each of the platforms. User Satisfaction and Engagement scores were generated by quantifying user ratings and reviews from the official Google Play Store and Apple App Store. Content Quality and Depth was evaluated by synthesizing expert reviews from established industry publications, including Forbes, PCMag, and TechRadar. Data for the Cost-Effectiveness criterion were collected directly from the official pricing pages of each platform, supplemented by user sentiment regarding value-for-money from community discussions of forums like Reddit. Finally, Accessibility and Usability were gathered based on qualitative user impressions including the ease of onboarding, cross-platform availability, and intuitiveness of the interface based on reviews by users and expert reviews. Each of these disparate qualitative/quantitative sources was then normalized into a coherent 1-10 scale for each platform-criterion pair, producing a large and well-justified dataset for the objective computational process of the PSI method.

Table 3. Initial data

	C_1	C_2	C_3	C_4
A_1	9.2	7	9.5	9.5
A_2	8.5	8.8	7	8
A_3	8.8	9.5	8	7.5
A_4	8	9	6	7
A_5	8.3	8	7.5	8.5

Source: Google Play, Apple App Store, Forbes, PCMag, TechRadar, company pricing pages, Reddit communities, Trustpilot

Because the initial data is in different units, the normalization procedure is performed by using Eq. (2) and (3). The obtained results are presented in Table 4.

Table 4. Normalized decision-making matrix

	C1	C2	C3	C4
A1	1.0000	0.7368	1.0000	1.0000
A2	0.9239	0.9263	0.7368	0.8421
A3	0.9565	1.0000	0.8421	0.7895
A4	0.8696	0.9474	0.6316	0.7368
A5	0.9022	0.8421	0.7895	0.8947

Source: Author

The mean value of normalized ratings ($\bar{r}_j$) was defined by using Eq. (5), and by applying Eq. (4) the preference variation values (χ_j) were calculated (Table 5). Also, by using Eq. (7) and (8), the deviations in the preference variation (Ω_j), and finally criteria weights (w_j) were determined and presented in Table 5.

Table 5. The criteria weights

	C1	C2	C3	C4	Σ
$\bar{r}_j$	0.9304	0.8905	0.8000	0.8526	
χ_j	0.0101	0.0425	0.0742	0.0410	
Ω_j	0.9899	0.9575	0.9258	0.9590	3.8322
w_j	0.2583	0.2499	0.2416	0.2502	1.0000

Source: author

For the last step, the PSI (Si) was calculated for all alternative platforms with the help of Eq. (9). The final ranking order of the alternatives involved in the decision-making was established, according to the values provided. Table 6 and Figure 1 show the achieved results.

Table 6. Preference selection index – final rank of alternatives

	C1	C2	C3	C4	Si	RANK
A1	0.2583	0.1841	0.2416	0.2502	0.9342	1
A2	0.2387	0.2315	0.1780	0.2107	0.8589	3
A3	0.2471	0.2499	0.2034	0.1976	0.8979	2
A4	0.2246	0.2367	0.1526	0.1844	0.7983	5
A5	0.2330	0.2104	0.1907	0.2239	0.8581	4

Source: author

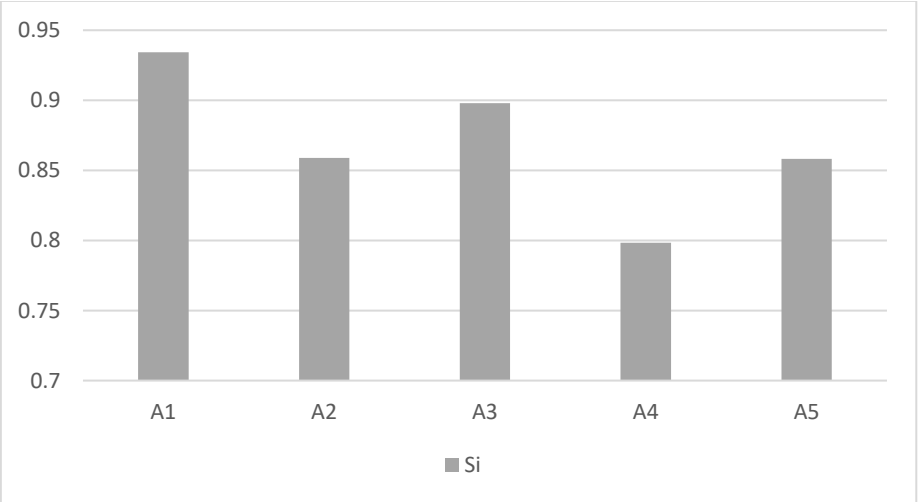


Figure 1. Final rank of alternatives
Source: Author

The first step of the given analysis consisted of the creation of a decision matrix. The matrix was populated with performance scores which were normalized from objective sources of information including official app store directories, independent expert reviews and direct prices for the platforms. This decision matrix was then normalized in order to make the criteria comparable on a common scale. The PSI decision making methodology had to implement a computational procedure that first calculated the mean normalized value for each of the criterion so as to establish a central tendency. Then the preference variation value had to be calculated, as it represents a potentially critical component of the analysis that reflects how far apart some or all of the performance data vary from the mean. The resultant preference variation values were used to extract the deviation.

User Satisfaction & Engagement has the first major weight of 0.2583, a finding that reflects the great importance of user experience and continuing engagement in digital learning. The weights assigned were almost equal for Accessibility & Usability (at 0.2502) and Content Quality & Depth (at 0.2499), showing that these similarities in weights reflect almost equal importance. Cost-Effectiveness was allocated objectively the lowest weight in this decision model (0.2416), which suggest that for this specific dataset upfront cost seems marginally a less decisive factor in comparison to usability and satisfaction, considering that platforms are evaluated holistically.

The final outcome, as determined by the PSI (Si), placed Duolingo in the first position. Overall it showed a predominant, high striking average across three factors (C1, C3, C4) considered and a bit weaker performance in Content Quality set (C2). Coursera and Babbel received marks in the second and third positions respectively with Cambly and Preply not far behind in marks awarded. What is interesting is that the hierarchy in the present instance demonstrates that a platform which offers a strong and balanced performance across multiple user-centric dimensions can achieve a considerably higher result in overall utility than an individual platform that outstands in a single criterion, such as cost or content alone. Hence, this study offers a nuanced, empirically-grounded framework that can significantly aid potential users in navigating the complex process and exploration of online English learning.

Conclusion

The main intention of this study was to tackle an indeed common problem nowadays of picking a suitable English learning platform. Using the Preference Selection Index (PSI) model across the five most prominent options moves the research away from marketing assertions and subjective preferences to a classification based on data and analysis. The results speak for themselves. The ultimate rankings, that is Duolingo, Coursera, Babbel, Cambly, Preply, imply a categorical scale for users based on empirical judgment. But even more interesting than the ranking per se are the objective criterion weights produced by the PSI.

Thus no model is perfect. The objectivity of the PSI is both its greatest virtue and its chief defect. The weights are completely dependent on the specific example of data. A different selection of platforms or a change in their features or costs could subtly alter the perceived importance of each criterion.

This study does not adjudge that a single platform is the “best“ in an absolute sense as the word is used. What it does is demonstrate with great clarity that a platform that gives a strong but balanced efficiency over a number of characteristics which are user-centred (usability, engagement, reasonable cost) will have higher over-all utility than any platform that excels in only one area. The high position of Duolingo and its superiority in three out of four criteria emphasizes this truth. To the undecided learner such information will give a firm starting point.

Ultimately, this study offers a nuanced, empirically-grounded framework that can significantly aid potential users in navigating the complex process and exploration of online English learning.

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Integration of Blockchain Technology into the Architecture of Next-Generation Telecommunications Networks to Increase the Security and Reliability of Data Transmission

Integracija blockchain tehnologije u arhitekturu telekomunikacionih mreža nove generacije radi povećanja sigurnosti i pouzdanosti prenosa podataka

Armin Čelarević[1]

[1]*International University Travnik, Travnik, Bosnia and Herzegovina, celarevicarmin@gmail.com*

***Abstract**: The development of next-generation telecommunications networks (5G and 6G) brings significant progress in data transfer speed, reliability and connecting a large number of devices in real time. The increased complexity of network architecture simultaneously requires new approaches to data protection and preserving communication integrity. Blockchain technology, based on the principles of decentralization, cryptographic protection and transparency, offers an innovative solution for improving the security of telecommunications systems. By integrating blockchain into the network architecture, it is possible to achieve resistance to cyberattacks, prevent data manipulation and enable decentralized authentication of devices and users. This paper analyzes the application of blockchain technology in authentication, digital identity management and data transmission protection, with special emphasis on its advantages, challenges and potential implementation models in 5G/6G networks. The goal is to point out the possibilities of increasing the security, reliability and efficiency of modern telecommunications systems.*

***Keywords:** Blockchain, decentralization, internet of things (IoT), 5G/6G networks, data security.*

***Apstrakt:** Razvoj telekomunikacionih mreža nove generacije (5G i 6G) donosi značajan napredak u brzini prenosa podataka, pouzdanosti i povezivanju velikog broja uređaja u realnom vremenu. Povećana kompleksnost mrežne arhitekture istovremeno zahtijeva nove pristupe zaštiti podataka i očuvanju integriteta komunikacije. Blockchain tehnologija, zasnovana na principima decentralizacije, kriptografske zaštite i transparentnosti, nudi inovativno rješenje za unapređenje sigurnosti telekomunikacionih sistema. Integracijom blockchaina u mrežnu arhitekturu moguće je postići otpornost na kibernetičke napade, spriječiti manipulaciju podacima i omogućiti decentralizovanu autentifikaciju uređaja i korisnika. Ovaj rad analizira primjenu blockchain tehnologije u autentifikaciji, upravljanju digitalnim identitetima i zaštiti prenosa podataka, sa posebnim naglaskom na njene prednosti, izazove i potencijalne modele implementacije u 5G/6G mrežama. Cilj je ukazati na mogućnosti povećanja sigurnosti, pouzdanosti i efikasnosti savremenih telekomunikacionih sistema.*

***Ključne riječi:** Blockchain, decentralizacija, internet of things (IoT), 5G/6G mreže, sigurnost podataka.*

Introduction

The development of next-generation telecommunications networks has brought significant advances in data transfer speed, communication reliability, and real-time connectivity for a large number of devices. These networks are the foundation for many modern technologies, including autonomous vehicles, smart cities, the Internet of Things, and high-bandwidth applications. At the same time, the increased complexity of network architecture and the massive proliferation of connected devices pose new challenges in the areas of security, privacy, and data integrity. Cyber attacks, unauthorized access, and data manipulation pose a serious threat to the efficient operation of modern telecommunications

systems. Existing security mechanisms, which rely on centralized entities and protocols (TLS, VPN, PKI), often do not meet the scalability and resilience requirements of next-generation networks. In this context, blockchain technology emerges as an innovative solution. Its decentralized architecture, combined with cryptographic protection and transparent transaction logging, enables secure user and device authentication, data integrity protection, and centralized management of network resources. Blockchain can thus reduce the risk of attacks and enable reliable data exchange among a large number of distributed nodes, especially within the IoT infrastructure. The application of blockchain technology in next-generation telecommunications networks can include device and user identity verification, real-time data flow monitoring, IoT device management, and the implementation of smart contracts to automate security processes. This approach enables reliable and secure information exchange among a large number of distributed nodes, reduces dependence on central authorities, and increases the network's resilience to sophisticated cyber attacks (Chen, 2023).

1. Next-generation telecommunications networks and security challenges

1.1. Basic characteristics of 5G/6G networks and their architecture

The development of fifth- and sixth-generation telecommunications networks represents one of the most significant steps in the evolution of global digital infrastructure, marked by the transition from traditional, static and centralized network concepts to highly distributed, virtualized and intelligent communication systems. These networks represent not only a technical improvement over previous generations, but also a fundamental transformation of the way information is transmitted, processed and protected in modern digital society. Fifth-generation networks have brought revolutionary changes in terms of performance, enabling data transfer speeds of up to 10 Gbps, extremely low latency (less than 1 millisecond), and the ability to simultaneously connect millions of devices per square kilometer. Such technical characteristics have enabled the development of new paradigms in industry and society – from autonomous vehicles and industrial robotics, through smart cities and telemedicine solutions, to augmented and virtual reality (AR/VR). At the heart of these capabilities is a flexible and modular network architecture that leverages the principles of software-defined networking (SDN), network functions virtualization (NFV), edge computing, and network slicing.

The concept of network slicing enables the creation of multiple virtual networks within a single physical infrastructure, with each network being optimized for massive IoT communications, while the other supports ultra-low latency for autonomous systems. Edge computing enables data processing closer to the user, reducing the load on central servers and increasing system responsiveness, while SDN enables centralized and intelligent management of network flows in real time.

The 6G network, currently in the research and standardization phase, goes a step further. 6G will be based on the deep integration of artificial intelligence (AI) into its network layers, from spectrum optimization and resource management to automation of security threat detection and prevention. In addition, the introduction of a quantum-resistant cryptographic framework is expected, which will protect communications from future quantum attacks, and the implementation of new types of wireless connections in the terahertz (THz) spectrum to achieve extreme transmission speeds. 6G networks will enable the conversation of terrestrial and satellite systems, which will make global coverage available even in the most remote areas. In addition, it will augment the physical and digital worlds through concepts such as the metaverse and digital twins, which will enable real-time synchronization of real and virtual environments for industrial, medical and educational purposes.

Although the aforementioned technologies bring exceptional performance, flexibility and the ability to innovate, they simultaneously increase the complexity of the network ecosystem and the number of potential security attack points. Distributed architecture, massive device connectivity and dynamic network management create new attack vectors and increase the risk of data compromise, which makes the security and integrity of communication one of the key challenges of modern telecommunications systems. Therefore, the modern development of 5G and 6G networks must be accompanied by the

parallel development of advanced security architectures, which will use a combination of classical and quantum-resistant cryptographic solutions, distributed authentication mechanisms, and AI-based threat monitoring and detection systems (3GPP, 2021).

1.2. Main security issues: authentication, privacy and data integrity

Telecommunications networks require a multi-layered security architecture that must ensure user and device authentication, confidentiality and integrity of data transmission, and privacy protection. Given that 5G and 6G systems integrate a large number of distributed components including base stations, edge nodes, virtualized functions and IoT devices, security is no longer limited to the central network level, but must be implemented in every segment of the communication chain.

One of the key challenges is the authentication of a large number of heterogeneous devices, especially within the IoT infrastructure, where traditional verification mechanisms (such as SIM-based authentication or centralized PKI systems) become inefficient, expensive and difficult to scale. 5G networks have introduced the concept of subscription concealed identifiers (SUCI) and the primary authentication framework defined in 3GPP TS 33.501, which enables user identity protection and authentication based on cryptographic keys. However, in networks with billions of IoT nodes, where many devices have limited computing resources, these approaches are not always applicable. The lack of a single standard for secure and interoperable device identification further complicates reliable access management, which increases the risk of rogue nodes and spoofing or Sybil attacks. Privacy protection is becoming one of the most complex aspects of security in next-generation networks. The huge amounts of data that are continuously collected, including geolocation information, biometric data, application usage patterns, and communication metadata, create a high risk of unauthorized access or misuse. In the case of compromise of centralized servers, attackers can gain access to sensitive information of millions of users. These problems are particularly pronounced in networks that use edge computing and network slicing, where different services share the same physical resources, resulting in potential data leaks between virtual network segments. Therefore, models based on decentralized identities (Decentralized Identifiers – DIDs) and zero-knowledge proof methods are being increasingly explored, which allow for identity verification without revealing the user's personal data.

Data integrity, or ensuring that information has not been altered, compromised, or falsified during transmission, is essential for applications that require high reliability and real-time responses, such as autonomous vehicles, smart factories, or critical infrastructure. Any manipulation of data, whether accidental or malicious, can cause system errors and serious security consequences. In addition, 6G networks rely on the concept of a trustless environment, in which data passes through multiple layers of processing and distributed entities. Therefore, it is necessary to introduce mechanisms for end-to-end integrity verification, as well as techniques for cryptographic proof of data authenticity. The lack of such mechanisms can lead to attacks such as man-in-the-middle (MITM), data tampering, session hijacking, and replay attacks, which seriously threaten the stability and reliability of the network. precisely because of these challenges, researchers and industry are increasingly considering the application of blockchain technology as a complementary solution, which could provide a decentralized, transparent, and immutable framework for authentication, access control, and data verification in next-generation networks (Akyildiz, Kak & Nie, 2020).

1.3. Limitations of existing centralized security mechanisms

Current security mechanisms in telecommunications are based on centralized control models, such as Public Key Infrastructure (PKI), Virtual Private Networks (VPN) and Transport Layer Security (TLS) protocols. Although these mechanisms have proven effective in conventional network environments, their application in distributed, dynamic and massively scalable 5G/6G networks is becoming increasingly difficult and limited. Centralized security models operate on the principle of one or more central entities (e.g. Certificate Authority – CA, Authentication Server, Key Management System) that are tasked with verifying the identity of users, issuing digital certificates and managing keys for encryption of communications. Although this approach allows for a clear hierarchy of trust, it also

introduces a single point of failure. In the event of a compromise of the central authority, an attacker can fraudulently issue certificates or access sensitive cryptographic materials, which leads to a complete violation of the security of the entire system. In addition to security risks, centralized models also face the problem of limited scalability. In 5G/6G networks, where the number of connected devices can reach billions, centralized processing of security requests (such as authentication, revocation and verification of certificates) can become a bottleneck that increases latency and reduces network efficiency. This problem is particularly pronounced in edge computing environments, where data must be processed locally, rather than through central points. Another limitation is the lack of transparency and auditability of security processes. Centralized systems often do not allow for independent verification of the validity of transactions, certificate issuance or change history, which makes it difficult to detect malicious activities and conduct forensic analysis of incidents. In environments involving multiple operators and entities, such as network slicing or multi-operator sharing, coordination between different security domains further complicates trust management. In this context, it becomes evident that existing centralized security mechanisms are insufficient for the needs of new generation networks. Future telecommunications systems require decentralized, scalable, and cryptographically verifiable trust models that can operate without relying on central authorities. This is where the potential of blockchain technology comes in, enabling distributed identity management, transparent logging of security events, and automatic enforcement of security policies through smart contracts. Blockchain integration can eliminate single points of failure, increase system resilience, and enable real-time auditability, which is critical for 5G/6G network architectures.

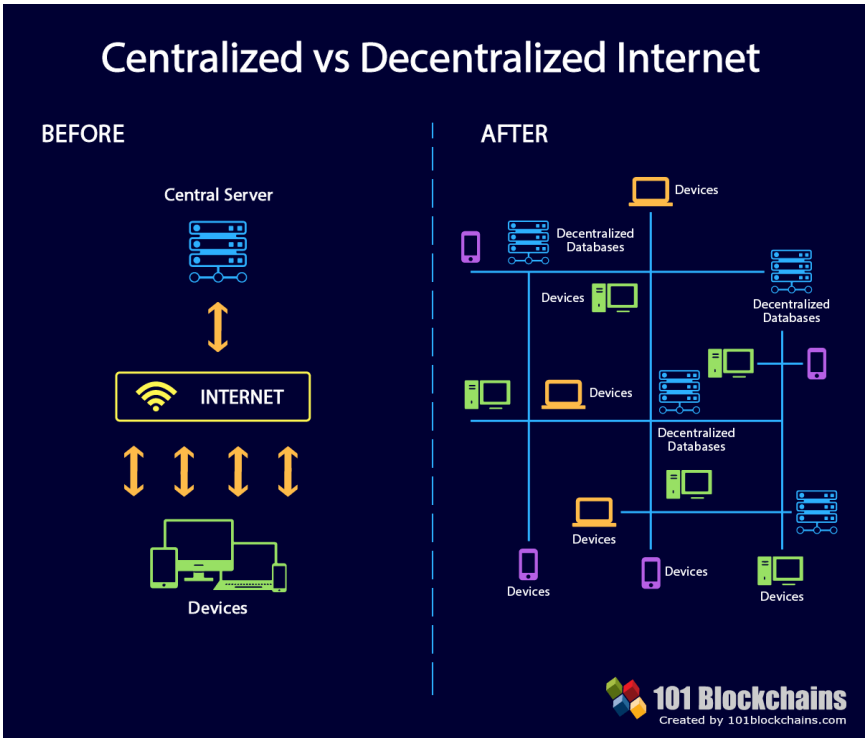


Figure 1. Comparison of centralized and decentralized network architectures
Source: https://101blockchains.com/centralized-vs-decentralized-internet-networks/

Figure 1 shows the difference between centralized and decentralized security approaches, clearly showing that a centralized system depends on a single authority, while a decentralized model allows for resistance to attacks and better distribution of control (Khan & Salah, 2018).

2. Basic principles of blockchain technology

Blockchain technology is a distributed digital data record system, in which information is stored in sequentially linked blocks that form a chain (block-chain). Each block contains a set of transactions, a timestamp and a cryptographic hash of the previous block, which ensures the immutability and integrity of the record. The key characteristic of blockchain is the absence of a central authority, data validation and verification takes place through consensus mechanisms between network participants, which achieves high resistance to manipulation and malicious attacks.

2.1. Blockchain structure and consensus mechanisms

Basically, a blockchain can be viewed as a distributed and decentralized database in which each node in the network owns an identical copy of the blockchain. A new block can only be added to the chain after it has been confirmed by a majority of network participants through a consensus mechanism – an algorithmic process that allows all nodes to agree on the validity of transactions without a central authority. The main purpose of the consensus mechanism is to ensure that all participants have the same view of the state of the network, even in the presence of malicious nodes. This ensures that no entity can unilaterally change records, making the blockchain resistant to attacks and data corruption.

The most commonly used consensus mechanisms include:

- Proof of Work (PoW) – is based on solving complex mathematical problems using cryptographic hash functions. PoW provides a high level of security and resistance to attacks, but is energy inefficient due to the high consumption of computing power. It is used in networks such as Bitcoin and early implementations of Ethereum.
- Proof of Stake (PoS) – eliminates the need for energy-intensive task solutions; validators are selected based on the amount of cryptocurrency they "invest" as a guarantee. This approach allows for faster block confirmation and reduces energy costs, making it suitable for integration into telecommunications and IoT systems where efficiency is key.
- Practical Byzantine Faul Tolerance (PBFT) – developed for environments with a known and limited number of nodes (e.g. private and consortium networks). The PBFT algorithm allows consensus to be achieved even if some of the nodes act maliciously or incorrectly. Due to its speed and low latency, PBFT is particularly applicable to 5G/6G networks and edge computing environments where real-time decisions are crucial.

By combining these approaches, hybrid consensus models are being developed, such as Delegated Proof of Stake (DpoS), Proof of Authority (PoA), and Proof of Space-Time (PoST), which combine the security of PoW, the energy efficiency of PoS, and the speed of PBFT. These models offer the scalability and adaptability needed for future distributed telecommunication systems, where a large number of nodes, high data throughput, and the need for minimal latency are expected. In the context of next-generation telecommunication networks, the choice of the optimal consensus mechanism depends on the specific requirements of the system – such as the number of connected devices, the level of trust between nodes, and the requirements for processing speed and energy efficiency. The implementation of customized consensus protocols in the 5G/6G architecture enables a reliable, transparent, and scalable security framework, supporting dynamic network services and automated communication management (Xu, Chen & Blasch, 2021).

2.2. Cryptographic protection, decentralization and transparency

The security of blockchain technology is based on strong cryptographic mechanisms, a distributed data structure and a transparent way of validating transactions. Together, these three components form the basis of the reliability and resilience of the blockchain system, which makes it extremely suitable for use in new generation telecommunications networks. The basic security mechanisms of blockchain include cryptographic hash functions and digital signatures. This mechanism creates a cryptographic chain of blocks in which each data change automatically changes the hash value, thus detecting any

unauthorized change. Digital signatures, based on public key cryptography (Public Key Cryptography), ensure the authenticity and non-repudiation of transactions. Each user has a pair of keys - public and private - where the transaction is signed with a private key and validated with a public key, thus proving the identity of the sender without the need for a central intermediary. This structure allows blockchain to function as a trusted system without trust (trustless environment), where the integrity of data is guaranteed by algorithms, not institutions.

Unlike traditional security models that rely on centralized entities (PKI systems), blockchain operates in a completely decentralized environment. Transaction validation is performed collectively, through distributed nodes that participate in the consensus process. This approach eliminates a single point of failure and increases resistance to attacks, as an attacker would have to compromise most nodes simultaneously, which is practically impossible in large networks. In the context of telecommunications, decentralization allows security decisions (device verification, access authorization or key distribution) to be made at the edge of the network, which improves speed and reduces latency, and thus the overall efficiency of the system.

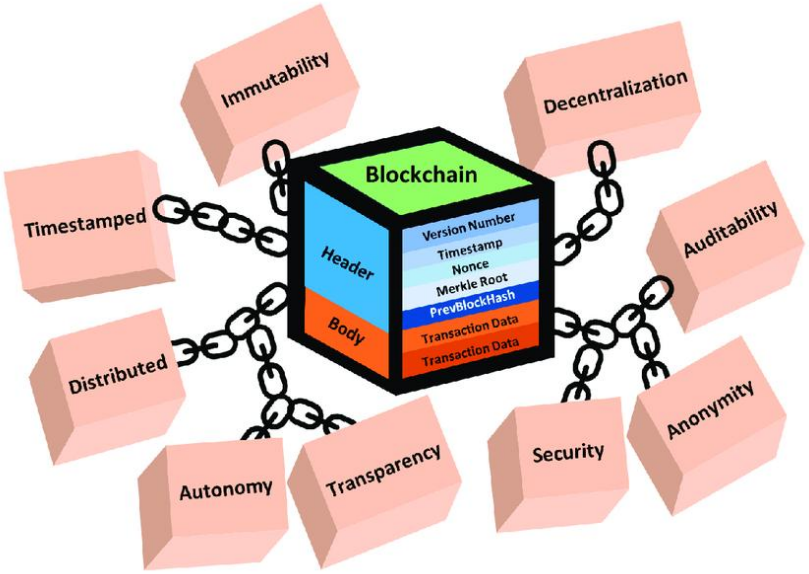


Figure 2. Key features of blockchain technology
Source: Wu et al., 2023

One of the key advantages of blockchain technology is data transparency. All validated transactions are permanently stored in a publicly available record (ledger), which all network participants can access and verify. However, thanks to pseudonymization and advanced encryption techniques (e.g. homomorphic encryption, zero-knowledge proofs – ZKP), it is possible to preserve user anonymity while ensuring the verification and integrity of transactions. Such transparency is particularly important in 5G/6G networks, where it is necessary to enable real-time monitoring of security events without violating user privacy. Blockchain can serve as an immutable record of network events, which facilitates attack detection, auditing of security processes and proving data authenticity (IEEE Spectrum, 2023).

The application of blockchain in next-generation telecommunications networks enables:

- Secure distribution of keys between devices without a central authority, which reduces the possibility of interception (e.g. in SIM-based systems).
- Decentralized authentication of IoT devices and network nodes.
- Real-time data integrity and origin monitoring, preventing man-in-the-middle and replay attacks.

- Transparent monitoring of security processes through cryptographically provable records.

2.3. Smart contracts and their application in network systems

Smart contracts are program codes stored on the blockchain that are automatically executed when predefined conditions are met. Their key advantage is the authorization of processes without intermediaries, which increases efficiency and reduces the risk of human error or abuse.

In telecommunications networks, smart contracts can be used for:

- Automatic authentication of devices and users in distributed 5G/6G systems,
- Dynamic allocation of resources between operators through SLA (Service Level Agreement) contracts on the blockchain,
- Real-time monitoring and billing of network service usage,
- Implementation of security policies and automated responses to network anomalies.

The integration of smart contracts with artificial intelligence systems enables the creation of self-managing networks that can autonomously make security decisions and adapt to applications in the network environment.

3. Blockchain integration in next-generation telecommunications networks

The development of 5G and 6G networks requires highly scalable, secure and reliable architectures that can support a large number of connected devices, low latency and diverse applications in real time. Blockchain technology is increasingly recognized as a potential solution for improving the security and resilience of these networks.

3.1. The potential of blockchain in 5G/6G architecture

Blockchain can serve as a secure layer for data exchange between nodes, automated transaction logging and transparent monitoring of network events. This means that all nodes in the network have an identical copy of the information, which facilitates auditability and reduces the possibility of unauthorized data manipulation. This principle is especially important in 5G/6G networks that support millions of connected devices, where traditional centralized security models often cannot effectively monitor or control all data flows. In scenarios such as smart cities, autonomous vehicles, industrial automation and e-health, where data must be transferred in real time and without errors, blockchain provides an additional layer of security, verification and resilience. It also enables interoperability between different operators and network segments, which is crucial for heterogeneous and globally connected environments. Ultimately, blockchain integration not only improves security and transparency, but also opens up opportunities for a new generation of innovative services and applications that require a high level of reliability, integrity and privacy of data (Rust, 2023).

3.2. Applications in authentication, identity management and data transmission protection

Within the 5G/6G infrastructure, blockchain can serve as a reliable framework for verifying devices, network nodes and users, where each authentication is recorded in an immutable block of transactions. This enables a transparent record of all network accesses, which greatly facilitates the detection of suspicious activities and increases the level of trust between network participants. When it comes to digital identity management, blockchain supports the development of the self-sovereign identity (SSI) model, which gives users full control over their own data. The user's identity is no longer stored in a central server, but is distributed and protected using cryptographic algorithms. This approach not only increases security, but also reduces the risk of unauthorized use of personal data, which is crucial in an environment that generates huge amounts of sensitive information. Regarding data transmission protection, blockchain allows all data to be exchanged within cryptographically signed transactions, which guarantees the authenticity and integrity of each message. In this way, any modification, loss or

attempt to falsify data can be immediately detected. This verifiability is particularly important in applications that require high reliability and low latency (Liu et al., 2024).

4. Advantages, challenges and implementation possibilities

The implementation of blockchain technology in next-generation telecommunications networks brings a number of significant advantages related to increasing security, resilience and trust in the network infrastructure. The decentralized nature of blockchain eliminates the need for a central authority and therefore reduces the possibility of data misuse or compromise at a single point in the system. Thanks to cryptographic protection and consensus mechanisms, each transaction within the network becomes immutable and transparent, which significantly increases the level of trust between different actors – operators, users and devices. In addition, blockchain enables process automation through smart contracts, which reduces the costs and time required for managing network resources, as well as for implementation between different entities.

However, in addition to the above advantages, there are also numerous challenges that slow down the wider implementation of blockchain solutions in telecommunications systems. One of the main problems is scalability, i.e. the ability of a blockchain network to process a large number of transactions in a short time, which is crucial in the 5G/6G network environment. Additionally, the energy consumption of certain consensus mechanisms (e.g. Proof of Work) can be too high for practical implementations, especially in mobile and edge computing environments. The third challenge relates to interoperability, i.e. the need for blockchain systems to be compatible with existing network protocols, management systems, and different types of devices that use different communication standards (Sharma, Chen & Park, 2020).

In the context of implementation options, researchers and industry propose different models tailored to the specific needs of the telecom sector. One approach is a hybrid blockchain, which combines the advantages of public and private networks, enabling high security with controlled access to data. The second model includes lightweight blockchain solutions optimized for IoT devices with limited resources. Practical applications include automated spectrum management, secure device authentication, decentralized service billing, and real-time quality of service (QoS) monitoring. In the future, the synergy between blockchain, artificial intelligence, and quantum-resistant cryptography could form the basis for the development of fully autonomous and self-regulating sixth-generation telecommunications networks (Li, Pei & Zhao, 2020).

Conclusion

The integration of blockchain technology into next-generation telecommunications networks represents one of the key steps towards creating more secure, reliable and autonomous communication systems of the future. The decentralized structure enables greater network resilience to cyber threats, transparency in data management and process automation through smart contracts. In the context of authentication and data protection, blockchain brings the possibility of verifying identity and monitoring the integrity of information in real time, thereby significantly improving the security architecture of 5G/6G systems. However, the successful implementation of this technology requires overcoming certain technical and operational challenges, primarily scalability, energy efficiency, interoperability with existing network protocols. Solutions such as hybrid blockchain models, energy-efficient consensus mechanisms and integration with computing infrastructure open the way to practical application in the telecommunications environment. Ultimately, the synergy between blockchain, artificial intelligence and quantum-resistant cryptography could become the foundation of a new generation of secure and self-managing communication networks. Such networks will not only improve technical performance and security, but will also shape a new ecosystem of trust in the digital economy of the future.

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Blockchain in Accounting and Auditing: Opportunities for Continuous Financial Reporting and Implications for Internal Controls

Blokchain u računovodstvu i reviziji: mogućnosti za kontinuirano finansijsko izvještavanje i implikacije na interne kontrole

Džejlana Čejvan[1], Aida Mehić[2]

[1]*International University Travnik, Travnik, Bosnia and Herzegovina, dzejlanacejvan@gmail.com*
[2]*International University Travnik, Travnik, Bosnia and Herzegovina, mehi5634@gmail.com*

Abstract: *The development of blockchain technology opens up new possibilities for the transformation of accounting and auditing processes, offering more transparent, secure and almost instantaneous recording of business events. This paper explores the potential of blockchain to establish continuous financial reporting and strengthen internal control systems. The aim of the research is to analyze how the application of distributed registers can improve the accuracy, reliability and timeliness of accounting information and how it affects the role of auditors and regulatory requirements. The methodological framework includes qualitative analysis and research in B&H and the region. The results indicate a growing interest and perception of the benefits of blockchain, but also obstacles in terms of regulatory mismatch, technical complexity and lack of professional competence. The work contributes to the development of theoretical and practical understanding of the application of blockchain technology in financial functions and offers recommendations for the implementation and adaptation of internal controls and auditing standards in a digital environment.*
Keywords: *Blockchain, accounting, auditing, continuous reporting, internal controls, digital transformation.*

Apstrakt: *Razvoj blockchain tehnologije otvara nove mogućnosti za transformaciju računovodstvenih i revizijskih procesa, nudeći transparentnije, sigurnije i gotovo trenutačno bilježenje poslovnih događaja. Ovaj rad istražuje potencijal blockchaina za uspostavljanje kontinuiranog finansijskog izvještavanja i jačanje sistema internih kontrola. Cilj istraživanja je analizirati kako primjena distribuiranih registara može unaprijediti tačnost, pouzdanost i pravovremenost računovodstvenih informacija te kako utječe na ulogu revizora i regulatorne zahtjeve. Metodološki okvir obuhvata kvalitativnu analizu i istraživanje u Bosni i Hercegovini i regiji. Rezultati ukazuju na rastući interes i percepciju koristi blockchaina, ali i na prepreke u pogledu regulatorne neusklađenosti, tehničke kompleksnosti i nedostatka stručnih kompetencija. Rad doprinosi razvoju teorijskog i praktičnog razumijevanja o primjeni blockchain tehnologije u financijskim funkcijama te nudi preporuke za implementaciju i prilagodbu internih kontrola i revizijskih standarda u digitalnom okruženju.*
Ključne riječi*: Blockchain, računovodstvo, revizija, kontinuirano izvještavanje, interne kontrole, digitalna transformacija.*

Introduction

The digital transformation of business over the past decade has had a profound impact on the accounting and auditing profession. Traditional reporting models, based on periodic calculations and manual verification of transactions, are increasingly giving way to technological solutions that enable continuous monitoring and verification of business processes. In this context, blockchain technology –

as a distributed and immutable transaction register – represents one of the most promising instruments for improving the accuracy, transparency and security of financial reporting.

Blockchain technology enables the recording and storage of transactions in a chain of blocks that are cryptographically linked to each other, thus eliminating the possibility of subsequent data changes without a trace. This strengthens trust in accounting information and opens up the possibility of the so-called triple-entry accounting model, which goes beyond the traditional principle of double-entry bookkeeping. Instead of accounting records being kept separately for each party to a transaction, blockchain provides a shared, decentralized record that is verified and accessible to all relevant actors.

In addition to increasing transparency, blockchain has the potential to enable continuous financial reporting – a process in which business data can be analyzed and distributed to financial information users in real time. This reduces the time gap between the origination of a transaction and its presentation in reports, which significantly improves the quality of decision-making and internal control.

However, the implementation of blockchain technology in accounting and auditing also poses a number of challenges. Technical complexity, the need for interoperability with existing ERP systems, legal uncertainty regarding the validity of digital records, and a lack of professional competence represent key barriers to wider adoption. In addition, the question arises of how auditing standards and internal control frameworks should adapt to new digital processes and automated reporting systems.

The aim of this paper is to explore the potential of blockchain technology in accounting and auditing, with a particular focus on the possibilities of continuous financial reporting and the implications for the internal control system. The paper seeks to offer a theoretical framework and practical recommendations for organizations, auditors and regulators, drawing on the latest research and practice in this area.

1. Blockchain technology and triple-entry accounting

Blockchain is a decentralized ledger, that is, a transaction register in which data is grouped into blocks, each block containing a cryptographic hash of the previous one, a timestamp, and transaction data ("Triple –Entry Accounting And Blockchain: A Common Misconception", 2017). Due to this structure, once entered, data is difficult to change without great risk, which achieves high integrity of the records. Traditional accounting implies that for each transaction there is a debtor and a creditor within a single company. While the triple-entry concept builds on this foundation by adding a third record, which can be a joint record between the parties to the transaction or a record in a decentralized register, which strengthens transparency and credibility. As they actually interact with each other, for example, company A enters its debt entry, and company B enters its entry, the third entry is a record on the blockchain that represents a joint register and confirms that the transaction was made and synchronized between the parties. In this way, the possibility of one party later changing the data without the other party not seeing it is reduced. This model allows for greater automation, coordination, and reduces risk and audit costs. According to Georgiou (2024), blockchain enables the so-called digital trail of trust through cryptographically secured transaction records. Which in the context of accounting would mean that business entities could share a common transaction ledger that is accessible in real time to all relevant parties and customers, suppliers, banks and auditors.

2. Blockchain and continuous financial reporting

Blockchain, as a decentralized and transparent digital register, enables real-time recording of transactions, thereby reducing the need for subsequent reconciliations and manual audits. Continuous reporting represents the evolution of the concept of digital accounting towards systems in which financial data is updated and available in almost real time. Dai and Vasarhelyi (2023) emphasize that blockchain enables a continuous flow of data that can be analyzed automatically using smart contracts. These contracts allow certain actions – e.g., posting a transaction or issuing an invoice – to be performed

automatically when predefined conditions are met, but such an approach significantly reduces the possibility of human error, but also increases the need for new types of controls – primarily IT controls, which ensure the correctness of algorithms and network security. This also redefines the role of the accountant: instead of manually entering and checking data, the focus shifts to monitoring automated processes and analyzing the generated information (Han, 2022). However, for the full implementation of continuous reporting on blockchain, it is necessary to develop regulatory standards, technical interoperability protocols, and common accounting models that enable digital verification of data in accordance with international financial reporting standards.

3. Implications for internal controls and audits

Blockchain implementation changes the structure of internal controls within organizations. While traditional systems rely on centralized access control, blockchain introduces distributed control and automated data verification. AICPA (2023) states in its guidance that blockchain can increase data integrity, but also create new risks — particularly with regard to access to private keys, integration with existing systems, and compliance with data protection legislation.

According to Vitali et al. (2023), auditors will have to develop new methods to verify the accuracy of data on the blockchain, understand the technical architecture of the network, and verify smart contracts. Digital tools such as data analytics and artificial intelligence have already begun to facilitate the process of "continuous audit", which additionally confirms the direction of development towards the increasing automation of audit procedures. With the introduction of this technology, there are new challenges for internal controls and auditing: users must develop competencies for evaluating blockchain platforms, understand the risks related to cryptographic algorithms and consensus mechanisms, and cooperate with IT departments and regulators in the development of standards and protocols, which would mean additional education in new areas that are not specifically related to accounting.

4. Regulatory framework and implementation challenges

Despite its great potential, the mass implementation of blockchain in accounting is still at an early stage. According to ACCA (2024), the main challenges include a lack of regulatory clarity, standardization and professional competence. In the EU and the US, there are currently no specific accounting standards that would fully define the treatment of transactions recorded on blockchain, which makes it difficult to recognize them in official financial statements. Existing international accounting standards (IFRS, ISA) are not fully adapted to digital, distributed record systems, which creates legal uncertainty regarding the recognition and verification of blockchain records as official documents. Regulatory bodies and professional associations, such as the International Federation of Accountants (IFAC) and the International Auditing and Assurance Standards Board (IAASB), are currently exploring ways to integrate blockchain into existing financial reporting and auditing frameworks (IFAC, 2023).

5. Blockchain application technologies in practice

Numerous audit firms are already developing and implementing their own blockchain-based tools to improve the collection, processing and verification of financial data. Among the most famous examples of such solutions are the EY Blockchain Audit Tool and the PwC Halo Platform, which are pioneering examples of the application of blockchain technology in professional accounting services. The EY Blockchain Audit Tool was developed by Ernst & Young (EY) as a platform for auditing and reconciling data from blockchain networks and "classic" accounting/business records. ("EY Blockchain Analyzer: Reconciler", 2022)

Specifically, the "Reconciler" version allows audit teams to compare internal data (off-chain books and records) with public blockchain transactions and data (on-chain) in large quantities — which helps

assess the integrity, full transparency, and possible differences between the data. ("EY releases new generation of blockchain solution", 2023).

Recently, advanced AI (artificial intelligence) functionalities have been added, especially for reviewing and analyzing smart contracts and tokens. This tool is an example of technological innovation in the field of auditing that affects:

- Transparency in business (especially in blockchain activities and crypto assets)
- Trust in data (on-chain vs off-chain)
- Compliance with regulatory requirements – for example, for financial institutions entering the blockchain and crypto sectors
- It helps audit firms and users better understand risks and potential inconsistencies in value chains involving blockchain technology.
- It may also be relevant in the analysis of business models that are digitalized, transparent, or use value distribution via DLT (Distributed Ledger Technology).

For example, imagine a company that deals in cryptocurrencies – say, a company that accepts payments in Bitcoin. In the traditional accounting process, an auditor would have to manually verify that all transactions recorded in the general ledger (GL) were actually executed on the blockchain network. This used to be a very complex and time-consuming process.

Using the EY Blockchain Analyzer: Reconciler tool, the auditor automatically reconciles data from an accounting system (e.g. SAP, QuickBooks or Oracle) with data from the blockchain. The tool automatically downloads all blockchain transactions from the company's specified wallet addresses,

compares them with internal records of income and expenses, marks each transaction as "matched" or "non-matched".

The company "CryptoTrade doo" records that on March 15, 2025, it received a payment of 0.5 BTC (valued at 20,000 KM) for the sale of a software license. EY Blockchain Analyzer automatically finds this transaction on the Bitcoin network, confirms that it was indeed made from the buyer's address to the company's address, and marks it as confirmed and reconciled in the audit report. If the value in the books were different from that on the blockchain (e.g. due to exchange rate differences or an entry error), the tool would automatically mark this as a discrepancy and generate a report for the auditor.

Although an important tool, it is not a perfect solution, as with all technologies, there are some drawbacks, such as:

- Data quality: If internal (off-chain) data is not well managed, comparison may be limited.
- Permissions and Access: In order to use on-chain data in an audit, there must be visibility, access and an appropriate relationship to privacy.
- Blockchain specifics: Working with different blockchain networks (public, private), it is necessary to adapt tools and methodology.
- Regulatory and ethical aspects: When using blockchain data, legal issues (money laundering allegations, regulation of digital tokens) become important—which coincides with your focus on the legal and media issues of the business.

The PwC Halo Platform is an analytical/data-audit platform that PwC uses as part of its audit process. Halo enables the processing of entire data populations (e.g. all transactions in the general ledger) instead of just a sample of controls, thereby increasing the depth of analysis. The platform enables the extraction, visualization and analysis of large amounts of data (Big Data approach) within the audit process. ("Audit of General Ledger with Halo", 2023). Halo is part of PwC's broader audit technology suite, together with tools such as Aura (for audit work management), Connect (for collaboration) and Extract (for data extraction).

The key features and functions of this tool according to ("PwC's Technology Enabled Audit", 2023) are:

- Analysis of entire data population: Halo can test large amounts of data – e.g. all general ledger items in the client system.
- Visualization and dashboards: The platform provides visual displays ("dashboards") that help auditors quickly spot patterns, anomalies, or risky transactions.
- Identifying risky transactions: For example, Halo can allow auditors to track specific transactions — who entered them, when, whether they were under the proper authorization.
- Greater efficiency: Automating manual tasks (e.g., data retrieval, filtering, visualization) reduces time and potential human errors.
- Improving audit quality: By using the Halo tool, PwC says it can provide deeper insight into a client's business and support its audit report with greater confidence.

While Halo has strong capabilities, challenges remain:

- Access to and quality of client data (if data is incomplete or of poor quality, effects may be limited).
- Adjustment of the internal audit process is required: Auditors must have the skills to work with such tools, interpret visualizations and make decisions in a more complex environment.
- Issues of privacy, data protection and security are very important: Working with large amounts of client data and analyzing it requires strong controls.

The PwC Halo Platform is a digital audit tool that uses blockchain technology to collect and verify financial data directly from the source, without the need for intermediaries. For example, in the process of auditing cryptocurrency transactions, PwC Halo allows auditors to connect directly to blockchain networks (e.g. Bitcoin or Ethereum) and automatically download all transactions that a client has recorded in their books.

Specifically, if a company owns digital assets (cryptocurrencies) and keeps them on the balance sheet, PwC Halo uses blockchain to confirm ownership of specific digital addresses (wallets), verify the existence of assets in real time, and reconcile amounts with the general ledger. In this way, the auditor does not have to seek manual confirmations or extracts from third parties, as the blockchain serves as an immutable and transparent source of truth.

For example, if a company has 50 BTC recorded in its accounting books, PwC Halo automatically checks the blockchain and confirms that the address actually contains 50 BTC and that there have been no unauthorized transactions. This significantly reduces the risk of errors, manipulation and misrepresentation of assets, and makes the audit process faster, more secure and based on real data from the blockchain.

6. Comparison Estonia vs Bosnia and Herzegovina

According to OECD reports (Estonia in the Digital Economy and Society Index, 2023), Estonia is among the most digitized countries in Europe, with a high rate of e-service use and advanced solutions in system interoperability. Estonia has built an almost completely digital state: citizens and businesses use government e-services (tax returns, health records, voting, registers) available online 24/7 with secure authentication and digital signature. Where the key components are: Digital ID and digital signature — government cards / certificates that enable secure login and signing of documents online. X-Road — a distributed, open layer for secure data exchange between government and private systems (allows systems to "talk" without a central repository). Specific e-services: e-Tax (digital tax return), e-Health, e-School, e-Police, e-Residency (digital "citizenship" for online business). Legal and organizational framework: legislation enables digital signatures, data access, access records and transparency obligations ("e-Estonia solutions").

Estonia is often cited as one of the most successful examples of digital transformation in the public sector, thanks to a clear political vision, continuity and strategic commitment to digitalisation since independence. The key foundation for success was a legal framework that recognised digital signatures

early on and regulated electronic registers, privacy protection and accountability from entities. At the technical level, the interoperable X-Road system was developed, which enables secure data exchange between independent state systems via a standardised network. In parallel, digital identification of citizens was introduced, which enables access to public and private e-services, including banking, healthcare and education. A particular focus was placed on security and resilience, through investments in cybersecurity, the creation of "data embassies" and the implementation of detailed audit logs of data access, with Estonia setting global standards in the field of digital governance. ("Land is so yesterday': e-residents and 'digital embassies' could replace country borders", 2016.)

The Western Balkans can use this example to start a pilot project, baking with a political strategy, as Estonia did, and a legal framework. It is necessary to build a federated architecture such as X-Road, which would enable the connection of existing registries. It is also necessary to work on user education and investment in digital ID, as well as creating transparent and secure tools for data protection. The goal is to create a basis and a digital foundation, as Estonia did, which not only has the technical and institutional capacities but also has concrete experience, experimental applications of blockchain technology in public records and administrative processes. Due to this digital maturity, it is considered the country that can most easily and quickly expand the application of blockchain in accounting, auditing, finance and e-commerce. Which means that the Western Balkan countries also need to do this first, so that they can then start implementing blockchain technology in business sectors.

Table 1 Comparison table Estonia vs Bosnia and Herzegovina

Criterion	Estonia	Bosnia and Herzegovina
Strategic vision and continuity of digitalization	High - digital state developed since the 1990s, strong political will, established system.	Weak-medium – strategies exist (e.g. Information Societies 2017-2021) but fragmented, without a comprehensive framework.
Legal regulation / digital identity / e-signature	Mature digital signature and ID card system, laws since the 2000s.	Still under development – the problem of digital identity and compliance with EU regulations.
Technical architecture and interoperability	Advanced: systems like X -Road for data exchange between registers, high level of services.	The technical infrastructure exists, but it is often unused or disjointed.
Coverage and use of services	High - a large number of services available online, high acceptance by citizens.	Lower - many services are still not fully digitized, differences between levels of government.
Benefits achieved	Efficiency, lower cost, high transparency, innovation.	Potential for a big shift, internet access already present, but still insufficiently used
Challenges / disadvantages	Security risks (cyber attacks), local parts of the system less efficient.	Organizational, regulatory, fragmentation of government, implementation capacities.
Implementation difficulty	Although demanding, it was made easier by a smaller population, political consensus, and a focus on digitalization.	Greater complexity due to multiple levels of government, disunity, lack of a unified vision and often fewer resources.

Source: authors

7. Advantages and disadvantages applications blockchain technologies on area Western Balkans

In the context of Western Balkan countries that are still in the process of digital transformation, the application of blockchain technology, first of all, allows for increased transparency and credibility of financial data, because all records are created in a decentralized system that is resistant to manipulation and forgery. Tools such as PwC Halo and EY Blockchain Audit Tool enable automatic verification of

transactions and ownership of digital assets, thereby accelerating the audit process and reducing the risk of errors. In addition, blockchain can improve trust between companies, investors and auditors, because data becomes verifiable in real time.

Although the benefits of blockchain seem promising, the Western Balkan countries face a number of limitations in its implementation. The most significant challenge is the insufficient digital infrastructure and technological readiness, as well as the small number of companies that are already using blockchain, as most companies still use outdated accounting software that is not compatible with blockchain platforms. There is also a lack of experts with knowledge of blockchain technology, which makes its practical application in auditing and financial reporting difficult. In addition, the regulatory framework in the Western Balkan countries is not yet aligned with international standards governing digital assets, cryptocurrencies and blockchain processes, so auditors often do not have a clear legal basis for the use of these tools in official reports, so an adaptation process is necessary. Finally, high implementation costs and limited trust in new technologies further slow down the wider application of blockchain solutions in accounting practice.

Conclusion

Blockchain technology represents a significant step forward in the modernization of accounting and auditing processes, offering greater efficiency, transparency and reliability of financial reporting. However, its implementation requires the establishment of new regulatory, ethical and technical standards that will enable the safe and controlled use of these solutions. In the context of Bosnia and Herzegovina and the Western Balkans, it is necessary to approach blockchain gradually — through pilot projects in the public and private sectors , while developing institutional capacities and a regulatory framework aligned with EU practices. The key to success lies in education and cross-sectoral cooperation between IT and accounting professionals, which would create the foundations for a digitally reliable and sustainable business environment. It is recommended that regulatory and professional institutions in BiH actively monitor international trends and develop guidelines for the standardized application of blockchain technology, so that the private and public sectors can more safely implement these innovations and maximize their benefits. In this way, blockchain can become not only a technological innovation, but also a driver of trust, integrity and competitiveness of the BiH economy. Examples from Europe show that countries with developed digital infrastructure and clear regulatory frameworks, such as Estonia, can quickly integrate blockchain into business and public processes, thereby achieving significant efficiencies and improving transparency. Given the global trend of business digitalization, blockchain technology is becoming a key tool for modernizing accounting, auditing and data management, providing a competitive advantage to organizations that successfully implement it.

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Costs of Implementing Safety Measures at Work in the Underground Exploitation of Mineral Raw Materials

Troškovi realizacije mjera zaštite na radu kod podzemne eksploatacije mineralnih sirovina

Kasim Bajramović[1], Irfan Bajramović[2], Irhad Bajramović[3]

[1]*International University Travnik in Travnik, Travnik, Bosnia and Herzegovina, kasimbajramovic@gmail.com*
[2]*EP BiH – Kakanj Thermal Power Plant, Kakanj, Bosnia and Herzegovina, irfanbajramovic95@gmail.com*
[3]*EP BiH – Kakanj Thermal Power Plant, Kakanj, Bosnia and Herzegovina, irhadbajramovicbajra@gmail.com*

Abstract: *Underground mining of mineral raw materials carries a high level of risk to the health and safety of workers due to specific working conditions such as confined spaces, the presence of harmful gases and the risk of collapse. Therefore, it is necessary to implement comprehensive occupational safety measures, which include the use of personal protective equipment, technical safety systems, employee training and appropriate work organization. The implementation of these measures requires significant financial investments, which raises the question of their economic justification. This paper analyzes the structure and amount of occupational safety costs in underground mining conditions, as well as their impact on the overall business of mining companies. By comparing costs with data on the reduction of injuries and work stoppages, the paper indicates the long-term benefits of investing in safety. The goal is to identify the optimal balance between effective protection and the economic sustainability of mining activities.*
Keywords: *Safety at work, underground exploitation, mining safety, costs, mineral raw materials.*

Apstrakt: *Podzemna eksploatacija mineralnih sirovina nosi visok nivo rizika po zdravlje i sigurnost radnika zbog specifičnih radnih uslova kao što su ograničen prostor, prisustvo štetnih gasova i opasnost od urušavanja. Zbog toga je neophodna primjena sveobuhvatnih mjera zaštite na radu, koje uključuju upotrebu lične zaštitne opreme, tehničke sisteme sigurnosti, obuke zaposlenih i odgovarajuću organizaciju rada. Realizacija ovih mjera zahtijeva značajna finansijska ulaganja, što otvara pitanje njihove ekonomske opravdanosti. Ovaj rad analizira strukturu i visinu troškova zaštite na radu u uslovima podzemne eksploatacije, kao i njihov uticaj na ukupno poslovanje rudarskih kompanija. Kroz poređenje troškova s podacima o smanjenju povreda i zastoja u radu, rad ukazuje na dugoročne koristi od ulaganja u sigurnost. Cilj je identifikovati optimalan balans između efikasne zaštite i ekonomske održivosti rudarskih aktivnosti.*
Ključne riječi: *Zaštita na radu, podzemna eksploatacija, rudarska sigurnost, troškovi, mineralne sirovine.*

Introduction

Underground exploitation of mineral resources represents a complex and high-risk process that requires a specific approach in the field of occupational safety. Workers in mines are exposed to numerous hazards, including collapses, explosive gases, poor ventilation, and difficult working conditions. Therefore, it is necessary to implement a series of safety measures to ensure the protection of employees and reduce the number of accidents. However, the implementation of these measures often requires significant financial resources, which poses a challenge for mining companies.

This paper analyzes the costs arising from the implementation of occupational safety measures in underground mining operations and examines their justification from the perspective of safety and economic efficiency.

1. Occupational safety in underground exploitation of mineral resources

Underground mining is characterized by a high level of diverse risks that endanger the safety and health of employees and company property, as well as the health and property of citizens. Therefore, mining companies face increased requirements regarding occupational safety.

Occupational safety is an integral part of work organization and the execution of work processes. It is implemented through the application of a series of rules prescribed by the Law on Mining, the Law on Occupational Safety, the Law on Environmental Protection, and other by-laws and technical regulations related to the design, construction, use, maintenance, and testing of work equipment. The main goal of these regulations is to eliminate or reduce workplace hazards and prevent injuries, occupational and other diseases, as well as other harmful consequences for workers, while also protecting company property.

The most important occupational safety regulations in the field of underground exploitation of mineral resources include:

- Precisely defining methods and procedures related to the execution of specific underground works within project documentation and other technical instructions;
- Development of technical safety devices on machines and equipment (e.g. protection against electric shock, noise and vibration, fire, electromagnetic and other radiation, etc.);
- Technical inspections of mining facilities, plants, and equipment, including inspections prior to obtaining an operating permit and commissioning, inspections during operation, as well as mandatory periodic inspections of certain types of equipment (e.g. electrical devices and installations);
- Provision of personal protective equipment (PPE) and gear to employees;
- Training and qualification of employees for the safe performance of assigned tasks (information sessions, training, and periodic knowledge assessments);
- Ensuring proper working and environmental conditions in terms of employee health protection (e.g. maintaining cleanliness through the construction of necessary hygienic and sanitary facilities; ensuring adequate temperature, humidity, air volume, and airflow; protection against harmful gases through the construction and maintenance of an appropriate ventilation system in underground spaces; air quality testing and protective measures against dangerous coal dust; protection against underground and surface water through adequate drainage systems; fire protection measures through proper fire safety infrastructure and equipment control; ensuring proper workplace lighting, etc.);
- Organization of a mine rescue team, first aid service, and fire brigade;
- Implementation of preventive health measures, including pre-employment, periodic, systematic, targeted, control, and extraordinary medical examinations of employees.

2. Structure of occupational safety costs in underground exploitation of mineral resources

The costs associated with the implementation of occupational safety measures in mines can be divided into several main categories:

2.1. Investment costs

- Procurement and installation of ventilation systems and gas detectors,
- Equipment for evacuation and rescue,

- Construction of emergency exits and securing of underground tunnels,
- Construction of shelters and safety chambers,
- Investments in automated monitoring systems (sensors, surveillance).

2.2. Operating (current) costs

- Maintenance and servicing of safety equipment,
- Procurement of personal protective equipment (helmets, lamps, self-rescuers, respirators, boots),
- Regular employee training and education,
- Medical examinations of workers,
- Operating costs of the safety and rescue service.

2.3. Indirect costs

- Loss of productivity due to work interruptions caused by accidents,
- Insurance costs and compensation for injuries,
- Legal and reputational consequences,
- Increased costs of rehabilitation and reintegration of workers into the work process.

3. Cost analysis in practice

Using the example of mines with underground exploitation in the Central Bosnian coal basin (e.g., Kakanj Mine, Zenica Mine, Breza Mine), the average annual costs for occupational safety range between 3 – 6 % of total production costs.

Of this amount:

- 40 % is allocated to the procurement and maintenance of equipment,
- 25 % to training and health protection,
- 20 % to monitoring and preventive systems,
- 15 % to insurance and administration.

It has been observed that mines which continuously invest in modern monitoring systems (methane sensors, automatic ventilation, digital worker tracking) achieve a reduction in the number of injuries and production interruptions by up to 30 %, which directly decreases total operational costs.

4. Economic aspects of investments in occupational safety in underground exploitation of mineral resources

Investments in occupational safety provide multiple economic benefits:

- Reduction in the number of injuries and sick leaves,
- Decrease in insurance and compensation costs,
- Increase in worker motivation and productivity,
- Improved company image and easier access to markets and investors.

According to estimates by the **World Health Organization (WHO)** and the **International Labour Organization (ILO), every 1 KM invested in occupational safety yields a return of 2–3 KM** through the reduction of accidents and losses.

5. Accounting treatment of the costs of implementing occupational safety measures

In order to establish an appropriate model for accounting calculation and recording of costs arising from the implementation of occupational safety measures, the previously mentioned groups of safety-related rules need to be analyzed separately.

The following table presents the method of accounting calculation and cost allocation related to the implementation of specific occupational safety measures, as determined through the conducted analysis.

Table 1. Method of accounting calculation and recording of costs incurred in the implementation of occupational safety measures in underground exploitation of mineral resources

Safety measure at work	Method of accounting recording and allocation of related costs
Methods and procedures for the implementation of specific underground mining operations.	1. They are an integral part of the execution of specific tasks and, therefore, should not be treated separately from the costs associated with the implementation of individual functions and tasks.
Design and installation of technical safety devices on machines and equipment.	1. Accounting into the book value of fixed assets in the function of which the safety devices are installed. 2. Investments with a useful life shorter than that of the main machine/equipment, recorded as: • Separate fixed assets, if their useful life exceeds one year; or • Current period production costs, if their useful life is less than one year, with the possibility of temporal allocation to the covered periods based on the number of months or hours of operation of the main asset. 3. Allocation of the recognized costs according to the actual purpose of use of the respective machines and equipment, i.e., based on the allocation of their depreciation costs.
Technical inspections of mining facilities, plants, and equipment.	1. **Inspections prior to obtaining an operating permit and commissioning** – recognition of the related costs as part of the acquisition cost of the asset. 2. **Mandatory periodic inspections** – recognition of the related costs as current period production costs, with the possibility of temporal allocation (if significant) and allocation according to the actual purpose of use of the respective machines and equipment.
Provision of employees with personal protective equipment (PPE) and gear *(e.g., mining helmet, work suit, mining boots, safety*	1. Collective recognition of personal protective equipment (PPE) with the same useful life (prescribed

Safety measure at work	Method of accounting recording and allocation of related costs
shoes, protective gloves, safety harness, self-rescuer, mining cap lamp, coverall, etc.).	replacement period) by type of work (workstations) as: • Fixed assets (protective equipment with a prescribed replacement period longer than 12 months) • Inventory costs (protective equipment with a prescribed replacement period up to 12 months), with temporal allocation to the relevant accounting periods. 2. Allocation of the corresponding portion of current accounting period costs to individual cost centers based on the number of employees engaged in specific workstations (types of work) for each operation.
Training of employees for the safe performance of assigned tasks (information, training, and periodic knowledge assessments).	1. **Recognition of the related costs as current period production costs, with the possibility of temporal allocation to the relevant accounting periods** (e.g., based on the prescribed training period) **and allocation in the same manner as for the previous measure.**
Organization of a rescue team, first aid service, and fire brigade.	1. **Recognition of costs related to the operation of the rescue team, first aid service, and fire brigade** (theoretical and practical training of team members, duties, and interventions) **as current period production costs, with allocation based on, for example, the total number of employees engaged in the execution of specific tasks.**
Provision of preventive health measures (pre-employment, periodic, systematic, targeted, control, and extraordinary medical examinations of employees).	1. Recognition of related costs as current period production costs, with the possibility of temporal allocation in accordance with the prescribed mandatory health examination periods. Recording of these costs is done by workstations, and their allocation is based, for example, on the hours worked at specific workstations in creating individual cost centers.

Source: Authors

6. Possibilities for cost optimization

In order to reduce costs while maintaining a high level of safety, the following measures are recommended:

- Preventive planning through risk assessment,
- Digitization of monitoring (IoT sensors and automation),
- Joint procurement of equipment through mining unions,
- Continuous training of employees and managers,
- Use of energy-efficient safety equipment (e.g., LED lamps and low-voltage fans).

7. Example from practice – RMU "Kakanj" d.o.o. Kakanj

7.1. The Kakanj mine — year 2023

1. Provisions for labor disputes and workplace injuries (non-material damages) were recorded as expenses during 2023 — BAM 183.910.
    - Context: The report states that during 2023, expenses were charged for provisions related to labor disputes and costs arising from workplace injuries (non-material damages) in the amount of BAM 183.910.
2. The company estimated (in its internal assessments) that the best estimate of the expenditures required to settle existing obligations amounted to a provision of BAM 244.000.
    - Context: The management recorded provisions as of the balance sheet date in the amount of BAM 244.000 as an estimate of the costs for settlement of legal disputes; the audit report noted a discrepancy between this figure and the estimate provided by the Legal Affairs Department.
3. Total lawsuits against the company (all types) amount to BAM 9.900.694; of this total, lawsuits filed by employees for workplace injuries (non-material damages) are stated in the amount of BAM 338.572 (recorded as part of total legal disputes).
    - Context: The report provides a breakdown of the value of lawsuits: commercial disputes, employee lawsuits (workplace injuries and labor relations), and others.
4. Other costs related to damages and injuries: The notes to the financial statements state that "Other expenses and losses (BAM 656.121) mostly relate to subsequently determined expenses from the previous period (BAM 303.111) and compensation costs for expropriation, workplace injuries, and other damages (BAM 299.468)." — therefore, part of the expenditures related to injuries and damages is also presented under this category.
5. Financial position and implications: The company reported a loss for 2023 in the amount of BAM 16,212,474, and an accumulated loss as of 31 December 2023 of BAM 183.685.463. The audit expressed doubt about the company's ability to continue operating without additional corrective measures (this is significant, as it limits the mine's capacity to implement broader occupational safety measures through its own investments).

7.2. Interpretation — what these data indicate about the costs of implementing occupational safety measures

- The amounts of BAM 183.910 and BAM 244.000 primarily refer to provisions and estimated liabilities for legal disputes and compensation for injuries, not to ongoing/operational expenses related to implementing occupational safety measures (e.g., procurement of ventilation systems, PPE, training, maintenance of gas detection systems, etc.). Thus, these figures represent the cost of consequences (claims and compensation) rather than the direct budget for prevention and safety.
- The auditors also noted that many actual investments and items (CAPEX in progress, public procurements, investment status) were insufficiently documented or scattered across various accounts. Therefore, the actual annual amounts that RMU Kakanj spends on preventive measures should be gathered from:

    a) CAPEX and investment items in the financial statement notes,
    b) public procurement sections (tenders for ventilation, pumps, detectors, PPE), and
    c) internal accounts related to "maintenance" and "other operating expenses."

Conclusion

Effective cost management requires a balance between safety, technology, and the economic capabilities of the mine. Investments in safety should not be viewed as an expense, but as an investment in the stability of the mining sector and the company's social responsibility. Occupational safety measures in underground mines represent a necessary component of sustainable operations. Although they generate significant costs, their implementation reduces risks in the long term, increases productivity, and saves human lives.

Occupational safety measures in underground mineral resource exploitation are a key factor in protecting workers' health and safety, as well as ensuring continuity of production. While their implementation requires considerable financial investment, the long-term effects—such as reduced injuries, minimized work stoppages, and prevention of potential damages—far outweigh these costs. Analysis of the cost structure clearly shows that preventive measures, regular maintenance of safety systems, and employee training contribute not only to a higher level of safety but also to greater operational efficiency.

Investing in occupational safety should therefore be regarded not as a cost, but as an investment in sustainability and responsible mining. Further optimization of existing measures is recommended through the adoption of modern technologies and the strengthening of safety awareness at all levels of management.

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Digital Storytelling and Generational Perception

Digitalna naracija i generacijska percepcija

Irena Gedle Giorgis[1], Tijana Đukić[2], Miloš Mastilović[3]

[1]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, irenanroma@gmail.com*

[2]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, tijana.djukic@mef.edu.rs*

[3]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, office@clickmedia.rs*

***Abstract**: This paper analyzes digital storytelling as a contemporary pedagogical framework that integrates narrative, multimedia, and generational learning preferences. The objective of the project is to investigate the impact of digital narratives on student engagement generations via interactive and visually dynamic forms. A comparative examination of digital platforms TikTok and YouTube was performed to discern variations in engagement patterns and learning preferences across generations. Research demonstrates that Millennials, Generation Z, and Generation Alpha favor concise, visually engaging content that amplifies emotional connection and cognitive involvement. The research emphasizes the capabilities of AR/VR technology in representing cultural heritage and the significance of educator-generated movies in online learning. The successful integration of digital storytelling in education necessitates addressing technological, pedagogical, and ethical difficulties.*
***Keywords**: Artificial intelligence, digital storytelling, generations, educational video, AR/VR.*

***Apstrakt**: Rad analizira digitalno pripovedanje kao savremeni pedagoški pristup koji obuhvata narativ, multimediju i generacijske preferencije učenja. Cilj rada je da istraži uticaj digitalnih narativa na angažovanje studenata različitih generacija putem interaktivnih i vizuelno dinamičnih formata. Sprovedena je komparativna analiza digitalnih platformi TikTok i YouTube radi utvrđivanja razlika u obrascima angažovanja i preferencijama učenja među generacijama. Istraživanja pokazuju da milenijalci, generacija Z i generacija Alfa preferiraju sažet, vizuelno privlačan sadržaj koji pojačava emocionalnu povezanost i kognitivnu uključenost. Rad ističe mogućnosti AR/VR tehnologija u predstavljanju kulturnog nasleđa i značaj obrazovnih video-materijala koje kreiraju nastavnici u onlajn okruženju. Uspešna integracija digitalnog pripovedanja u obrazovanje zahteva rešavanje tehnoloških, pedagoških i etičkih izazova.*
***Ključne reči**: Veštačka inteligencija, digitalna naracija, generacije, obrazovni video, AR/VR.*

Introduction

Digital storytelling has emerged as an essential and revolutionary tool for educational engagement, particularly in accordance with generational preferences. The rapid evolution of digital communication has redefined how messages are created, shared, and perceived in modern media ecosystems (Kostovski & Đukić, 2025). This transformation underpins the rise of digital storytelling as a convergence of narrative, marketing, and interactive technologies. It highlights the significant impact of interaction and multimedia on the ways various age groups process, engage with, and remember content. Millennials, Generation Z, and Generation Alpha exhibit a pronounced preference for formats that integrate narrative, visual, and interactive elements, indicative of their early involvement in digital settings. These learners are drawn to dynamic and visually engaging forms that align with their technology proficiency and inclination for experiential learning. Motivation and engagement are key behavioral factors that vary significantly across generations, influencing how individuals interact with digital content and learning tools (Mladenović, Petrović, & Novović, 2024).

Digital tales create profound, immersive experiences by integrating storytelling with multimedia elements, including images, sound, video, and interactive components. This amalgamation of media not only improves cognitive involvement but also cultivates emotional connection and interactive learning. The author contends that digital storytelling may make traditional topics, like cultural heritage, more accessible and relatable by incorporating various multimedia components into interactive documentary formats. Interactive experiences elicit profound emotional responses and foster engagement in participation, making the learning process more active and meaningful compared to static or linear media (Pentescu, 2023). Generational disparities additionally influence choices in audience engagement with digital tales. Millennials, born from the early 1980s to the mid-1990s, constitute a transitional generation that connects the pre-digital and digital epochs, valuing both extensive, long-form content and vibrant internet media. Conversely, Generation Z and Generation Alpha, having developed wholly within digital environments, prefer concise, high-impact styles characteristic of platforms like TikTok, Instagram, and YouTube. This generational tendency for brevity, immediacy, and involvement underscores the need to adapt instructional methods to current digital consumption trends. The integration of multimedia storytelling in education not only engages attention but also improves understanding and retention. Li et al. (2022) assert that the incorporation of past knowledge with multimedia design in educational settings markedly enhances learning efficiency, emphasizing the instructional value of tailoring information to the cognitive preferences of various generations.

Digital storytelling integrates education, culture, and technology, transforming conventional learning paradigms via multimedia interactivity and audience-focused involvement. It redefines the construction and dissemination of knowledge, converting learners from passive recipients into active contributors to meaning-making.

1. Generational differences in video engagement

The analysis of generational disparities in video interaction reveals a significant contrast between older and younger audiences regarding their choices, motives, and interactive behaviors across different platforms. This trend is especially apparent when comparing interaction on platforms such as TikTok and YouTube, where audience demographics and watching behaviors profoundly influence content tactics. Studies demonstrate that younger populations, especially Generation Z, favor concise, engaging, and visually stimulating information, exemplified by platforms like TikTok (Etta et al., 2024; Salka et al., 2023). This audience engages with content that is frequently humorous or fashionable, prioritizing entertainment above substance (Valiño et al., 2022). Conversely, older demographics choose sites like YouTube, which provides longer-form content suitable for comprehensive debates and educational videos (Oh & Choeh, 2021). The extended video format enables authors to convey comprehensive tales or instructive material, aligning with the informational requirements of older generations (Tur, 2025).

Research indicates that although TikTok's interactive elements promote creativity and user-generated content, they frequently result in diminished engagement rates despite elevated view counts (Vassey et al., 2022; Martí-Ochoa et al., 2024). The design of the TikTok platform facilitates rapid consumption, resulting in a swift audience but without necessarily encouraging substantive participation or discourse regarding the material. Concurrently, YouTube videos created by credible sources, such as healthcare professionals, generally achieve elevated engagement metrics owing to their perceived quality and stringent content guidelines (Gomes et al., 2024). This indicates that video duration and context are crucial factors affecting engagement levels, influencing how various generations interact with the offered content.

The emotional appeals utilized in video material substantially influence engagement levels among different generations. Research indicates that videos utilizing emotional resonance, particularly in health messages, might improve viewer engagement; yet, younger audiences may be less responsive to conventional emotional appeals, preferring authenticity and relatability (Jerin et al., 2024). On TikTok,

creators employing comedy or personal tales generally connect more effectively with younger audiences, indicating a transition towards content that is perceived as relatable rather than merely educational (Fong et al., 2024). Consumer behavior reveals significant disparities in engagement metrics across various video formats and platforms. TikTok's algorithm prioritizes viral content that rapidly enhances user profiles and cultivates community among its youthful audience, whereas YouTube underscores the importance of source legitimacy and content quality. Videos produced by reputable media organizations typically garner better user interaction than those created by independent content providers, owing to established credibility and superior production quality (Alraqiq et al., 2021; Ma & Gu, 2022). This variation in material engagement underscores the generational divide, necessitating that the context and presenting style correspond with the audience's expectations and digital competence. Generational disparities in video interaction draw attention to the importance of customized content strategies that correspond with audience demographics. Concise, captivating content that emphasizes inventiveness draws younger audiences, while older audiences prefer information dissemination that emphasizes depth and dependability. Consequently, artists and marketers must meticulously tailor their strategies to accommodate these unique interaction patterns, acknowledging that the efficacy of video content is intrinsically linked to the platform's user demographics and the generational traits of its audience. A comparative overview of generational engagement across platforms is presented in Table 1.

Table 1. Comparison of generational engagement patterns on TikTok and YouTube

Generational group	Preferred platform	Content characteristics	Engagement style	Educational potential
Millennials (1981–1996)	YouTube	Longer, structured, informative videos	Analytical engagement, comment-based interaction	Suitable for tutorials, professional learning, and in-depth discussions
Generation Z (1997–2012)	TikTok	Short-form, visually stimulating, trend-driven videos	Rapid, emotional, and participatory (duets, reactions)	High potential for micro-learning and creative assignments
Generation Alpha (2013–present)	TikTok / YouTube Kids	Interactive, gamified, story-driven content	Immersive, visual-first, driven by interactivity	Effective for early-stage learning, digital literacy, and narrative-based education
Older Generations (Gen X and above)	YouTube	Informational, documentary-style content	Observational, less interactive	Valuable for lifelong learning and cultural education

Source: Author's processing based on Tur (2025), Valiño et al. (2022), and Etta et al. (2024).

2. Educational applications and student engagement

The incorporation of educational videos into learning processes has become more vital for improving student engagement in diverse educational settings. Recent studies demonstrate that the incorporation of videos enhances student emotional involvement, which is essential for promoting active participation in educational activities (Ocampo & Junaidi, 2024). Educational movies not only convey information but also engage students emotionally, thus enhancing their motivation and dedication to their studies (Alsaid et al., 2025). Videos created with targeted educational goals can successfully engage attention if they are well-organized and pertinent to students' learning requirements (Basmayor, 2022; Maloney et al., 2022). The quality of educational videos and their capacity to captivate students can be profoundly affected by their design and context of utilization. Research indicates that videos featuring interactivity,

such as quizzes or reflective prompts, generally foster higher engagement levels than conventional lecture formats (Wang et al., 2022; Singh et al., 2023). Interactive components promote active learning, urging students to engage critically with the material instead of merely absorbing information. Studies demonstrate that learner engagement frequently diminishes in conventional video formats, hence constraining the efficacy of these resources in improving educational outcomes (Yuniarti et al., 2024). The utilization of teacher-created videos is particularly advantageous, since it enhances instructor presence and encourages a closer relationship between students and their educators. This approach can boost student motivation and engagement, especially in online learning environments that limit direct interaction (Hilton, 2022; Truss et al., 2024). Research on students' attitudes toward online learning highlights generational variations in engagement and adaptability to digital platforms (Božić, 2023), confirming that Generation Z demonstrates higher receptivity to multimedia-based learning than older cohorts. Videos can cultivate a sense of community among students by emulating some elements of in-person interactions when visual and vocal signals from instructors are incorporated. Moreover, research indicates that reduced class sizes and interactive video materials can improve engagement in synchronous online sessions (Händel et al., 2022).

Researchers have employed analytics and log data from Learning Management Systems (LMS) to investigate student engagement patterns and their interactions with video content (Maloney et al., 2022). Understanding these behaviors is crucial for improving educational methods, as higher engagement levels correlate with superior learning outcomes (Zeidan et al., 2022). The use of embedded quizzes in lecture videos has shown considerable enhancements in student engagement, suggesting that educators should contemplate the adoption of interactive formats to complement conventional approaches (Singh et al., 2023). Despite the considerable advantages of educational videos, problems remain in their application. Certain studies emphasize concerns like passive engagement, wherein students may view videos without actively assimilating the material conveyed (Alsaid et al., 2025; Mirriahi et al., 2021). This problem underscores the imperative for educators to implement pedagogical approaches that foster active engagement with video information, thereby enhancing cognitive involvement and comprehension (Hamadi et al., 2023; Oviawe, 2020).

Interactive technologies, such as video-based collaborative tools, have demonstrated the ability to cultivate a participatory learning environment and improve the overall educational experience (Hamadi et al., 2023; Valencia et al., 2023). Moreover, novel strategies like the integration of gamification into video content have demonstrated efficacy in sustaining student engagement and motivation throughout the learning process (Mohammadi et al., 2024).

The strategic implementation of educational videos markedly enhances student engagement when meticulously prepared and incorporated into a systematic learning framework. By utilizing interactive elements and fostering emotional connections through video content, educators may cultivate a more dynamic and engaging learning experience that enhances academic achievements and stimulates student motivation to study.

3. Technological advancements: AR, VR, and cultural heritage stories

Accelerated advancements in technology, particularly Augmented Reality (AR) and Virtual Reality (VR), are broadening the scope of digital storytelling. This is especially apparent in areas such as cultural heritage tourism, where immersive storytelling can captivate visitors in unparalleled ways. Augmented Reality (AR) and Virtual Reality (VR) enable users to engage with narratives not merely through reading or viewing, but by immersing themselves within the story: VR facilitates a 360° immersion into historical settings, whereas AR superimposes narrative elements onto the physical environment, such as visualizing ruins via a mobile device and witnessing augmented animations of the ancient civilization. Adewojo (2025) emphasizes that the integration of AR/VR with digital storytelling has transformed the protection and transmission of cultural assets. These technologies generate immersive experiences that captivate varied audiences, especially the younger demographic familiar with digital media. A virtual

reality tour enables Gen Z users to navigate a historical city or museum gallery, engaging with artifacts and listening to narrations, transforming a static textbook chapter into an immersive experience.

This immersive storytelling cultivates a deeper emotional bond and encourages active engagement, transforming people from passive spectators into co-creators of cultural tales. Studies indicate that VR-based historical narratives can enhance visitors' emotional involvement and their likelihood of visiting or supporting cultural places. Similarly, augmented reality applications on smartphones can gamify heritage exploration, analogous to scavenger hunts or Pokémon Go-style missions at historical locations, rendering learning enjoyable and interactive for younger audiences. Kasemsarn and Nickpour (2025) note that the ability of AR and VR to generate interactive narrative environments is crucial for engaging younger audiences and maintaining their interest in cultural content. By integrating diverse voices and views (e.g., experiencing a historical event through various characters' eyes in VR), these tools foster inclusivity and enhance comprehension of cultural variety. In summary, immersive technology enhances digital storytelling by engaging many senses and facilitating personal exploration, which is especially successful for Generation Z and Alpha, who anticipate significant engagement in digital experiences.

The tourism sector is utilizing these findings. Numerous cultural heritage sites currently provide augmented reality and virtual reality storytelling experiences, such as applications that enable tourists to direct their cameras at a castle to witness a reenactment of a medieval battle or virtual reality stations that allow them to "time-travel" to old markets. Such projects engage younger visitors in their own technical domain. According to one study, emerging technologies such as VR and AR offer innovative instruments to stimulate adolescent engagement in cultural heritage, thereby augmenting both educational significance and fun. Preliminary research indicates that this fosters enhanced appreciation and sustained interest in heritage among youth, since the emotional and experiential influence of immersive narratives renders history vibrant rather than distant.

3.1. Effects on literacy and language learning

Digital storytelling substantially enhances reading and language skills at many school tiers. The incorporation of multimedia tales into reading and language training improves comprehension, retention, and learner motivation. Research indicates that students engaged with digital narratives exhibit superior reading comprehension and prolonged knowledge retention relative to those utilizing solely text-based resources. The integration of text, visuals, audio narration, and animation stimulates several sensory modalities, enhancing comprehension and facilitating visualization especially advantageous for visual learners (Sarıgöz & Yıldırım, 2024). Digital storytelling enhances active participation, inventiveness, and emotional engagement in language acquisition. Studies conducted by Sartika and Syafryadin (2025) and Munajah et al. (2022) demonstrate that the creation of digital narratives bolsters learners' confidence and ownership, hence alleviating the anxiety frequently associated with foreign language acquisition. Similarly, Tyrou (2022) emphasizes that digital storytelling positively influences students’ motivation and attitudes toward language learning, fostering greater engagement and self-expression. Through the construction, narration, and editing of their narratives, students enhance linguistic precision and fluency via repetition and contextualized discourse. Furthermore, digital storytelling enhances critical thinking and intercultural comprehension. When students utilize personal or cultural experiences, the classroom transforms into a collaborative and reflective space. Educators indicate that even less active learners participate more readily when discussing peers' digital narratives, transitioning emphasis from rote exercises to substantive conversation. Thus, digital storytelling converts language acquisition into an experiential endeavor that amalgamates reading, listening, speaking, and writing competencies, fostering independence and enhanced cognitive involvement.

4. Challenges and considerations for implementation

Digital storytelling has become a vital and transformative instrument for educational engagement, aligning with generational preferences; nonetheless, its application poses intricate issues that require smart solutions. Digital storytelling, as an interdisciplinary media that amalgamates narrative, visual, and interactive components, redefines education by converting students from passive recipients into active co-creators of meaning. This transition necessitates a strong infrastructural, pedagogical, and ethical foundation to guarantee sustainability and inclusivity. A key problem is the technology infrastructure and accessibility required for effective digital storytelling. Dependable technology, multimedia editing software, and stable internet access are essential requirements that several educational institutions, particularly in developing areas, are unable to regularly supply. Such gaps threaten to exacerbate the digital divide among learners, as unequal access to technology may marginalize specific communities from participation. Maintaining these technologies incurs institutional expenses associated with equipment upkeep, digital storage, and system enhancements. Ensuring technological fairness is essential for democratizing digital storytelling.

Equally essential is the readiness of educators to create and implement digital storytelling experiences. Implementing digital storytelling requires organizational adaptability and continuous transformation in both technological and pedagogical structures (Momčilović & Doljanica, 2024). Educators frequently possess insufficient formal training in digital media production, visual communication, and interactive teaching methodologies. In the absence of sufficient expertise, digital storytelling may regress into a shallow multimedia display instead of facilitating significant experiential learning. The educator's role must transition to promoting narrative development, guiding students through introspective processes, and linking storytelling with explicit educational goals. Professional development programs centered on digital pedagogy and media literacy are crucial for enabling educators to fully leverage the potential of digital storytelling.

Pedagogical design presents problems of cognitive overload and instructional alignment. Although multimedia components augment engagement, excessive interactivity or rich visual content may inundate learners, especially those with restricted digital proficiency. Effective digital storytelling necessitates a harmonious design, wherein visual, aural, and textual elements enhance understanding rather than detract from it. Meticulous selection of media, organized arrangement of information, and focus on conceptual clarity are essential for preserving cognitive manageability. When handled meticulously, digital storytelling enhances cognitive processing by amalgamating sensory input with emotional involvement.

Ethical and cultural factors further impede execution. Student-created narratives frequently encompass personal or culturally rooted experiences, prompting issues about data privacy, intellectual copyright, and representational integrity. In the absence of explicit ethical constraints, storytelling initiatives may violate individual rights or reinforce cultural stereotypes. Educators must develop critical digital literacy, instructing pupils on authorship, consent, and cultural sensitivity. Institutions must have transparent regulations regulating the ownership, distribution, and preservation of digital artifacts to uphold ethical norms. Ethical considerations, including intellectual property rights and content authenticity, are crucial in designing sustainable digital storytelling ecosystems (Milošević & Đukić, 2024). A further intricate aspect is evaluation. Assessing digital storytelling necessitates approaches that surpass conventional grading systems, given that these projects include creativity, technical proficiency, and scholarly content. Standardized rubrics frequently do not adequately reflect the complexities that underlie these outcomes. Effective assessment must prioritize reflective thinking, narrative consistency, and learning outcomes, bolstered by formative feedback. Integrating peer assessment and process documentation can promote equity and enhance metacognitive awareness. Long-term sustainability relies on institutional dedication. In the absence of curricular integration and administrative backing, digital storytelling is likely to remain a marginal or experimental endeavor. Integrating it into academic policy, securing funding, and embedding it inside accreditation systems guarantees scalability and

sustainability. The objective is not just the deployment of technology but the comprehensive reform of educational culture. Generational and motivational disparities must also be acknowledged. Generation Z and Alpha have a predisposition for digital and interactive activities, frequently valuing amusement and immediacy above depth and contemplation. In contrast, older learners may demonstrate technological anxiety or favor traditional learning methods. Effective digital storytelling must adapt to generational characteristics, blending engagement with intellectual rigor and sincerity. Ultimately, emerging technologies like Augmented Reality (AR) and Virtual Reality (VR) present both potential and novel ethical dilemmas. These immersive tools enhance story potential but necessitate substantial technological capability and ethical supervision over representation and data governance. Their implementation must prioritize inclusion, accessibility, and psychological well-being, ensuring that technological immersion enhances rather than replaces critical thinking. The effective execution of digital storytelling in education relies on the convergence of technology, pedagogy, and ethics. Rectifying infrastructural disparities, enhancing educator proficiency, and promoting critical digital literacy are essential measures for actualizing its revolutionary potential. Digital storytelling should be regarded not simply as a technological advancement but as a transformative change that redefines the creation, experience, and dissemination of knowledge across generations, fostering a learning environment that is interactive, emotionally impactful, and intellectually enriching.The conceptual model of generational engagement through digital storytelling is summarized in Table 2.

Table 2. Model of generational engagement through digital storytelling (framework for education)

Component	Description	Educational function	Expected outcome
Input (Technological & Generational Factors)	Integration of digital platforms (TikTok, YouTube, VR/AR) aligned with generational media habits	Enhances accessibility and relevance of educational content	Increased motivation and platform familiarity
Process (Narrative Design & Interaction)	Use of storytelling, multimedia, and interactivity tailored to generational learning styles	Encourages active participation and emotional resonance	Improved engagement, retention, and comprehension
Output (Learning & Cultural Outcomes)	Knowledge transfer through immersive and collaborative storytelling experiences	Promotes reflective learning and cross-generational understanding	Strengthened digital literacy and lifelong learning skills

Source: Author's conceptualization based on Ramalia (2023), Adewojo (2025), and Kasemsarn & Nickpour (2025).

Conclusion

Digital storytelling signifies a revolutionary advancement in the construction, dissemination, and experience of knowledge across generations. The amalgamation of narrative, technology, and pedagogy has transformed learning into an active, participating endeavor instead of just a passive transmission of knowledge. Digital storytelling integrates textual, visual, and audio elements, going beyond conventional educational limits and promoting cognitive engagement, creativity, and emotional resonance.

This synthesis converts learners into co-creators of meaning, promoting critical thinking and engaged learning. It reconciles generational disparities by harmonizing the tastes and cognitive frameworks of Millennials, Generation Z, and Generation Alpha. Each group exhibits unique engagement patterns, ranging from prolonged narrative immersion to swift, interactive consumption, requiring adaptive teaching tactics that foster inclusivity, motivation, and relevance. Platforms like TikTok and YouTube illustrate this gap, with younger audiences emphasizing immediacy and relatability, whereas older

learners favor depth, context, and legitimacy. The perceived quality and credibility of digital communication channels significantly influence user engagement and trust across generations (Marković & Vukotić, 2024). Maintaining equilibrium between engagement and academic rigor is a fundamental instructional problem. Technological advancements like Augmented Reality (AR) and Virtual Reality (VR) broaden the realm of digital storytelling, fostering immersive experiences that enhance cultural heritage, language acquisition, and social sciences. These instruments improve access to culture and education, prioritizing ethical design, accessibility, and digital literacy. Their success relies on intentional integration that prioritizes inclusion, data safety, and instructional coherence over mere technical innovation. Digital storytelling personalizes technology. It enhances literacy, linguistic competence, and intercultural awareness by integrating learning into genuine and innovative circumstances. To achieve its maximum potential, educational institutions must engage in media literacy training, curricular integration, and egalitarian infrastructure. By integrating narrative depth with technology innovation, digital storytelling can transform 21st-century education, fostering generations that are not just digitally adept but also critically conscious, empathic, and culturally engaged.

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Challenges and Opportunities of Artificial Intelligence Application in Digital Marketing for Small and Medium-Sized Enterprises (SMEs)

Izazovi i mogućnosti primene veštačke inteligencije u digitalnom marketingu malih i srednjih preduzeća

Naida Biševac[1], Binela Šabanović[2], Amela Ljajić[3]
[1]*University of Novi Pazar, Novi Pazar, Srbija, naida.b@uninp.edu.rs*
[2]*University of Novi Pazar, Novi Pazar, Srbija, binela.s@uninp.edu.rs*
[3]*University of Novi Pazar, Novi Pazar, Srbija, a.ahmatovic@uninp.edu.rs*

Abstract: *In the modern business environment, small and medium-sized enterprises (SMEs) are key drivers of innovation, crucial for reducing unemployment and boosting GDP. The adoption of Industry 4.0 technologies is becoming a critical success factor for SMEs, while the emergence of artificial intelligence (AI) is further accelerating their market growth. This paper aims to present and compare the results of two studies focused on digital marketing and AI application within SMEs. The first study, conducted in 2020 on a sample of 87 Serbian companies, analyzes the application of digital marketing, focusing on the acquisition of digital literacy and the development of effective strategies. The second study, conducted in 2023 on a sample of 30 Romanian companies, assessed the impact of AI in digital marketing, thereby examining a higher level of technological integration. The Serbian study addresses foundational digital marketing practices, whereas the Romanian study highlights advanced AI applications. This comparison aims to illustrate the different stages of digital skill development in Serbia and Romania, contrasting their respective technological adoption levels.*
Keywords: *Small and medium-sized enterprises, digital marketing, artificial intelligence, technological integration.*

Apstrakt*: U novonastalim okolnostima poslovnog okruženja mala i srednja preduzeća čine glavne nosioce inovacija, bitan segment kod smanjenja nezaposlenosti jedne zemlje kao i porasta BDP-a. Učestala upotreba tehnologija industirije 4.0 postaje kritični faktor za uspeha malih i srednjih preduzeća (MSP) na tržištu, dok pojava veštačke inteligencije ubrzava rast i razvoj MPP na tržištu. Cilj ovog rada je da predstavi rezultate dva istraživanja usmerena na digitalni marketing i primenu veštačku inteligenciju (AI) u kontekstu MSP, prikaže njihovo poređenje, prednosti i nedostatke. Prvo istraživanje fokusira se na sticanje digitalne pismenosti i razvoj efektivnih strategija digitalnog marketinga, pri čemu je analizirana primena digitalnog marketinga u MSP u Srbiji. Empirijsko istraživanje izvršeno je tokom 2020. godine, na uzorku od 87 preduzeća koja posluju na teritoriji Republike Srbije. Drugo istraživanje usmereno je na procenu uticaja veštačke inteligencije (AI) u digitalnom marketingu u preduzećima na teritoriji Rumunije, izvršeno je 2023. godine na uzorku od 30 preduzeća, čime se ispituje viši nivo tehnološke integracije. Istraživanje sa teritorije Republike Srbije bavi se osnovama digitalnog marketinga, istraživanje sprovedeno na teritoriji Rumunije prikazuje naprednu primenu veštačke inteligencije (AI). Komparacija ova dva istraživanja ima za cilj da detaljno prikaže različite faze razvoja digitalnih veština na teritoriji Republike Srbije i Rumunije kao zemlje članice Evropske Unije (EU).*
Ključne reči*: Mala srednja preduzeća, digitalni marketing, veštačka inteligencija, tehnološka integracija.*

Introduction

Marketing represents a comprehensive business discipline that is applied in all spheres of social and business life. Its essence lies in the process of exchanging goods and services, in which the needs of consumers are identified and their satisfaction is ensured through a series of activities. In today's

context, marketing is far more than just selling; it includes an innovative approach and complex goals, and scientific and technological progress plays a key role in its development. With the advent of artificial intelligence, digital marketing is experiencing global expansion and accelerated development. Companies, especially small and medium-sized companies, which represent the backbone of the economy, are intensively striving to improve communication with their existing and potential consumers. The advent of artificial intelligence has forever changed the way businesses approach digital marketing. The implementation of digital marketing and artificial intelligence in SMEs in Serbia faces significant challenges. Internet marketing enables better communication with certain target groups of customers through digital tools and strategies (Stanišić, 1999). Digital marketing is changing the traditional approach to the market by providing more precise segmentation and more effective promotion of products and services. AI-based digital tools now available to SMEs include data analysis, the ability to personalize content, chatbots enabling easier access to a large number of customers, 24/7 availability and more efficient marketing management. (Awad, 2023) The main problems stem from limited financial and human resources, as well as a lack of strategic understanding of these tools (Verma, Somjai & Rusmee, 2023). Many SMEs lack the necessary digital literacy, leading to a reactive rather than proactive approach to marketing. Consequently, they are not using the full potential of analytics, SEO optimization and paid advertising. In addition, the application of artificial intelligence is hampered by the unavailability of professional staff and high implementation costs (Enshassi et al., 2022). Due to these obstacles, SMEs often remain at the basic level, which threatens their long-term competitiveness in the market. The authors Bawaneh & Abdul Wahab pointed out that the application of AI in business enables greater profitability and better market positioning (Bawaneh & Abdul Wahab, 2025). An additional problem is the still limited awareness of the application of AI in marketing business and ignorance of its potential (Arfah, 2024). This paper has the task of presenting and performing a comparative analysis of two researches in this area and in this sense represents an important step forward both for theory and for practice. In a theoretical sense, it contributes to the understanding of the digital transformation of SMEs in the Southeast European region, providing a unique comparison between countries at different stages of economic and technological development. The practical contribution of the work provides insight into the real situation, highlights key gaps and provides a basis for decision-making by managers, policy makers and entrepreneurs.

1. Overview of previous research

A review of the available literature shows the growing interest of researchers in the field of digital marketing application in SMEs. System review and bibliometric analyzes show that there are more and more works targeting companies that use AI in their business. This indicates the fact that AI is moving from an experimental stage to a widely applied technology, but most research is based on the application of AI in large enterprises (Ziakis & Vlachopoulou, 2023), which is one of the limitations of this research. The analyzed studies indicate positive effects from the implementation of AI in business, however, the majority point out that the effects are variable and that they depend on other factors in the company such as the database, professional staff as well as technology (Gabelaia, N. (2024). Looking at the previous literature, certain gaps were observed, such as the lack of research on the application of AI in SMEs. The two studies that were available and that met the criteria of the defined problem are: studies by Ravić et al. (2022) in Serbia and Simion et al. (2023) in Romania, provide an insight into the different aspects of digital marketing. Research in Serbia shows that SMEs use social networks more advancedly. However, there is no research that directly compares these different stages of development, which creates a gap in the existing literature.

Table 1. Overview of relevant research on the implementation of artificial intelligence in the digital marketing of SMEs

Autori	Earth	Research objective	AI application possibilities	Challenges	Key findings/recommendations
Awad 2023	Egypt	The impact of AI on the marketing business	Personalization of offers, automation of campaigns, improvement of user experience	Lack of professional knowledge	Implementing AI increases user engagement and achieves better business efficiency
Enshassi et al. 2022	Global (TOE framework)	Barriers to adopting AI in digital marketing	Analytics and decision making	Financial constraints, lack of staff, ethical problems	Success depends on a combination of technological, organizational and environmental factors
Arfah 2024	Indonesia/ Fashion Industry	Application of AI in fashion SMEs	Predictive analytics, consumer segmentation	High costs and limited digital literacy	It contributes to branding and a better competitive position
Gabelaia 2024	Georgia	The impact of AI on advertising	Automated advertising, content creation	Lack of transparency of algorithms	AI is redefining advertising and increasing the effectiveness of campaigns
Verma et. al 2023	Thailand	Readiness of SMEs to integrate AI	Sales automation, market analysis	Distrust of technology, lack of support	SME readiness grows with education and the availability of other (cloud) tools.
Bawaneh & Abdul Wahab 2025	UAE	The relationship between AI and the digital performance of SMEs	Increased digital presence, better targeting of consumers	Lack of local infrastructure	AI significantly improves performance if there is a market orientation

Source: Authors based on several different sources

1.1. Research objective

The aim of this paper is to, based on the analysis and comparison of two available empirical studies, identify differences in the approach and level of application of digital marketing and artificial intelligence in small and medium-sized enterprises in the Republic of Serbia and Romania. Through a comparative analysis, the paper will determine the extent to which companies in Serbia have adopted the basic channels of digital marketing and compare it with the advanced use of AI in Romanian companies, thus filling a perceived gap in the literature..

1.2. Research questions

Based on the set goal, the following research questions were defined:

1. What are the basic characteristics and level of application of digital marketing among small and medium-sized enterprises in Serbia?

2. What are the key advantages and disadvantages of using artificial intelligence in digital marketing, according to the experiences of Romanian SMEs?

3. How do the approaches and levels of digital transformation in SMEs in Serbia and Romania differ from each other, taking into account the time gap and economic specificities of both countries?

4. What recommendations for future research and practice emerge from this comparison?

1.3. Methodology

This paper uses a qualitative analysis and a comparative method to compare the results of two independent empirical studies. Instead of conducting new primary research, the paper relies on secondary data, specifically on the results of the study by Ravić et al. (2022) and studies by Simion et al. (2023). The research process includes a detailed analysis of methodological approaches, collected data and key conclusions of both studies, followed by a comparative analysis of key parameters such as time frame, level of technological application and geographical context. This approach enables, without direct contact with respondents, to identify key differences in the approach to digital transformation in SMEs in the region and to formulate relevant recommendations.

2. Marketing as a strategic approach to business

To date, no single definition of marketing has been adopted that everyone would accept, therefore we can say that the definition differs from author to author. The author's definition itself depends on the way in which marketing is viewed and to which segment the views of it refer. Marketing is not only advertising or a form of advertising of products and services on the market as most people think, but a much broader concept. Marketing is required to recognize and fulfill consumer needs. Profitable fulfillment of needs represents one of the shortest definitions of marketing (Kotler & Keller, 2008, p. 5).

When the word marketing is mentioned, many immediately think of advertisements, promotions and sales. However, in modern business, marketing is much more than that - it becomes a strategic approach, that is, a way of thinking that is deeply involved in all parts of the company (Armstrong & Kotler, 2017). Strategic marketing implies long-term thinking. The goal of marketing goes beyond mere transactional selling. Instead of focusing exclusively on the placement of products and services, the modern marketing approach emphasizes building and maintaining long-term relationships with customers. Marketing today is viewed as a broader strategic process that includes long-term value and customer relationship planning, and not just as mere advertising or promotion. Effective strategic marketing creates competitive advantage and long-term relationships with consumers (Milenović, 2013).

Effective application of strategic marketing results in the creation of strong brand equity. Brand recognition, its reputation and perceived value are key factors that foster customer loyalty and establish trust. Such an approach ensures repeat purchases and creates brand advocates, which directly contributes to the sustainable growth and competitive advantage of the company. Basically, marketing as a strategy means that an entrepreneur does not only think about how to sell what he already has, but how to constantly create value for customers, understand their needs, monitor the market and, based on that, plan the creation of future products, services, the realization of new business collaborations and long-term development (Kalač et al., 2017).

Strategic marketing is a way of thinking and a process by which organizations try to survive and develop in the competitive conditions of a relatively free market (Iršić, 2024).

Strategic marketing enables companies to be flexible and to react quickly to changes, whether it is about enhancing online business, introducing sustainable solutions or new ways of communication. The fact

is that with the advent of technology, social networks, online mining and finally artificial intelligence, digital marketing has become part of the everyday life of every individual as a future consumer in the market.

3. The term of digital marketing in SMEs

Digital marketing represents the achievement of marketing goals through the application of the Internet and other digital technologies (information and communication technologies) in business (Mahmutović, 2021, p. 8).

Digital marketing represents all marketing activities that include digital channels and technologies to promote products and services.

Digital marketing includes the following activities:

- marketing through social networks (facebook, instagram, linkedin...)
- e-mail marketing
- optimization for search engines
- Internet advertising (Google Ads, Meta Ads)
- content marketing (blogs, video, infographics)
- marketing through mobile applications and websites.

On the question of how a company can achieve all marketing goals, the authors (Kalač et al., 2017) point out that companies wishing to achieve all planned tasks and set goals can achieve this only by knowing the subjects of the market, i.e. competition, trade and consumers. Unlike large corporations, SMEs are often more flexible and adapt to new technologies faster, but lack the resources for long-term investments. For small businesses, internet marketing is an affordable and effective tool that enables direct contact with customers and quick response to their needs, which is especially important due to limited resources (Bildi, 2018). Digital tools enable audience targeting, measurement of results and direct communication with consumers. Considering that digital marketing compared to traditional marketing does not require excessive investment of financial resources, it is an ideal solution for small and medium-sized companies. Digital marketing enables affordable promotion with high reach with minimal financial investment. Digital marketing uses digital channels and tools to achieve the company's marketing goals, whereby SMEs have a special benefit due to adaptability and efficiency compared to traditional methods (Petković, 2021).

Digital tools make it possible to show advertisements exactly to those who have an interest in a certain product or service: by age, location, gender, interests, type of work they do or hobbies. Also with digital marketing, through tools such as Google Analytics and Facebook Insights, it is possible to accurately measure results in real time, i.e., how many people saw the ad, how many individuals viewed certain content, how many consumers bought a product or requested a service, on the basis of which small and medium-sized companies can formulate strategies more effectively. Through regular placement of advertising content and announcements, small and medium-sized companies create trust with users and leave an impression of professionalism, thus creating a recognizable image on the networks, even without a large marketing team. Digital platforms enable the direct sale of products, by making purchases via Instagram, Facebook or Marketplace and similar mobile applications.

Digital marketing is not only a means of promotion, but also a tool that encourages innovation in the development of products and services. Companies can test their ideas in practice, that is, try out new ideas without too much investment, through surveys, fun tests and promoted announcements; access is also possible through the involvement of the audience and users in the process of creating an innovation and a new product through competitions, proposals and prototype testing, where companies can get a large response from potential customers and assess with certainty whether they

like the innovation or not, as well as what level of success they expect. Artificial intelligence enables the automation of marketing processes, personalization of messages and detailed analytics of consumer behavior, with which SMEs can achieve significantly better results with lower costs (Advanced Technologies, 2023).

Thanks to social networks, entrepreneurs have the opportunity to present their products and services worldwide, while the emergence of artificial intelligence (AI) facilitates access to customers by recognizing their ultimate needs and satisfying them in the most efficient way. That's why digital campaigns are crucial for the visibility of SMEs in the online market. The development of technology, the expansion of social networks in recent years have greatly contributed to the visibility of products and services.

4. Interdependence of marketing and entrepreneurial orientation

Frequent changes in the market, the growth of competition, online platforms for the sale of goods and services require small and medium-sized enterprises to adopt and apply the concept of digital marketing and entrepreneurial orientation. By adopting the mentioned business concept, the risk in business is reduced while at the same time ensuring the efficiency and effectiveness of the company. The largest number of companies, especially small businesses, were formed based on the idea of selling their own products (if it is a manufacturing company) and to increase the capital invested in the business (Petković, 2010, p. 34).

Entrepreneurial orientation and marketing orientation are interconnected and together contribute to the innovation and competitiveness of companies. Marketing orientation enables recognition and satisfaction of customer needs, while entrepreneurial orientation emphasizes proactivity and taking business risks (Subotić, 2017).

The task of marketing orientation is reflected in satisfying the needs and wishes of consumers who have purchasing power on the market, while entrepreneurial orientation focuses on spotting suitable innovative opportunities and being proactive in work. Marketing orientation is a focus on desires and needs, so it is necessary to highlight the needs of the market for production, and then sales. Marketing orientation represents the level at which a company collects and uses information about customers, and develops and implements strategies with the aim of effectively satisfying their needs and desires. It can be said that marketing and entrepreneurial orientation are interconnected and strive for the same goal. Marketing orientation depends on entrepreneurial orientation in order to be able to adequately respond to changes in the market, while entrepreneurial orientation requires marketing orientation so that innovation is focused on customer needs. This claim is based on the fact that marketing- and entrepreneurial-oriented companies share the same opinion on the issue of sharing and acquiring knowledge within the organization. The basic task of marketing is actually to recognize the needs of the market (customers) and to satisfy them, while digital marketing, as a new sphere in the economy, aims to facilitate access to certain goods and services through online networks such as social networks, pages and online articles. Entrepreneurial orientation means the way people or organizations think and act when creating new businesses. It includes their practices, actions and decisions they make to start a new business, which often carries risk (Al-Swidi & Mahmood, 2011, p. 299).

Entrepreneurial orientation is considered to be the main driver of economic activity. It also aims to recognize market opportunities and use the best among them. The company's ability is reflected in seeing an opportunity, and then taking advantage of it in a timely manner while following the leading trends and keeping customers interested in the long run. The entrepreneurial concept shows how much risk a company is willing to take compared to others. It is important that the company fulfills all three dimensions of entrepreneurial orientation at the same time. Today, it is considered a key driver of the free market.

5. Research methodology

The aim of this paper is to present a comparison of two methodological approaches based on available research, namely: the research carried out by Ravić et al. (2022) on the territory of the Republic of Serbia shows the following findings:

The research was conducted at the end of 2020.

- The sample was made on 87 enterprises (SMEs) in the territory of the Republic of Serbia.
- The criterion for participation was aligned with the legal definition of SMEs in Serbia (≤250 employees, revenues ≤35 million dinars, assets ≤17.5 million dinars).
- Survey questionnaires were collected through an electronic Google questionnaire
- All conducted survey questionnaires were valid
- In the structure of the respondents, the respondents are aged between 25 and 55 years. Respondents' answers to survey questions indicated that:
    - 41.4% of SME respondents do not have an official website.
    - 57.5% of SME respondents do not have a marketing manager

From the conducted research, the author concludes that SMEs in Serbia pay more attention to advertising through social networks compared to the Google search engine. As expected, the most popular social network is Instagram, followed by Facebook, followed by websites and YouTube. Respondents expressed their satisfaction on the topic of digital marketing and digital communication, as the main factor they highlighted the speed of visibility on the networks as well as the satisfaction of the younger generation's attendance. Based on the research conducted at the end of 2020, it is concluded that subjects from this sector have mastered certain skills in the field of digital marketing, the author also concludes that advertising through social networks is not unknown to SMEs in the territory of the Republic of Serbia. Conducted research by Petronela Cristina SIMION et al. (2023) was conducted through an online questionnaire that contained 11 questions that aimed to establish the amount of use of artificial intelligence in digital marketing. The research was conducted on the territory of Romania in Bucharest, in the period between 2022 and 2023. Through the conducted survey of SMEs, 30 valid responses were received. The author (Petronela Cristina SIMION et al., 2023) aimed to show the importance of artificial intelligence in digital marketing companies.

Answers based on the respondents to the survey questions pointed to:

- The research was conducted in the period 2022-2023. year
- Machine learning is the most used artificial intelligence.
- Respondents confirm that they recognize the capabilities of artificial intelligence in digital marketing and highlight the tools they use the most, namely: Marketing message personalization, SEO, sales process automation or all tools together.
- Research shows that quality use of artificial intelligence is a competitive advantage.
- The survey shows the attitude of the respondents: It is necessary to monitor the development of artificial intelligence in order to monitor market trends.
- The main advantage of using artificial intelligence is the ability to adapt to the demands of customers in the market.
- Inadequate privacy protection is the biggest drawback of using artificial intelligence in digital marketing.

- As the greatest benefit for digital marketing and the development of small and medium-sized enterprises, work on improving and creating personal artificial intelligence that would identify consumer needs in detail, and then facilitate their satisfaction, is considered.
- All respondents believe that artificial intelligence is important for digital marketing, but they give a brief overview of the future when more experimentation with the use of it would be gained and the trust of customers would be gained.
- Company employees believe that customers are partially willing to share their information.

Based on the conducted research, the author draws the conclusion that artificial intelligence is still in the early stages of discovery and examination by the market, he points out its advantages that facilitate the solving of digital marketing tasks. It is believed that neural networks, natural language processing and machine learning will be used in many segments of digital marketing development as well as consumer sentiment analysis in the near future. In addition to numerous advantages, the author also mentions disadvantages in the form of a lack of data privacy and a lack of ethical principles. The comparison of the aforementioned studies aims to present the difference between the two countries, firstly the Republic of Serbia, and then Romania as a member state of the European Union (EU). The research was carried out three years apart, which in the digital world represents a big gap in progress. The aforementioned research on the territory of the Republic of Serbia shows how willing business owners are to use digital marketing channels and which are the most common advertising channels. It must be noted that the year 2020 is known for the global Covid 19 pandemic and that it was the trigger for numerous technological developments, while in parallel, on the other hand, the research carried out in Romania shows artificial intelligence and its early development. Based on the presented research, it can be seen that a small number of respondents were collected in both mentioned researches, which represents a limitation for the adoption of a global law.

Conclusion

This paper, through a comparative analysis of two studies, clearly shows the different stages of the development of digital transformation in small and medium-sized enterprises (SMEs) in Serbia and Romania. In Serbia, research from 2020 indicates that SMEs make extensive use of digital marketing, primarily through advertising on social networks, with Instagram and Facebook being the most represented channels. Although business owners have mastered these basic skills, a significant percentage of them (41.4%) still do not have an official website, and more than half (57.5%) do not employ a marketing manager, indicating a reactive rather than a strategic approach. On the other hand, research in Romania from 2022-2023. , conducted three years later, shows a higher level of technological integration – a focus on artificial intelligence (AI). Romanian respondents recognize the capabilities of AI in digital marketing, using tools for personalization, SEO and automation of sales processes. The bottom line is that quality use of AI is a competitive advantage. However, despite numerous advantages, significant disadvantages are also recognized, such as inadequate privacy protection and lack of ethical principles. The research confirms that AI is still at an early stage of application in the SME sector, but with great potential. A comparison of these two surveys shows that SMEs in Serbia are mainly focused on acquiring basic digital skills and presence on social networks, while Romanian companies are experimenting with advanced AI technologies, thereby gaining a competitive advantage. This difference in approach can be partially explained by the time gap of the research, but also by the status of Romania as a member of the European Union, which potentially enables faster access to new technologies and trends. The conclusion that can be clearly seen from the theoretical framework is that digital marketing is an important driver for the development of small and medium-sized companies on the market, and artificial intelligence is a new tool that accelerates, facilitates and improves the development of global networks.

Summary

Small and medium-sized enterprises (SMEs) are key drivers of economic development and innovation. In the modern business environment, digital marketing is becoming a necessary tool for their competitiveness. Artificial intelligence (AI) further accelerates the development of digital marketing. The aim of this paper is to compare the results of two studies on the application of digital marketing and AI in SMEs in Serbia and Romania, in order to show the different stages of technological development in these two countries. The first survey, conducted in 2020 in Serbia, found that SMEs have mastered the basic skills of digital marketing, especially advertising on social networks (Instagram and Facebook). However, shortcomings were noted, such as the lack of websites and marketing managers. The second survey, carried out in Romania in 2022-2023. , showed that Romanian companies are using more advanced AI tools (like machine learning) for personalization and automation, seeing it as a key competitive advantage. Despite this, problems related to privacy protection and ethical principles were highlighted. Finally, the comparison showed that SMEs in Serbia are working on the adoption of basic digital channels, while SMEs in Romania face the challenges and advantages of advanced application of artificial intelligence. The paper points to the need for further research, especially through a re-examination of the SME sector in Serbia, in order to monitor their growth and compare achievements with EU countries.

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AI-Powered Social Media Strategies as a Driver of Modern Brand Building

Strategije društvenih mreža zasnovane na veštačkoj inteligenciji kao pokretač moderne izgradnje brenda

Tamara Ristić[1], Kristina Jauković Jocić [2], Olgica Milošević[3]

[1]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, tamara.ristic@mef.edu.rs*

[2] *University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, kristina.jaukovic@mef.edu.rs*

[3] *University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, olgica.milosevic@mef.edu.rs*

Abstract: *Artificial intelligence (AI) has revolutionized digital marketing and social media branding, shifting communication from broad promotion to tailored, data-informed engagement. This study analyzes the impact of AI technologies, including machine learning, natural language processing, predictive analytics, and generative models, on marketing strategy, brand identity, and customer engagement. The research employs a qualitative evaluation of contemporary academic and professional literature, augmented by a comparative analysis of AI-driven marketing methods. Research demonstrates that AI improves efficiency, precision, and scalability in communication, while simultaneously presenting ethical dilemmas related to data protection, creativity, and algorithmic responsibility. The findings indicate that the development of sustainable brands relies on a harmonious partnership between humans and AI, wherein automation enhances rather than supplants strategic and creative decision-making. The study finds that firms that include responsible AI systems with ethical governance attain enhanced trust, agility, and sustained competitiveness in the digital marketplace.*

Keywords: *Artificial intelligence, social media branding, personalization, predictive analytics, automation, consumer behavior.*

Apstrakt: *Veštačka inteligencija (AI) postala je poznata kao značajan pokretač promena u digitalnom marketingu i komunikaciji brenda. U kontekstima društvenih medija, AI tehnologije pružaju sofisticirano profilisanje publike, prilagođenu distribuciju sadržaja, prediktivno modeliranje ponašanja potrošača i automatizovano upravljanje interakcijama. Ove tehnike zamenjuju linearnu komunikaciju usmerenu na kampanje prilagodljivim, na podacima zasnovanim angažovanjem brenda. Rad ima za cilj da analizira uticaj AI tehnologije na brendiranje društvenih medija, angažovanje kupaca i prepoznatljivost brenda. Studija koristi kvalitativnu evaluaciju savremene literature i uporednu analizu okvira brendiranja vođenih AI. Istraživanja pokazuju da, iako AI poboljšava efikasnost, relevantnost i skalabilnost, istovremeno postavlja izazove u vezi sa autentičnošću, originalnošću i etičkim korišćenjem podataka. Održiva vrednost brenda nastaje kada AI poboljšava, a ne zamenjuje ljudsku kreativnost i stratešku nameru, čime se podstiče odgovorna inovacija i trajno poverenje.*

Ključne reči: *Veštačka inteligencija, brendiranje na društvenim mrežama, personalizacija, prediktivna analitika, automatizacija, ponašanje potrošača.*

Introduction

Artificial intelligence has transitioned from a supplementary digital instrument to a fundamental framework that influences brand identity formation and audience engagement. As marketing shifts from mass communication to personalized, data-driven engagement, social media platforms have become the principal arenas for this transformation. Artificial intelligence technologies, such as natural

language processing, predictive analytics, and generative content systems, now facilitate essential communication functions, encompassing audience insights, behavioral forecasting, automatic message customization, and content generation. These breakthroughs enable companies to discern user intent, modify content instantaneously, and enhance their digital strategy through continuous learning.

The incorporation of AI presents strategic and ethical problems. Although automation enhances productivity and communication accuracy, excessive reliance on algorithms may diminish creativity, homogenize creative expression, and undermine brand identity. Concurrently, transparent data practices, algorithmic accountability, and the preservation of user autonomy are emerging as vital components of responsible digital communication.

This research analyzes the impact of AI technology on branding in social media environments. This analysis examines the technological underpinnings of AI-driven brand strategies, their effects on customer engagement and competitive differentiation, as well as the concerns linked to excessive automation and data-centric decision-making. The results bring home the importance of equitable human-AI collaboration, wherein algorithmic intelligence augments rather than supplants human strategic design, creativity, and ethical discernment, thus ensuring enduring brand relevance and trust in an increasingly algorithmic communication environment.

1. Integration of artificial intelligence in contemporary marketing

Artificial intelligence has become a crucial element in transforming modern marketing, altering both strategic and operational frameworks across several sectors. The implementation signifies a pivotal shift from intuition-based managerial judgments to rigorously data-driven and algorithmically optimized methodologies. In this context, AI technologies empower companies to analyze extensive data with unparalleled speed and precision, enhancing campaign planning, segmentation accuracy, and resource allocation efficiency (Verma et al., 2021; Pan et al., 2023; Kamkankaew et al., 2024). Based on real-time analytics and customer insights (Chintalapati & Pandey, 2022; Alqurashi et al., 2023; Haleem et al., 2022), marketing processes have changed from being reactive or episodic to being continuous, adaptive, and self-optimizing.

Recent research highlights that machine learning, natural language processing, and sophisticated segmentation algorithms are the cornerstone technologies of personalized digital marketing (Huang & Roland, 2020; Kasneci et al., 2023; Jackson et al., 2022). These technologies enable marketers to dynamically modify content according to user preferences and behavioral indicators, thereby enhancing engagement, emotional connection, and brand loyalty (Theodoridis & Gkikas, 2019; Rabby et al., 2021; Zhao et al., 2022). The increasing significance of conversational AI—evident in chatbots, virtual assistants, and voice interfaces—illustrates this transformation by automating consumer interactions and ensuring consistent, high-quality communication experiences (Huang & Rust, 2020; Cao et al., 2023; Agarwal, 2023).

From 2023 to 2025, the expansion of generative AI technology has significantly transformed marketing practices, encompassing not only automation but also creative and strategic areas. Generative systems now enhance content ideation, dynamic campaign testing, audience behavior modeling, and scenario-based decision assistance, therefore enriching the creative and analytical aspects of marketing strategy (Kasneci et al., 2023; Jackson et al., 2022; Kamkankaew et al., 2024). Simultaneously, AI-powered dynamic pricing systems have become prominent, allowing real-time price adjustments based on varying market signals, competitive activities, and customer behavior trends (Zhao et al., 2022; Rabby et al., 2021; J.W., 2020). These advancements illustrate a managerial framework where data analytics and algorithmic intelligence are essential not only as auxiliary tools but also as strategic necessities that dictate long-term competitiveness (Fountaine et al., 2019; Huang & Rust, 2018; Luo et al., 2019).

The use of AI in marketing presents many ethical, regulatory, and organizational dilemmas. Concerns regarding data privacy, algorithmic transparency, and accountability have become essential factors

influencing customer trust and brand legitimacy (Mende et al., 2019; Frey & Osborne, 2017; Cao et al., 2023). Overdependence on automated decision-making may engender prejudice, diminish creative variety, and undermine established standards of authenticity and human discernment. Therefore, effective AI deployment in marketing needs strong data governance frameworks, ethical monitoring, and ongoing human supervision to guarantee fairness, accountability, and alignment with values.

The application of AI in marketing indicates not only technological advancement but also a fundamental shift of the profession. Marketing is transforming into an intelligent, predictive, and self-learning environment, where strategic success increasingly relies on an organization's ability to merge technological sophistication with social responsibility and human creativity. The collaboration between human strategic purpose and algorithmic intelligence serves as the principal foundation for enduring brand competitiveness and market uniqueness.

1.1. Evolution of digital marketing and the role of AI

Digital marketing has progressed from basic internet advertising and manual analytics to a complex, data-driven framework defined by automation, interaction, and real-time reaction. Initial methodologies were predominantly descriptive, depending on static material and historical performance measures. Conversely, modern marketing utilizes algorithmic targeting, predictive modeling, and ongoing optimization of customer involvement (Dwivedi et al., 2021; Kumar et al., 2022; Chatterjee et al., 2023). This transformation has been driven by enhancements in processing power, cloud infrastructure, and extensive behavioral data collection, facilitating unparalleled accuracy in consumer insights and decision-making (Sheth, 2021; Wamba et al., 2022).

Academics characterize this evolution as a transition from descriptive to predictive and prescriptive intelligence, when AI systems not only analyze patterns but also independently propose or implement strategic measures (Mikalef et al., 2021; Mariani & Borghi, 2022; Wedel & Kannan, 2023). In this context, AI functions as the primary catalyst that improves pattern recognition, behavioral prediction, and scalable personalization (Grewal et al., 2022; Huang & Rust, 2021; Zeng et al., 2023). Machine-learning systems facilitate segmentation, content distribution, and media investment, transforming marketing from reactive adaptation to proactive orchestration of customer experiences (Chintalapati & Pandey, 2022; Pan et al., 2023; Haleem et al., 2022).

Natural language processing enhances sentiment analysis, conversational marketing, and social listening, whereas generative AI expedites the production of adaptable and emotionally impactful content (Kasneci et al., 2023; Jackson et al., 2022; Li et al., 2024; Cao et al., 2023). Organizations that effectively integrate these technologies with robust data governance frameworks and organizational learning processes have notable enhancements in performance and innovation (Luo et al., 2019; Fountaine et al., 2019; Chatterjee et al., 2023).

Nonetheless, the growing dependence on AI presents novel management and regulatory concerns. Algorithmic bias, privacy concerns, and the widening gap in digital skills highlight the imperative for responsible implementation and human oversight (Frey & Osborne, 2017; Mende et al., 2019; Wirtz et al., 2023). The evolution of digital marketing signifies a systematic shift towards intelligent, adaptable, and morally aware ecosystems.

1.2. Key AI technologies in marketing processes

The systematic expansion of digital marketing, along with the incorporation of artificial intelligence, has established a complete technical framework that significantly alters how businesses assess, forecast, and influence customer behavior. These technologies provide an integrated ecosystem that improves automation, customization, and decision-making precision, enabling marketers to formulate adaptive and data-driven strategies. The complexity of AI-driven marketing processes arises from several fundamental technology areas, each enhancing prediction, automation, content creation, and behavioral modeling in evolving digital landscapes.

Machine learning (ML) serves as the fundamental technological foundation of AI-driven marketing, owing to its exceptional ability to identify consumer patterns, automate segmentation, and create adaptive advertising systems informed by behavioral data streams (Brock & von Wangenheim, 2019; Jha et al., 2022; Kumar et al., 2023). Supervised learning techniques facilitate targeted campaign optimization and customer retention forecasting, whereas unsupervised methods uncover latent linkages between market clusters and developing consumer micro-trends (Berman, 2022; Ghose & Chae, 2023). Reinforcement learning enhances ad-placement timing, message sequencing, and resource allocation by persistently learning from user interaction input across many digital touchpoints (Akter et al., 2021; Li & Gal, 2024).

Natural language processing (NLP) has revolutionized marketing communication through sentiment analysis, automated content production, voice assistant integration, and context-aware message delivery (Belanche et al., 2020; Jain et al., 2021; Santos & Gonçalves, 2023). NLP systems evaluate extensive volumes of unstructured text from social media, customer reviews, and search queries, identifying changes in emotional tone, emergent debate trends, and brand sentiment in real time (Gursoy et al., 2022; Ray et al., 2023; Stathopoulou & Balabanis, 2024). The advent of multilingual transformer-based designs, including BERT and the GPT families, has significantly enhanced cross-cultural communication by enabling precise translation, semantic coherence, and worldwide brand alignment (Liu et al., 2023; Yuan & Xu, 2024).

Computer vision systems enhance marketing intelligence via picture and video recognition, visual search, and exposure analysis. These technologies facilitate the recognition of brand components, identification of counterfeit products, and enhancement of visual merchandising in e-commerce and retail environments (Yang et al., 2022; Chen & Zhang, 2023; Petrovic et al., 2024). Visual analytics assist organizations in deciphering customer attention and engagement trends, offering insights into audience interactions with product images, advertising design, and digital shelf positioning (Hussain et al., 2023; Rahman et al., 2024).

Generative AI (GenAI) has become a significant disruptive factor in creative marketing. Transformer-based models like GPT, DALL·E, and Stable Diffusion enhance content ideation and production, facilitating the generation of high-quality text, images, and multimedia assets with minimum human intervention (Dwivedi et al., 2023; Zhang et al., 2024; Pereira & Costa, 2024). Organizational study underscores the efficacy of GenAI in adaptive campaign testing, creative concept formulation, and product-positioning simulations, especially in resource-constrained environments (Rezaei & Javadi, 2023; Martins et al., 2024). These technologies do not replace human creativity; instead, they enhance it by enabling extensive customization and accelerating the pace of creative iteration (Amin & Chaudhry, 2024).

Predictive analytics, supported by probabilistic modeling, clustering algorithms, and time-series forecasting, is a vital component of AI-driven marketing. These instruments provide precise demand forecasting, pricing optimization, churn prediction, and customer lifetime value modeling, hence augmenting return on investment (ROI) and marketing efficacy (Sun et al., 2022; Al-Shammari et al., 2023; Villa-Lopez et al., 2024). AI-driven attribution models diminish ambiguity in multi-channel media expenditures by offering detailed insights into the efficacy of each communication touchpoint across the customer journey (Barrett & Saraf, 2023; Morales & Ortega, 2024).

As AI architectures advance, marketing departments are transforming into hybrid analytical and creative settings where algorithmic intelligence enhances human intuition and strategic thinking. The operational efficacy of such settings relies on the preparedness of digital infrastructure, ethical data governance, and the ongoing enhancement of personnel competences in AI literacy. Thus, AI functions not only as a technology tool but also as a transformational organizational asset—revolutionizing how companies create value, maintain competitiveness, and foster innovation in the age of intelligent marketing.

1.3. Ethical, regulatory, and organizational challenges in AI-driven marketing

The extensive implementation of artificial intelligence in marketing presents a range of complex ethical, legal, and organizational concerns that transcend mere technological management, impacting human rights, social equality, and institutional accountability. The difficulties stem from algorithmic opacity, exploitation of consumer data, and diminished user autonomy, collectively prompting inquiries about fairness, consent, and accountability in digital interactions. Academic studies highlight that automated targeting systems and algorithmic recommendation models may inadvertently perpetuate social and cultural biases, affect consumer choices without informed consent, and limit individual autonomy through predictive profiling and behavioral conditioning (Kshetri, 2021; Martin et al., 2022; Liu & Sundar, 2022). The growing use of emotional analytics, persuasive algorithms, and micro-segmentation methods intensifies ethical dilemmas, raising apprehensions about manipulation, digital reliance, and psychological susceptibility (Pizzi et al., 2021; Vincent et al., 2023; Narayanan et al., 2024).

Regulatory agencies are increasingly implementing stringent control of AI-driven marketing systems to guarantee compliance, equity, and accountability. Regulatory frameworks like the General Data Protection Regulation (GDPR) and the forthcoming EU Artificial Intelligence Act impose rigorous requirements for openness, documentation, and explainability in automated decision-making (Veale & Borgesius, 2021; Floridi et al., 2022; Hacker, 2024). Organizations are now mandated to substantiate data processing methodologies, uphold verifiable consent protocols, and provide algorithmic parameters influencing user experience. Companies that do not implement compliance data governance and algorithm audit procedures encounter heightened risks of financial fines, reputational harm, and diminished customer trust (Smith & Neely, 2022; Mittelstadt, 2024). These findings demonstrate a wider shift from voluntary corporate responsibility to established algorithmic accountability as a need for market credibility.

From an organizational standpoint, the ethical use of AI necessitates adherence to external rules as well as the establishment of internal governance frameworks to guarantee responsible innovation. This encompasses the establishment of algorithm-audit protocols, human-supervision systems, and multidisciplinary ethical committees that consistently assess the social implications of marketing automation (Rust & Huang, 2021; Rahwan, 2022; Dwivedi et al., 2023). Effective execution necessitates digital proficiency, open reporting mechanisms, and a business culture that incorporates ethical thinking into strategic and operational decisions. Research demonstrates that numerous organizations, especially small and medium-sized enterprises (SMEs), encounter enduring obstacles associated with constrained resources, skill deficiencies, and organizational inertia that impede effective governance (Bunte et al., 2021; Weber et al., 2024; Adeleye et al., 2024).

Empirical data from regional SME ecosystems highlights the necessity of reconciling technology innovation with transparency and consumer protection. Companies that embrace responsible data management and execute customer-focused digital transformation strategies typically experience enhanced brand trust and strategic resilience (Jauković Jocić et al., 2024). Moreover, firms that include established internal policies, accountability frameworks, and ethical brand-management norms have a heightened potential to use AI sustainably and in accordance with social expectations (Đukić et al., 2024). Tackling the ethical, regulatory, and organizational difficulties of AI-driven marketing necessitates a comprehensive governance strategy that integrates legal adherence, ethical anticipation, and cultural adjustment. The future of AI in marketing will hinge on companies' capacity to institutionalize responsible innovation, ensuring technical progress while safeguarding human dignity, privacy, and autonomy. Attaining this equilibrium converts ethics from a limitation into a strategic advantage, enhancing brand credibility and enduring competitiveness in the digital economy.

2. Social media as the backbone of modern sales and brand communication

Social media has become the primary framework for modern sales and brand marketing, transforming how firms engage with customers and create value in digital environments. In contrast to conventional

mass-media channels that functioned through unilateral advertising messaging, social platforms provide ongoing, multidirectional, and data-informed communication that integrates customization, immediacy, and interaction (Felix et al., 2024; Sheth & Kellstadt, 2022). The shift from broadcast marketing to algorithmically tailored interaction signifies not simply a technology change but a significant strategic reorganization of marketing principles. The extensive utilization of mobile technologies and the nearly universal availability of digital networks have rendered social platforms crucial points of contact in the consumer journey, enabling product discovery, comparison, evaluation, and purchase within a unified interface (McClure & Seock, 2023; Shareef et al., 2022).

Empirical studies demonstrate that user-generated content (UGC), visually engaging narratives, and peer endorsement systems significantly influence customer attitudes, trust, and purchasing choices (Kim & Johnson, 2023; Lou & Yuan, 2022). Consumers are increasingly dependent on genuine, experience-driven narratives instead of corporate advertising, which points to the importance of participatory content ecosystems. Social commerce platforms, particularly Instagram, TikTok, and YouTube, have institutionalized the "inspiration-to-transaction" model, where product discovery, social validation, and purchase occur in a seamless and accelerated flow (Grewal et al., 2023; Sun & Hudders, 2024). This change has reconfigured the purchase funnel into a real-time behavioral loop where customers actively co-create brand significance through interaction, response, and sharing.

A key feature of this environment is the rise of influencer-driven communication as a primary branding tool. Influencers serve as cultural mediators, converting brand identity into relevant and emotionally impactful material, so connecting corporate messaging with consumer experiences (Wiedmann et al., 2023; Djafarova & Trofimenko, 2023). Their apparent genuineness and storytelling approach cultivate trust and emotional closeness, rendering them efficient conduits of symbolic value and brand distinction. As a result, the partnership between companies and influencers has evolved from a tactical approach to a structural one, embedded inside long-term business strategies that emphasize community development, narrative construction, and emotional engagement.

In addition to promotional roles, social media operates as a strategic tool for managing brand reputation and facilitating crisis communication. Organizations utilizing sophisticated social listening techniques and sentiment analysis frameworks may track real-time public discourse, detect developing dangers, and respond proactively to impending crises (Pesonen & Komppula, 2023; Hanaysha & Pech, 2022). This ongoing feedback system enhances trust and transparency by facilitating open communication and adaptive brand actions. The consistency of brand identity across platforms, visual elements, and linguistic styles is essential for maintaining brand coherence and achieving long-term distinctiveness in saturated digital environments (Blackett & Boad, 2023; Davis & Dunn, 2024).

Social media constitutes a hybrid ecosystem that amalgamates visibility, interaction, and transaction within a cohesive digital framework. It enables firms to execute focused, data-informed communication while preserving emotional and cultural significance across varied audiences. The strategic influence of social media resides in its dual capability: it expedites customer feedback loops while concurrently fostering enduring brand-consumer connections based on trust, authenticity, and loyalty. As digital interaction emerges as the predominant method of market exchange, companies that adeptly utilize social platforms not only improve sales performance but also collaborate in generating social value and sustaining long-term brand equity in a progressively interconnected marketplace.

2.1. Transformation of brand–consumer communication

The digital revolution has dramatically changed the structure and dynamics of brand–consumer relationships, replacing traditional one-directional marketing communication with an interactive, participatory, and data-informed discussion. Consumers have transitioned from being passive recipients of brand messaging to active co-creators of meaning and value, influencing brand perception through their interactions, preferences, and digital behaviors (Iankova et al., 2022; Voorveld, 2023). Modern marketing surpasses the model of mass persuasion, evolving into real-time, tailored, and adaptable communication systems that react to environmental and behavioral cues. Through

algorithmic targeting, machine learning, and behavioral analytics, brands can adjust their content to fit user intent, emotions, and situational needs, fostering relevance, immediacy, and resonance (Barakat et al., 2024; Shan et al., 2023).

This novel communication strategy regards the customer not as a passive recipient but as a strategic partner in the branding process. Contemporary brand ecosystems prioritize co-creation, wherein user-generated content (UGC), peer endorsements, and social validation methods significantly affect the perceived authenticity and symbolic significance of brands (Coudounaris & Sthapit, 2024; de Oliveira & Souza, 2023). Viral posts, online evaluations, and community engagement foster trust and relational capital, thereby democratizing brand dialogue and shifting ownership from corporations to networked publics (Naeem, 2023; Kamboj et al., 2024). This participative dynamic obscures the distinction between producer and consumer, as individuals become prosumers concurrently serving as content makers and interpreters of marketing narratives.

The expansion of instant communication technologies, such as chat-based customer support, direct messaging, and live-streaming, has reduced response times, allowing brands to maintain continuous engagement instead of sporadic promotional interactions (Ismagilova et al., 2022; Araujo et al., 2024). The old linear communication strategy has transformed into an iterative, feedback-driven loop in which customers consistently shape brand tone, message design, and content direction.

Narrative-driven communication has become an essential tool in this change. Emotionally impactful storytelling incorporates symbolic elements, visual branding, and individualized storylines to enhance customer affiliation with businesses (Tafesse, 2023; Dessart & Durrieu, 2024). Narrative material, in contrast to informative or transactional communications, fosters emotional depth and authenticity, hence strengthening long-term brand loyalty. Furthermore, openness, ethical stance, and uniformity in communication tone are critical to preserving trust and credibility in oversaturated digital landscapes (Schlegelmilch & Szőcs, 2024; Busalim et al., 2023). Ethical clarity and coherence safeguard brand reputation and bolster consumer loyalty by connecting company ideals with society expectations.

Modern brand-consumer communication functions as a dynamic, reciprocal, and co-creative process influenced by data insights, emotional engagement, and ongoing connection. The competitive advantage of modern brands is now contingent upon their capacity to cultivate significant, experience-oriented relationships with consumers rather than on message frequency or media prevalence. Brands that effectively combine emotional storytelling with real-time data analytics attain more engagement, sustained relational equity, and cultural relevance in the digital marketplace.

2.2. Social media as a channel for brand building

Social media platforms have transformed into essential arenas for brand promotion, functioning not just as communication conduits but also as complex ecosystems for identity formation, value distribution, and enduring relationship cultivation. They empower firms to define their brand identity, convey corporate principles, and foster communities of devoted customers via ongoing and interactive participation (Chetioui et al., 2023; Godey et al., 2024). Unlike conventional marketing channels marked by intermittent communication, social platforms enable businesses to sustain a continuous digital presence that evolves with audience expectations, cultural trends, and social storylines in real time. Their intrinsic adaptability to integrate visual, interactive, and narrative formats spanning films, live sessions, polls, and augmented experiences—augments the development of symbolic meaning and emotional engagement with audiences (Hammedi et al., 2023; Hilken et al., 2024).

Research repeatedly indicates that brand equity on social media is contingent upon perceived authenticity, transparency, and the consistency of identity across various touchpoints (Bruhn & Schnebelen, 2022; Balmer & Podnar, 2023). Brands that have a consistent tone, iconography, and ethical alignment across digital platforms attain enhanced recognition and customer confidence. Engagement metrics, including likes, shares, comments, and community interaction, serve as digital markers of legitimacy, offering concrete proof of consumer engagement and endorsement (Talwar et al., 2023;

Algharabat et al., 2024). In addition to quantitative engagement measures, the emotional impact of social material is crucial in cultivating attachment, as consumers assimilate and reinterpret brand significance inside their digital and social identities (Hudders & Lou, 2022; Christodoulides et al., 2023).

A significant catalyst for brand development on social media is influencer-mediated communication. Influencers act as semi-autonomous agents of brand storytelling, converting corporate messaging into authentic, relatable, and culturally relevant narratives. Their credibility stems from perceived knowledge and authenticity, which increases message acceptance and fortifies relational connections with followers (Audrezet & Moulard, 2023; Tafesse & Wood, 2024). Concurrently, algorithmic recommendation systems enhance these dynamics by aligning brand messages with individual consumer profiles, preferences, and identification indicators, therefore augmenting customization and message pertinence (Osei-Frimpong & McLean, 2024; Verhoef et al., 2024). The exponential growth of short-form video formats such as TikTok Reels, Instagram Stories, and YouTube Shorts has expedited this phenomenon by merging immediacy, emotional resonance, and visual allure in swiftly digestible narrative segments (Chen et al., 2024; Rodríguez & Sandoval, 2023).

Social media has fundamentally altered branding from a regulated, hierarchical, and corporate-driven process to a collaborative, flexible, and culturally negotiated activity. Brand significance today arises from a continuous discourse among enterprises, influencers, and digital communities, wherein participation and emotional involvement supplant conventional persuasion. Organizations that effectively integrate social media into brand management systems enhance exposure, promote cultural relevance, and create sustainable competitive distinction based on authenticity, empathy, and shared identity.

2.3. The role of data and consumer behavior in the digital ecosystem

In the modern digital landscape, data and customer behavior patterns are the primary catalysts for marketing intelligence and strategic decision-making. Every digital interaction, including search queries, click paths, content engagement, advertisement responses, and purchase transactions, generates a quantifiable data footprint that accurately discloses consumers' motivations, preferences, and psychological triggers (Alavi & Habel, 2023; Mahrous & Hassan, 2024; Miranda et al., 2022). The exponential increase of user-generated data has revolutionized marketing from a reactive and descriptive field into a predictive, analytical framework that can foresee demands and provide contextually pertinent experiences instantaneously.

Empirical research demonstrates that behavioral data allows marketers to segment audiences according to motivational factors, contextual variables, and value orientations, enhancing message relevance and minimizing informational overload (Nguyen et al., 2023; Zhou & Wong, 2024; Yaseen & Haseeb, 2023). Brands may dynamically adjust content through algorithmic analysis and real-time feedback loops based on micro-signals such as dwell duration, navigation patterns, interaction frequency, and emotional tone (Han et al., 2023; Gera et al., 2022). These analytical methods underpin hyper-personalization, enabling firms to customize communication at the individual level while perpetually enhancing user experience and campaign efficacy. In addition to tactical advantages, behavioral analytics offer strategic insights into customer journeys, facilitating the identification of loyalty determinants, churn indicators, and developing consumption patterns that influence long-term brand strategy.

The extensive collecting and processing of customer data provide substantial ethical and regulatory concerns with privacy, consent, and algorithmic responsibility. As algorithmic technologies increasingly facilitate the interaction between businesses and customers, concerns regarding transparency and user autonomy have become more significant in academic and management discussions. Studies demonstrate that customers anticipate clear information about data utilization, alongside assurances of equity and non-manipulative algorithmic decision-making (Gursoy et al., 2023; Rosenthal & Feldman, 2024; Bartsch & Dienlin, 2023). Neglecting to meet these expectations undermines confidence and may lead to reputational harm or regulatory penalties. As a result, enterprises must

establish responsible data governance frameworks that incorporate ethical monitoring mechanisms, privacy-by-design principles, and interdisciplinary data ethics committees (Mehta & Sridhar, 2024).

Behavioral data serves as the foundational framework of the digital marketing ecosystem, guiding customization, enhancing decision-making, and facilitating value generation across the customer lifetime. However, its strategic influence depends on ethical governance and organizational openness. Brands that effectively incorporate behavioral analytics within an ethical governance framework and prioritize user empowerment enhance communication efficacy and foster enduring trust, loyalty, and legitimacy in the data-driven marketplace.

Conclusion

The integration of artificial intelligence into digital marketing and social media has profoundly transformed how businesses formulate communication strategies, establish identity, and cultivate customer connections. Current data indicates that AI-driven customization, behavioral forecasting, sentiment analysis, and automated content processes markedly improve strategic accuracy, enabling companies to implement responsive, scalable, and contextually aware communication. Organizations are increasingly utilizing models that learn from individual user behavior, contextual signals, and emotional cues, rather than depending on static messages or wide targeting, therefore facilitating highly customized brand experiences. This technological transition also presents significant problems. Although automation enhances productivity and expedites content creation, overreliance on algorithms may undermine creativity, compromise story authenticity, and lead to the uniformity of brand representation. Ethical imperatives, responsible data practices, transparent algorithmic methods, and substantial protection of consumer agency are crucial for maintaining confidence in AI-mediated settings. The results demonstrate that lasting advantage is derived not from the solitary deployment of AI, but from intentional hybrid systems where algorithmic intelligence enhances, rather than replaces, human strategic and creative judgment. The most efficient businesses create systems where technology offers analytical depth and operational efficiency, while human skill ensures uniqueness, ethical integrity, and cultural significance. Brands that incorporate AI as a systematic strategic tool hold a competitive advantage in this environment. Entities that can synchronize technological proficiency with enduring brand principles and genuine customer interaction will be poised to not only adjust to evolving market dynamics but also to influence the advancement of digital communication norms.

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The Role of the Digital Economy in Advancing Smart Cities

Uloga digitalne ekonomije u unapređenju pametnih gradova

Petar Ciganović[1]

[1]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, pciganovic80@gmail.com*

***Abstract**: The paper researches the process by which the digital economy expedites the conversion of cities into smart tourism destinations by incorporating intelligent urban governance, data analytics, and information and communication technologies. It elucidates the conceptual nexus among smart cities, digital transformation, and sustainable tourism, highlighting the circumstances in which technology bolsters competitiveness while mitigating social and environmental repercussions. This qualitative, theory-driven overview of current worldwide research underscores how smart technologies enhance efficiency, tourist experience, and resource management when integrated with principles of sustainability and inclusion. The research establishes the intersection of digitization and sustainability as a feasible paradigm for enhancing urban tourism through increased resilience, creativity, and environmental accountability.*
***Keywords**: Digital economy, smart cities, smart tourism, sustainable development, ICT, urban tourism.*

***Apstrakt**: Rad istražuje proces kojim digitalna ekonomija ubrzava pretvaranje gradova u pametne turističke destinacije uključivanjem inteligentnog urbanog upravljanja, analitike podataka i informaciono-komunikacionih tehnologija. Razjašnjava konceptualnu vezu između pametnih gradova, digitalne transformacije i održivog turizma, ističući okolnosti u kojima tehnologija jača konkurentnost dok istovremeno ublažava društvene i ekološke posledice. Ovaj kvalitativni, teorijski zasnovan pregled aktuelnih svetskih istraživanja naglašava kako pametne tehnologije poboljšavaju efikasnost, turističko iskustvo i upravljanje resursima kada su integrisane sa principima održivosti i inkluzije. Istraživanje uspostavlja presek digitalizacije i održivosti kao izvodljivu paradigmu za unapređenje urbanog turizma kroz povećanu otpornost, kreativnost i ekološku odgovornost.*
***Ključne reči**: Digitalna ekonomija, pametni gradovi, pametni turizam, održivi razvoj, IKT, urbani turizam.*

Introduction

The digital economy is essential in converting cities into intelligent tourist destinations by utilizing technology innovation to improve urban tourism systems. Information and communication technologies (ICT) are enhancing urban efficiency, data use, and sustainability, hence optimizing urban management and enriching the visitor experience. Smart cities incorporate sophisticated digital technologies to enhance services, tailor tourist experiences, and encourage sustainable tourism practices. The interplay between the digital economy and smart tourism has a synergistic effect, wherein technological advancements propel tourist expansion, enhance operational efficiency, and foster new visitor interaction. As urban settings develop, the implementation of smart technologies, including mobile applications, artificial intelligence, and the Internet of Things, facilitates real-time engagement, accessibility, and enhanced resource management. These technologies facilitate sustainable development by mitigating environmental effects and promoting eco-friendly activities, thus enhancing the appeal of cities to both inhabitants and tourists. The advent of smart destinations signifies a fundamental transformation in destination management. Technology has transcended its role as a basic support tool; it has emerged as the cornerstone of innovation, sustainability, and competitiveness in the tourist sector. Through the integration of intelligent systems and digital infrastructures, cities may enhance their tourist potential by providing contemporary, interactive, and ecologically friendly

experiences that adhere to the tenets of sustainable urban development. This background sets the stage for the following theoretical framework, which explores in greater depth how the digital economy and smart technologies drive the transformation of cities into sustainable and competitive tourism destinations.

1. Theoretical framework

The digital economy significantly influences the evolution of smart cities as tourist destinations by utilizing technology innovation to improve urban tourism systems. As cities evolve into intelligent, data-centric ecosystems, they utilize information and communication technology (ICT) to enhance urban services, improve visitor experiences, and promote sustainable tourism practices. The interplay between the digital economy and smart tourism cities constitutes a mutually beneficial dynamic, wherein enhancements in digital infrastructure and services catalyze tourism expansion, enhance operational efficiency, and promote innovative forms of visitor interaction. The use of digital technology in urban planning and tourist administration is fundamental to the development of smart tourism cities. A digitally focused economy facilitates enhanced tourist engagement via tailored experiences, effortless accessibility, and effective service provision. Liu and Ai-Lian (2025) assert that the digital economy propels tourism growth by enhancing the online visibility and accessibility of locations, resulting in a rise in visitor arrivals and consumer spending. Lee et al. (2020) contend that equitable development in smart tourist cities relies on new ICT applications that convert traditional tourism into a more integrated and sustainable framework. Digital connection and data-informed decision-making are the basis for improved tourism experiences in smart cities. Herscovici et al. (2022) emphasize that the strategic utilization of consumer data to customize tourist products may markedly enhance satisfaction and visitor loyalty, hence reinforcing a destination's competitive edge. Utilizing advanced technologies like mobile applications and real-time digital platforms, cities may provide immediate access to information on attractions, services, and transportation alternatives, thereby enhancing visitor convenience and engagement (Kang, 2025). Moreover, these technologies enhance sustainability by reducing resource utilization and encouraging environmentally conscious tourist practices (Archi et al., 2023). The digital economy supports the establishment of robust infrastructure essential for urban tourism. Investments in digital technologies improve economic flexibility and urban governance, enabling transparent transactions and efficient service delivery. Monstadt and Saltzman (2025) note that digital infrastructures enhance urban experiences while inciting critical discussions on sustainability and social inclusiveness. They assert that well-structured digital frameworks allow cities to effectively control tourist flows, minimizing disturbances to local life and fostering a balanced and resilient tourism ecosystem. Furthermore, the integration of smart tourism with environmental stewardship highlights the revolutionary capacity of digital economies. Zhao et al. (2022) demonstrate that smart cities augment tourist performance and boost green total factor production via efficient resource allocation. As environmental issues escalate, smart cities increasingly promote low-emission tourism, sustainable mobility, and circular economy concepts (Du, 2025). Cong et al. (2023) assert that effective policy integration in smart city governance may alleviate the adverse externalities of tourism, harmonizing urban development with long-term sustainability goals. The use of modern technology in urban settings has resulted in the development of smart tourism destinations that emphasize sustainability, innovation, and improved visitor experiences. By using ICT, communities may establish efficient, engaging, and sustainable tourism ecosystems that advantage both locals and visitors. The transformation of smart cities into smart tourism destinations signifies a fundamental change in destination management, with technology serving a pivotal role in the future of tourism. In modern language, the term “smart” has gained prominence, denoting a novel business strategy reliant on intelligence and information technology. Technological advances have propelled the advancement of smart tourism, with the effects of digital transformation apparent in both the sector and the tourists (Femenia-Serra et al., 2019). These modifications are evident at every stage of travel, as information and communication technology has become an essential component of the tourism experience. A "smart

destination" refers to an intelligent, sustainable, and interconnected city that employs contemporary information and communication technology to foster an environment suitable for residents and tourists alike (Gangotia et al., 2018). Individuals have immediate access to essential information via the internet and contemporary technology, enhancing involvement and competition in the market. The internet is a key part of ICT. It is a global network that connects people and makes e-tourism possible. With the rising demand for tourist services, expectations and rivalry among organizations also escalate, as they progressively implement digital strategies to attract visitors (Šarenac, 2019). The emergence of the digital economy has significantly influenced the evolution of smart cities as essential elements of tourism destinations. Smart cities seek to leverage ICT to improve resource management, provide new services, and include both people and tourists in the economic and social dynamics of urban settings (Nižić, 2020). Their commitment to technology, sustainability, and innovation has enhanced people' quality of life and impacted visitors' destination preferences (Mjdy˛ et al., 2022). The notion of smart destinations derives from the smart city paradigm; however, it goes beyond mere technology to encompass integrated management, sustainable development, and astute resource stewardship (Cardoso & Ruiz, 2021). The interplay between smart cities and smart destinations is apparent in the manner technology improves service delivery, fosters creative experiences, and guarantees sustainable growth (Mello & Fakina, 2021). Direct reservations via digital platforms have emerged as a hallmark of intelligent destinations, facilitating efficient and economical transactions for digital customers (Popova & Malcheva, 2020). The primary differences between smart tourism and e-tourism include the integration of digital and physical environments, reliance on sensors and smartphones rather than websites, the ongoing utilization of ICT during the travel experience, the implementation of big data, collaborative experience creation, ecosystem-oriented value frameworks, and the establishment of public-private partnerships in destination management. The utilization of ICT in trip planning has grown prevalent, employing websites, social media, and mobile platforms that impact all tourism stakeholders (Zheng et al., 2015). Internationally appealing locations, especially historical and cultural cities, are progressively implementing clever strategies to attain sustainability. A smart city incorporates diverse technologies, like water recycling, improved energy grids, and mobile communications, to reduce environmental impact and enhance people's quality of life (Giffinger, 2007). Dominik (2017) asserts that smart cities are defined by the integration of information and communication technologies, smart grids, energy-efficient smart metering, machine-to-machine communication (M2M), the Internet of Things (IoT), and Intelligent Transport Systems (ITS). This integration enhances recycling and resource efficiency (Latinović & Jovanović, 2019) while establishing the infrastructure necessary for the progression of smart and sustainable tourism. Intelligent destinations employ contemporary technology, like IoT, mobile communication, cloud computing, and artificial intelligence, to improve visitor experiences (Gok & Salvarci, 2022). These technologies enhance access to databases that monitor visitor preferences, therefore aiding local enterprises and optimizing resources (Cunha et al., 2022). The use of digital technology in smart city management fosters urban regeneration by encouraging sustainable behaviors and renewable resources (Bazazo et al., 2022). The essence of smart destinations is the incorporation of intelligence across all aspects of everyday life, government, economics, and environment to improve sustainability and quality of life for inhabitants and tourists alike (Habeeb & Veli, 2020). Intelligent destinations are defined by the widespread application of modern technologies that facilitate digital ecosystems, data analytics, and effective destination management (Chang, 2023). The technical advancement of tourism, sometimes termed "digital" or "smart" tourism, has transformed the management and experience of locations (Zadel et al., 2021). The use of intelligent technology in tourism is essential for providing tailored experiences, enhancing service quality, and augmenting tourist pleasure (Nezai et al., 2021). In summary, the digital economy and the advancement of smart technology have converted cities into vibrant, intelligent, and sustainable tourism attractions. By integrating ICT, artificial intelligence, and data analytics, cities are transforming tourism standards to provide customized, efficient, and ecologically sustainable experiences. Creating intelligent urban settings necessitates a thorough comprehension of all critical aspects affecting smart city growth and its congruence with sustainable tourism advancement.

2. Smart cities and digital transformation in tourism

The interaction between smart cities and digital transformation is considerably altering the tourist scene, improving urban settings while presenting complications that require sophisticated comprehension. The notion of a smart city amalgamates sophisticated technology and data to optimize urban governance and improve the quality of life for residents, as well as the experiences of tourists. This link is crucial as destinations strive to maintain competitiveness in a digital economy that prioritizes efficiency, connectivity, and sustainability. The emergence of smart cities greatly influences digital transformation in the tourist sector. As urban areas engage in smart technologies, including the Internet of Things (IoT) and big data analytics, the ensuing infrastructure enables the tourist sector to optimize service delivery, augment accessibility, and elevate guest experiences. Lee et al. assert that smart tourism development transcends traditional tourist models, fostering inclusive solutions that engage all stakeholders while safeguarding local communities (Lee et al., 2020). The shift to "smart tourism" embodies the use of intelligent solutions to enhance visitor services and experiences, in accordance with the overarching goals of sustainable urban management emphasized by Vardopoulos et al. (2023). The significance of digital technology in the evolution of urban tourism is paramount. Kumar et al. note that the use of digital solutions is essential for reacting to market developments, especially among younger, technologically proficient generations (Kumar et al., 2023). This digital transformation includes virtual tourism and novel strategies for engaging visitors, such as customized mobile applications that offer real-time information on sites and services (Kumar et al., 2023). Moreover, Marchesani et al. emphasize that smart mobility practices boost tourism flows and optimize logistical operations in urban settings, which is essential for enhancing visitor experiences (Marchesani et al., 2023). However, the use of digital technology in urban tourism presents issues, especially regarding fairness and accessibility. Vujko et al. assert that although intelligent solutions might enhance access to information and services, they may unintentionally exacerbate the digital divide, disadvantaging less technologically adept people (Vujko et al., 2025). Furthermore, Akhtar et al. emphasize the necessity of collaborative strategies to prevent the marginalization of certain groups throughout digital transition (Akhtar et al., 2021). This suggests that, although smart cities might enhance visitor experiences, meticulous policy deliberation is crucial to preventing any socioeconomic inequalities. Sustainability is a fundamental subject in the dialogue around smart cities and tourism. The digital economy fosters ecologically friendly activities in urban areas, in accordance with the sustainability objectives advocated by urban planners and tourist officials. Research by Zhao et al. substantiates that smart city efforts improve sustainable practices in tourism, leading to diminished environmental consequences and fostering effective resource management (Zhao et al., 2022). The interplay between technology innovation and sustainable practices indicates that smart cities may successfully promote tourist sectors to achieve both economic development and ecological equilibrium. Data analytics and digital tools are crucial in improving the entire visitor experience. Virtual reality tours and augmented reality programs enable travelers to interact with urban settings in innovative and engaging manners, as observed by Zhang (Zhang, 2024). The insights obtained from tourist data enhance tailored experiences and assist cities in managing visitor flows while optimizing economic gains from tourism. Research demonstrates that the implementation of information technology in tourism enhances operational efficiencies and elevates visitor satisfaction, resulting in greater economic benefits for local communities (Myrovali et al., 2025; Rahayu & Rahayu, 2025). The integration of smart city frameworks with digital transformation characterizes the modern urban tourism experience. Intelligent technologies improve operational efficiencies and encourage sustainable practices; yet, they also require inclusive policies to address equality issues. As urban areas transform into intelligent tourist destinations, it is essential to combine technology integration with social responsibility to cultivate adaptable and sustainable tourism ecosystems.

3. Sustainable development and smart tourism

The incorporation of sustainable development ideas into smart tourism frameworks profoundly influences the future of metropolitan regions worldwide. Smart tourism, integrating new technology with tourist practices, is essential for cities to provide sustainable and enjoyable experiences for visitors while protecting the environment and improving people's quality of life. This transition requires significant alterations in urban administration, resource management, and the involvement of many stakeholders in the tourist ecosystem. The collaboration between smart cities and sustainable tourism is essential. A "smart tourism city," as described by Lee et al., is an innovative tourist destination that incorporates smart city concepts to achieve enhanced sustainability and increased competitiveness in the tourism sector (Lee et al., 2020). This combination addresses the increased demands of visitors for connection and convenience while simultaneously highlighting the necessity for environmental conservation and cultural preservation. In the realm of sustainable development, smart tourism emerges as a method to draw visitors while reducing ecological footprints by optimizing resource utilization (Saputra, 2023). Recent studies suggest that smart tourism may substantially enhance economic development while fostering environmental sustainability. Vujko et al. assert that technology innovations, including IoT, big data, and mobile apps, can augment operational efficiency and improve visitor engagement, resulting in favorable economic outcomes for urban regions (Vujko et al., 2025). Utilizing information and communication technology (ICT), cities may enhance tourist experiences, draw additional visitors, and bolster local economies while minimizing environmental harm (Ye et al., 2020). Furthermore, the use of intelligent transportation systems has become a crucial element in the sustainable tourism framework. Marchesani et al. assert that the advancement of smart mobility practices in urban environments enhances tourist traffic while simultaneously reducing carbon emissions linked to conventional transportation systems (Marchesani et al., 2023). This advancement is essential for urban areas seeking climate resilience while ensuring elevated tourist contentment. Sustainable growth in smart tourism compels cities to ensure equitable resource allocation among all stakeholders. Almeida et al. assert that the advantages derived from digitalization and intelligent technology should be available to local communities, so strengthening local economies and promoting social inclusion (Almeida et al., 2020). The discourse on sustainability in smart tourism must address socioeconomic gaps by advocating for programs like community-based tourism, which often garners local support and guarantees that tourist development coincides with people' objectives (Archi et al., 2023). The connection between digital transformation and environmental sustainability is gaining recognition. Technologies enable the oversight of sustainable operations and promote compliance with environmentally friendly rules in the tourist industry. The utilization of digital technologies for waste management in tourism hotspots is crucial for executing circular economy plans, as demonstrated by case studies of smart tourism efforts in many cities (Oktriono et al., 2025). These measures improve waste management techniques, diminish pollution, and encourage responsible consumption among visitors. Evidence indicates that enhancing public knowledge of sustainable practices can produce substantial advantages. Studies demonstrate that educational and outreach programs can alter visitors' behavior toward more sustainable options, enhancing the beneficial effects of tourism in urban settings. Sustainable practices enhance user experiences and are essential for preserving the cultural and historical integrity of tourism places. The incorporation of sustainable development into smart tourism frameworks is an effective strategy for improving urban tourism experiences and reducing environmental consequences. Smart cities may significantly contribute to sustainable tourism by utilizing technology to enhance efficiency, stimulate economic growth, and guarantee equitable distribution of tourism benefits. The dedication to sustainability in tourism requires the cooperative efforts of governments, local communities, and visitors, resulting in a robust and sustainable tourism environment.

4. Challenges and opportunities of the digital economy for tourism

The transformational interaction between smart cities and digital innovation establishes sustainable development as a fundamental pillar in determining the future of smart tourism. As metropolitan areas adopt digital technology to optimize management and enrich visitor experiences, sustainability emerges as the fundamental concept that guarantees technical advancement is consistent with environmental preservation, social inclusion, and enduring economic development. The intersection of digital transformation and sustainability establishes a new paradigm for urban tourism, aiming to harmonize technical progress with ecological and human welfare. The incorporation of sustainable development concepts into smart tourism is essential for cities aiming to maintain competitiveness while confronting the time-sensitive issues of climate change and resource depletion. Smart tourism integrates sophisticated digital technologies with sustainable practices, allowing cities to provide stimulating experiences for visitors while safeguarding natural and cultural resources. This strategy transforms destination management by enhancing efficiency and creativity via the judicious application of information and communication technology (ICT). According to Lee et al. (2020), a "smart tourism city" represents an advanced destination concept that integrates smart city principles to improve sustainability and competitiveness. This alignment fulfills the increasing demands of tourists for digital connectivity and comfort while emphasizing the significance of environmental stewardship and cultural preservation. In this context, technology serves as a facilitator for ecological transition by optimizing energy usage, controlling urban transportation, and reducing waste through intelligent systems (Saputra, 2023). Recent studies highlight that smart application of technological advancements may enhance both the economic and ecological aspects of tourism. Vujko et al. (2025) emphasize that the integration of IoT networks, mobile platforms, and big data analytics enhances operational efficiency and visitor engagement, fostering sustainable urban development. Ye et al. (2020) illustrate that ICT-driven innovations draw tourists while preserving environmental equilibrium by facilitating data-informed decisions that enhance resource efficiency. Mobility is a fundamental element of sustainable smart tourism. The advancement of intelligent transportation solutions, encompassing electric automobiles, cohesive public transit networks, and real-time navigation technology, signifies a critical progression in the reduction of carbon emissions. Marchesani et al. (2023) assert that smart mobility enhances visitor flows and is crucial for attaining urban climate objectives, so connecting tourism enjoyment with environmental efficacy. Sustainability encompasses not only environmental issues but also equity and community involvement. Almeida et al. (2020) assert that the economic advantages of smart tourism should be equitably allocated among stakeholders to promote social inclusion and enhance local economies. This perspective supports community-based tourism initiatives that empower local residents, promote cultural authenticity, and align tourist growth with social welfare (Archi et al., 2023). The use of digital technology enhances the oversight and execution of sustainable activities. Intelligent technologies provide instantaneous data acquisition and analysis for waste management, energy efficiency, and the implementation of circular economy concepts. Case studies by Oktriono et al. (2025) demonstrate that digital waste management and eco-monitoring systems are essential for upholding sustainable standards in metropolitan areas. Awareness and education are essential in fostering sustainable behavior among tourists. Research demonstrates that digital communication platforms may successfully promote environmentally responsible choices by educating users about sustainable consumerism, local ecological efforts, and the preservation of cultural heritage. These initiatives enhance the quality of the visitor experience and bolster the city's reputation as a sustainable destination. Sustainable development serves as the ethical and strategic foundation of intelligent tourism. By integrating technology intelligence with ecological awareness, smart cities may develop resilient tourist ecosystems that produce economic wealth while preserving environmental and social integrity. Collaboration among politicians, urban planners, local communities, and visitors is crucial for achieving the aim of sustainable, inclusive, and future-oriented urban tourism.

Conclusion

This study's findings unequivocally illustrate that the digital economy is a pivotal factor in reshaping the interplay of urban growth, technology, and tourism. By integrating information and communication technologies (ICT), artificial intelligence, the Internet of Things (IoT), and big data analytics, cities are transforming into intelligent, interconnected ecosystems that provide personalized, efficient, and sustainable tourism experiences. The digital revolution of urban environments has reconfigured the tourist sector, transitioning it from a conventional, reactive model to an adaptable, data-driven, and strategically sustainable framework. The investigation verifies that smart city frameworks and digital technologies collaboratively enhance efficiency in resource management, urban transportation, and service delivery, while simultaneously improving the visitor experience. This change also presents difficulties with inclusion and the digital divide. The results highlight that the efficacy of smart tourism relies not just on technology capabilities but also on fair access, stakeholder cooperation, and legislative structures that guarantee all socioeconomic groups benefit from digital advancements. Sustainability has become the paramount factor directing the incorporation of the digital economy into tourism. Smart cities demonstrate how technology can enhance climate resilience, energy efficiency, and sustainable consumption via intelligent transportation, circular economy strategies, and real-time environmental surveillance. These models affirm that sustainable tourism is an essential environmental and economic necessity that fosters growth while safeguarding the cultural and natural legacy of destinations. The integration of the digital economy, intelligent urban administration, and sustainable tourism signifies a transformational model for future urban development. This integration enables cities to achieve technical advancement, social inclusivity, and ecological balance. The way ahead involves strategic collaboration among governments, academics, private firms, and local communities to guarantee that innovation benefits both human and environmental welfare. The influence of the digital economy on the evolution of smart cities as tourism attractions is significant and multifaceted. When driven by sustainability and inclusion, digital transformation serves as a driver for urban resilience, competitiveness, and enduring prosperity, redefining the global tourist scene to be intelligent, adaptive, and sustainable.

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Integrating NLP into Strategic Communication Management

Integracija NLP-a u upravljanje strateškim komunikacijama

Tanja Ristić[1], Kristina Jauković Jocić[2], Tamara Ristić[3], Tijana Đukić[4]

[1]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, simsiric@yahoo.com*

[2]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, kristina.jaukovic@mef.edu.rs*

[3]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, tamara.ristic@mef.edu.rs*

[4]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, tijana.djukic@mef.edu.rs*

***Abstract**: This paper investigates the function of Natural Language Processing (NLP) in the automation of communication and the improvement of audience analysis in digital marketing environments. The objective of the research is to investigate how NLP technologies, such as sentiment analysis, topic modeling, and conversational AI, facilitate adaptive, data-driven engagement and transform audience comprehension. The managerial, ethical, and operational implications of NLP implementation were identified by employing a qualitative analytical approach to synthesize the results of recent academic studies. The findings indicate that NLP significantly improves personalization, responsiveness, and decision-making efficiency. However, ethical governance remains essential for the preservation of user trust and transparency. The study concludes that the integration of NLP with human governance and emotional intelligence establishes a sustainable communication model that reconciles automation, empathy, and authenticity in digital brand interactions.*

***Keywords**: NLP, audience analysis, communication automation, sentiment analysis, digital marketing.*

***Apstrakt**: Ovaj rad istražuje funkciju obrade prirodnog jezika (NLP) u automatizaciji komunikacije i poboljšanju analize publike u digitalnim marketinškim okruženjima. Cilj istraživanja je da se istraži kako NLP tehnologije, kao što su analiza raspoloženja, modeliranje tema i konverzaciona veštačka inteligencija, olakšavaju adaptivno, angažovanje vođeno podacima i transformišu razumevanje publike. Menadžerske, etičke i operativne implikacije implementacije NLP-a identifikovane su primenom kvalitativnog analitičkog pristupa za sintezu rezultata nedavnih akademskih studija. Rezultati ukazuju da NLP značajno poboljšava personalizaciju, brzinu odziva i efikasnost donošenja odluka. Međutim, etičko upravljanje ostaje neophodno za očuvanje poverenja i transparentnosti korisnika. Studija zaključuje da integracija NLP-a sa ljudskim upravljanjem i emocionalnom inteligencijom uspostavlja održivi model komunikacije koji pomiruje automatizaciju, empatiju i autentičnost u interakcijama digitalnih brendova.*

***Ključne reči**: NLP, analiza publike, automatizacija komunikacije, analiza raspoloženja, digitalni marketing.*

Introduction

The utilization of Natural Language Processing (NLP) in audience research and communication automation signifies significant progress in modern digital marketing and corporate communication. NLP enables companies and organizations to read, analyze, and produce human language, hence enhancing their understanding of audience emotions, intents, and attitudes conveyed on social media and digital platforms. Consequently, communication tactics are progressively transitioning from static, unidirectional distribution to adaptive, data-driven interaction models that prioritize customization, contextual relevance, and engagement. NLP technologies have emerged as a pivotal element in social media, greatly improving brands' capacity to discern primary discussion topics, analyze semantic

structures, and evaluate emotional responses (Zouganeli et al., 2024; Castro et al., 2023; Park & Min, 2022). Organizations may get enhanced audience segmentation and message targeting by deciphering language and behavioral cues, therefore matching digital content with user sentiment and dynamic conversational situations (Elmadany et al., 2023; Gupta & Jain, 2022). Sentiment analysis is a prevalent use of NLP in digital communication, facilitating the automatic identification of positive, negative, and neutral emotions within user-generated information. Insights obtained from these studies facilitate reputation management, assessment of consumer satisfaction, and real-time adaptation of communication tactics (Coban et al., 2024; AlHassan & Song, 2023; Hossain et al., 2023). These solutions enable firms to identify early indicators of audience discontent or behavioral changes and to engage proactively before communication issues intensify (Deng & Li, 2022). Simultaneously, chatbots and virtual assistants driven by NLP facilitate the automation of consumer interactions, delivering real-time, tailored, and contextually relevant communication. These technologies expedite response times, diminish operating expenses, and improve service accessibility while preserving a natural and human-like tone in brand communication (Pereira et al., 2024; Rahman & Hoque, 2023; Sarkar & Dutta, 2024). NLP facilitates the automation of community management, which includes content moderation, topic filtering, and the early identification of disruptive or harmful behavior to maintain constructive and stable online environments (Galvis et al., 2023; Lopez-Sarmiento & Soto, 2024; Prakash et al., 2022). When integrated with predictive modeling, NLP serves as a robust decision-support tool that enables enterprises to adapt their communication strategies, optimize resource distribution, and maintain scalable engagement frameworks (Ramaswamy & Kannan, 2023). As NLP systems increasingly permeate digital ecosystems, the research issue is to investigate the practical implementation of these technologies while maintaining authenticity, openness, and compliance with ethical communication norms.

NLP surpasses its technical role to serve as a strategic facilitator of significant, sympathetic, and responsive digital communication. It enables enterprises to convert communication from simple information dissemination into an ongoing, adaptable dialogue that fosters trust, loyalty, and relevance in a swiftly changing digital environment.

1. Theoretical framework

Natural Language Processing (NLP) is an interdisciplinary domain that integrates computational linguistics, artificial intelligence, and data analytics, primarily focused on facilitating machines to understand, interpret, and produce human language with semantic accuracy and emotional depth. It incorporates several analytical layers, such as lexical analysis, syntactic parsing, semantic interpretation, and discourse modeling, which are crucial for deriving meaning from textual input and discerning the underlying purpose of communication. The subject has progressed from rule-based linguistic models to sophisticated machine learning and deep learning systems that exhibit self-adaptive language comprehension. Techniques such as word embeddings (e.g., Word2Vec, GloVe) and transformer models (e.g., BERT, GPT) have transformed NLP by enabling contextualized word representations and cross-domain understanding, thereby enhancing the accuracy of sentiment detection, emotion classification, and content personalization (Arab et al., 2025; Khan, 2025). The analytical capability of NLP has evolved from just language comprehension to include psychological and sociocultural analysis of conversation. NLP systems facilitate marketers and communication professionals in comprehending audience cognition, emotional states, and behavioral proclivities by analyzing linguistic clues such as tone, metaphor, and emotional intensity (Dutta et al., 2025). NLP has become a critical instrument inside the digital marketing ecosystem, facilitating both analysis and communication design. Organizations can utilize techniques such as sentiment analysis, topic modeling, and semantic clustering to analyze extensive unstructured data from social media, customer reviews, and online discussions, enabling them to identify emerging themes, monitor consumer sentiments, and predict behavioral changes (Khudhair et al., 2025; Krsmanović, 2025). These data assist companies in enhancing positioning strategies, personalizing messaging, and formulating more accurate, adaptive communication models

that correspond with audience mood and conversational context. Integrating NLP with predictive analytics enables enterprises to discern sentiment fluctuations, forecast public responses, and enhance message dissemination across many platforms. This integration converts digital marketing from a reactive strategy to a proactive, perpetually adaptive communication framework. The predictive capability of NLP facilitates segmentation according to emotional resonance, preference alignment, and brand authenticity perception, hence fostering long-term loyalty and strategic differentiation (Syam, 2025; Gujrati, 2025). This analytical depth enhances competitive intelligence by facilitating real-time benchmarking and the ongoing refinement of marketing strategies. NLP functions not just in analytical contexts but also as a fundamental tool for automating communication via chatbots, virtual assistants, and AI-driven conversational agents that utilize intent recognition and context-sensitive answer production. These technologies augment the immediacy and customization of brand communication, promote operational efficiency, and diminish reaction latency while preserving natural, contextually relevant engagement (Verma & Fatma, 2025; Gujrati, 2025). They are especially significant in high-engagement sectors, such as e-commerce and hotels, where prompt and pertinent communication directly influences consumer happiness and retention. The emergence of automation creates a significant conflict between efficiency and authenticity. NLP improves responsiveness and customization; yet, overdependence on algorithms may diminish emotional depth and perceived authenticity in brand communication. The effective deployment of such systems necessitates a balance between algorithmic accuracy and human empathy so that automation enhances rather than supplants authentic interpersonal interaction (Dutta et al., 2025). The proliferation of NLP technology in extensive audience analysis and automated communication presents intricate ethical and governance issues with algorithmic bias, transparency, and data protection. Researchers observe that NLP systems developed on imbalanced or biased datasets may perpetuate prejudices or skew emotional interpretations, resulting in morally questionable or exclusionary communication results (Jundon et al., 2025; Zhang & Zhang, 2023). Furthermore, the opacity of deep learning models frequently obstructs accountability, as it becomes progressively challenging to ascertain how algorithmic decisions affect content curation and audience segmentation. The use of responsible AI frameworks is crucial to tackle these difficulties, highlighting fairness audits, explainability, and user consent methods in all NLP applications. Ethical and open governance ensures compliance with regulations and builds user trust, which has become a strategic asset in the age of algorithmically mediated communication (Arab et al., 2025). NLP can transform intelligent communication systems by integrating these characteristics. NLP's analytical prowess provides deep insights into audience behavior, sentiment, and conversation, while its generative and automated functionalities facilitate personalized, adaptable, and scalable interactions. The genuine worth of NLP is realized only when its technological capabilities are harmonized with ethical principles and human supervision. NLP functions as an interpretive mechanism that converts audience data into strategic communication insights and as an operational interface that facilitates real-time, ethically regulated, and data-driven communication activities. NLP transforms organizational comprehension, engagement, and the establishment of enduring relationships with audiences in the digital age through its dual function.

2. The role of NLP in audience analysis

Natural Language Processing (NLP) is widely acknowledged as a crucial instrument in digital marketing for improving audience profiling and optimizing communication methods. NLP facilitates the transformation of extensive unstructured text data into actionable insights through applications like sentiment and emotion analysis, topic identification, and real-time feedback systems. I will summarize the practical uses of NLP in digital marketing, accompanied by pertinent references to substantiate each assertion. 1. Sentiment and Emotion Assessment The ability of NLP to analyze sentiment and emotion is among its most significant uses in digital marketing. Organizations employ sentiment analysis to assess audience responses to campaigns, goods, and brands, enabling them to classify feelings as positive, negative, or neutral. This prompt feedback system allows marketers to modify their plans

instantaneously. Research indicates that sentiment analysis techniques effectively evaluate public reactions, enabling managers to adapt messaging or goods in response to customer input (Mishev et al., 2020; Joseph, 2024). Moreover, sophisticated emotion recognition allows companies to comprehend intricate emotional states, thus enabling preemptive reactions to possible crises or opportunities (Feizollah et al., 2025). 2. Identification of Topics and Mapping of Trends NLP enables the detection of major themes and developing trends using techniques like topic modeling and keyword extraction, in addition to sentiment evaluation. This study allows marketers to identify prevailing topics in consumer discourse, which can be essential for content development and campaign strategy. Research demonstrates that comprehending these patterns facilitates the prompt production of content that resonates with audience interests, hence improving engagement levels (Singh et al., 2022; Claus & Stella, 2022). By adeptly analyzing trends, companies may promptly address public issues and tactically refine their messaging (Sudarmaji et al., 2024). 3. Audience Segmentation and Behavioral Analysis NLP enhances the precision of audience segmentation by analyzing linguistic patterns, word choices, and sentiment across various demographic and psychographic classifications. This capability enables marketers to classify consumers not just by age or region but also by emotional tone and communication style. For instance, particular language selections may reveal diverse emotional reactions across distinct audience segments (Köckritz et al., 2025; Almanna et al., 2025). Tailoring material to appeal to these categories markedly enhances engagement potential and conversion rates (Babatunde et al., 2024). 4. Immediate Feedback and Tailored Communication Utilizing NLP-based dashboards, enterprises may perpetually assess sentiment and engagement across digital platforms. This skill facilitates swift reactions to changes in public sentiment. For example, if unexpected adverse feedback emerges about a campaign, NLP systems can notify marketing teams, driving rapid remedial actions (Pyate & Srinivasan, 2024). This adaptive messaging guarantees that brand communication stays pertinent and in harmony with audience feelings, therefore cultivating a consistent and responsive brand image (Jiang et al., 2023). 5. Integration with Predictive Analytics The integration of NLP with predictive analytics equips marketers with insights into prospective audience behaviors. Through the analysis of previous data and communication patterns, predictive modeling may forecast audience responses to future campaigns or product launches. This predictive capacity enables the evaluation of diverse communications techniques to determine the most effective, enhancing budget allocation and campaign optimization (Nasution & Onan, 2024; Sakyoud et al., 2023). Incorporating NLP into marketing automation systems improves the distribution of tailored content by predicting user behavior (Imamguluyev, 2023). Enhancing Customer Experience Using Conversational AI Conversational AI, driven by natural language processing, markedly improves client interactions via chatbots and virtual assistants. These systems employ NLP algorithms to analyze user inquiries and deliver pertinent, context-sensitive replies. In addition to enhancing customer service, they collect significant conversational data that disclose user preferences and opinions, thus augmenting audience analysis skills (Azarpey et al., 2025; Buchem et al., 2022). Research indicates that these interactions not only facilitate service requests but also enhance comprehension of client mood (Narasamma & M., 2022). 7. Ethical and Operational Considerations The benefits of NLP in digital marketing are significant; nonetheless, its implementation requires careful attention to ethical considerations, especially with data protection and transparency. Robust data management methods and compliance with privacy legislation are crucial for sustaining user confidence and preventing misunderstanding of insights generated by automated systems (Yadav et al., 2025; Chung et al., 2024). Establishing ethical oversight and human review mechanisms is essential for maintaining the credibility of communication methods guided by NLP (Luo, 2023). NLP automates and enhances audience research in digital marketing, enabling firms to monitor public mood, discern new trends, segment audiences more efficiently, and adjust messages in real time. When employed judiciously, NLP not only improves marketing efficacy but also cultivates genuine connections between businesses and customers by ensuring communication is pertinent, responsive, and aligned with audience feelings.

3. Automating communication with NLP

Insights obtained from audience research using Natural Language Processing (NLP) serve as the basis for the subsequent strategic advancement in digital marketing: the automation of communication. Upon comprehending audience emotions, preferences, and linguistic actions, corporations may leverage NLP technology to respond to this insight instantaneously. Automation embodies the actual application of analytical findings, converting static audience data into dynamic and responsive interactions. It enables companies to not only analyze sentiment but also to interact via tailored, context-sensitive, and scalable communication platforms that adapt to user behavior. Natural Language Processing has emerged as an essential element of modern marketing frameworks, enabling the automation of communication procedures and the improvement of customer experience. By integrating intelligent systems with language comprehension capabilities, firms may address queries, provide customized content, and sustain ongoing consumer connection across several platforms. This technology revolution guarantees efficiency, precision, and uniformity in brand communication, integrating automated procedures with strategic marketing objectives. A significant domain of NLP application is the creation of chatbots and virtual assistants that replicate human-like dialogue. These AI-driven systems analyze user intent, identify contextual signals, and produce coherent, pertinent replies. They adeptly handle standard inquiries, offer tailored product suggestions, and assist clients in making purchasing or service-related choices, hence enhancing response time and service quality (Pavone et al., 2024; Remountakis et al., 2023). Utilizing NLP's ability to comprehend semantics and tone, such systems tailor messages to user context, guaranteeing that communication seems personalized and emotionally resonant (Cui & Mohib, 2025). A significant contribution of NLP is the enhancement of customized and interactive communication. Algorithms designed to assess previous interactions and user behavior empower marketers to provide customized information and suggestions that align with customer preferences and intents. Automated systems may generate tailored emails, promotional offers, and notifications that align with client histories and interests, thus enhancing engagement and cultivating emotional loyalty (Bauer et al., 2025; Abdullah et al., 2024). Studies demonstrate that this degree of customization enhances consumer retention and conversion rates inside digital environments (Filieri et al., 2021; Abdullah et al., 2024). NLP enhances real-time analytics and facilitates continuous feedback mechanisms, in addition to personalized messages. Through the monitoring and analysis of user feedback across digital platforms, firms may identify sentiment fluctuations and new concerns, allowing proactive modifications to marketing tactics. This response is crucial for preserving reputational stability and averting catastrophes. Brands utilizing real-time sentiment analysis via NLP may promptly adjust tone, enhance marketing narratives, and rebuild audience trust in response to unfavorable feedback (Sedgwick et al., 2023; Krugmann & Hartmann, 2024). The capacity to discern emotional subtleties as they emerge guarantees that automated communication stays empathic, contextually relevant, and in accordance with user expectations. NLP enables extensive content production across several communication modes, in addition to conversational automation. Advanced language models like BERT and GPT provide grammatically accurate, contextually relevant, and stylistically uniform content appropriate for social media postings, advertising, product descriptions, or blog entries (Wang, 2025; Sayeed et al., 2023). The automation of creative output expedites production cycles and maintains consistency in brand voice across various digital platforms. Moreover, NLP-driven content systems may assess several textual variants to determine whether tone or phrasing elicits stronger audience engagement (Hou et al., 2025). Automation facilitated by NLP improves total consumer engagement by rendering conversations more responsive and emotionally astute. Intelligent conversation systems may recognize emotional signals like irritation, contentment, or enthusiasm and modify their communication strategies appropriately. This adaptive reactivity promotes ongoing engagement and fortifies enduring brand ties. Research demonstrates that firms using NLP-driven automation have elevated satisfaction levels, enhanced engagement metrics, and increased brand loyalty (Khairuddin et al., 2022; Karhade et al., 2022). Notwithstanding its myriad benefits, the deployment of NLP-based automation raises significant ethical concerns. The legitimacy of AI-mediated interactions, user privacy, and data protection are

significant concerns within the digital ecosystem. Automated methods may mask the human aspect of communication, thereby fostering notions of impersonality or manipulation. To address these challenges, firms must guarantee openness in their AI use, adhere to privacy legislation, and formulate explicit ethical norms for automated involvement (Shen, 2025; Michael, 2023). Effective data governance, coupled with human supervision, maintains user confidence and protects brand integrity in more algorithmic communication contexts (Luri et al., 2023). NLP-based automation, when considered a cohesive process, converts communication management from a reactive, manual endeavor into an intelligent, adaptable system. By integrating verbal comprehension, emotional assessment, and predictive modeling, it allows companies to maintain significant relationships that are effective, genuine, and strategically aligned with user anticipations. NLP enables firms to transcend mechanical automation by integrating technology and communication strategy, fostering a model of communication that is guided by data, empathic, and centered on human interaction.

4. Practical implications and managerial recommendations

The integration of Natural Language Processing (NLP) into communication management offers revolutionary possibilities for firms aiming to improve audience engagement, refine decision-making, and maintain sustainable brand competitiveness. Effective implementation requires a strategically informed and morally principled approach that aligns technical capabilities with business goals and human values. NLP transforms the comprehension of audience intelligence from a managerial standpoint. Conventional segmentation methods that rely predominantly on demographic or behavioral metrics are progressively being supplanted by psycholinguistic and sentiment-driven frameworks that reveal more profound motivational and emotional dimensions of customer behavior. Managers may now obtain real-time insights into audience perceptions and emotions, rather than depending exclusively on retrospective surveys or statistical data. This transition facilitates a proactive strategy for managing brand reputation, responding to crises in real-time, and continuously adapting communication tactics to evolving audience dynamics. NLP tools should be integrated into a comprehensive strategy framework rather than utilized as standalone technology solutions. When thoroughly integrated into customer relationship management (CRM) and marketing automation systems, natural language processing (NLP) facilitates a continuous feedback loop between audience sentiment and communication answers. This connection guarantees that insights obtained from language-based data immediately influence message creation, tone adjustment, and campaign customization. This approach necessitates investment in robust data infrastructure and effective communication across marketing, IT, and analytics teams to ensure the accuracy, interoperability, and ethical utilization of audience data. NLP has become crucial for improving customization and user experience, in addition to its operational advantages. Semantic and emotional analysis facilitates precise message customization that accounts for tone, context, and user intent. Sentiment-aware recommendation systems may adapt marketing material in real-time based on a user's emotional state or preferences, so enhancing engagement and relevancy. Automated interactions, including chatbots and virtual assistants, must be crafted to embody the brand's identity, language, and cultural subtleties. When automation is integrated with emotional intelligence, firms attain enhanced authenticity, increased customer happiness, and fortified loyalty, shifting communication from transactional to relational. As NLP increasingly facilitates contact between businesses and customers, ethical governance and transparency become essential management priorities. Data privacy, algorithmic fairness, and user permission should be regarded not only as compliance obligations but as essential elements of business responsibility. Managers must guarantee compliance with standards like GDPR while fostering transparency regarding the utilization of automated technology. Clear transparency about AI-driven interactions fosters trust and reduces feelings of manipulation. Formulating corporate ethical guidelines and performing regular audits to identify and rectify algorithmic bias are crucial measures for responsible deployment. The incorporation of human oversight in automated communication processes enhances accountability and cultivates public trust in technology-assisted

discussion. A crucial managerial aspect entails ongoing learning and change. NLP systems progress with data feedback, necessitating frequent monitoring, evaluation, and refinement of their performance. Managers must foster a culture focused on learning that prioritizes the retraining of algorithms, the integration of new language patterns, and the enhancement of digital communication methods in reaction to evolving customer behavior. Ongoing professional development in data literacy and AI understanding should accompany these initiatives, ensuring that staff can properly comprehend and use insights derived from NLP technology. Although automation improves scalability and efficiency, human connection is essential for preserving emotional authenticity and trust. The ideal strategy involves creating hybrid communication systems in which automated processes oversee regular or data-heavy jobs, while human agents address complicated, sensitive, or high-stakes exchanges. This equilibrium maintains the human aspect of communication, enabling technology to act as an intelligent support system rather than a substitute for empathy, inventiveness, or discernment. Assessing the efficacy of NLP-driven tactics necessitates transcending conventional performance indicators. Alongside engagement rates and conversions, managers have to assess qualitative metrics such as sentiment stability, perceived trust, message consistency, and user satisfaction with automated conversations. Creating multidimensional frameworks that incorporate emotional and behavioral involvement offers a more thorough evaluation of NLP's impact on organizational communication objectives and overall brand reputation. The management execution of NLP necessitates a dual emphasis: attaining operational efficiency via automation while maintaining ethical, human-centered communication principles. Organizations that effectively incorporate NLP into their communication systems will expedite processes, boost responsiveness, and build genuine, lasting connections with their audiences grounded in empathy, transparency, and trust. By integrating data intelligence with ethical governance, managers may convert NLP from a technical tool into a lasting strategic asset enhancing corporate performance while upholding the overarching ideals of responsible and human-centered digital communication.

Conclusion

Natural Language Processing (NLP) has revolutionized communication and digital marketing from intuition-based to data-driven decision-making. NLP enables firms to comprehend audience sentiment, anticipate behavioral trends, and provide responsive, customized interaction through its analytical and operational functionalities. NLP enables organizations to develop flexible, emotionally impactful, and contextually accurate communication strategies by transforming unstructured linguistic data into actionable insights. A study indicates that NLP transcends language interpretation to enhance audience engagement through automation and real-time interaction. NLP integrates information and action via sentiment analysis, subject modeling, predictive analytics, and conversational AI. This transformation enables firms to anticipate audience needs, adapt to emerging discourses, and maintain authenticity across digital platforms. NLP serves as both an interpretive framework that transforms audience behavior into strategic insights and an operational infrastructure that facilitates ethical discourse. The ethical and managerial dimensions of NLP implementation are equally significant. The paper underscores that technology advancement must integrate transparency, accountability, and human principles. Governance must tackle algorithmic bias, data privacy, and the legitimacy of AI-mediated interactions. The application of ethical NLP safeguards user trust and guarantees algorithmic equity and inclusivity. This necessitates strong control mechanisms, human oversight in automated communication systems, and adherence to increasing regulatory standards. The incorporation of NLP into communication management represents both a managerial opportunity and responsibility. Organizations that integrate NLP with strategic objectives, emotional intelligence, and ethical considerations can enhance efficiency, personalization, and brand loyalty. The integration of automation with human creativity establishes a hybrid communication model that preserves empathy and authenticity while employing data-driven accuracy. Emotional engagement, sentiment consistency, and trust assessment can quantify the influence of NLP on organizational communication and

reputation enhancement. As technology, languages, and ethics converge, NLP epitomizes the future of digital communication. It may imbue technology with a human touch, rendering machine-mediated interactions more responsive, significant, and emotionally astute, rather than merely automating or analyzing data. NLP is fundamental to a sustainable communication strategy that harmonizes efficiency with empathy, intelligence with integrity, and innovation with human-centered values as organizations navigate digital transformation.

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The Impact of e-Promotion on the Selection of Tourist Destinations: An Analysis of Respondent's Attitudes

Uticaj e-propagande na izbor turističkih destinacija: Analiza stavova ispitanika

Oliver Momčilović[1], Jovana, Ljubisavljević[2], Adriana Radosavac[3], Sanja Anastasija Marković[4]

[1]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, oliver.momcilovic@mef.edu.rs*
[2]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, jovana.ljubisavljevic@mef.edu.rs*
[3]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, Adriana.radosavac@mef.edu.rs*
[4]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, sanja.markovic@mef.edu.rs*

***Abstract**: This paper examines the impact of e-promotion on the selection of tourist destinations, with a focus on demographic factors such as gender, education, and age of tourists. Using a quantitative method, the research analyzes tourists' attitudes toward various forms of digital marketing, such as video and audio materials on the websites of tourism businesses. Furthermore, the study investigates the role of mobile devices, computers, and the internet in enhancing communication and relationships between tourists and tourism organizations. The findings indicate the significant role of electronic media in the decision-making process, as well as differences in attitudes among various demographic groups.*
***Keywords**: e-Promotion, destination selection, digital marketing, tourism sector, internet, tourists' attitudes, demographic differences.*

***Apstrakt:** Rad istražuje uticaj elektronske propagande na izbor turističkih destinacija, s fokusom na demografske faktore kao što su pol, obrazovanje i starosna dob ispitanika. Koristeći kvantitativnu metodu, istraživanje analizira stavove ispitanika prema različitim oblicima digitalnog marketinga, kao što su video i audio materijali na veb sajtovima turističkih preduzeća. Pored toga, ispituje se uloga mobilnih uređaja, računara i interneta u poboljšanju komunikacije i odnosa između ispitanika i turističkih organizacija. Rezultati istraživanja ukazuju na značaj elektronskih medija u procesu donošenja odluka, kao i na razlike u stavovima različitih demografskih grupa.*
***Ključne reči:** e-Propaganda, izbor destinacija, digitalni marketing, turistički sektor, internet, stavovi ispitanika, demografske razlike.*

Introduction to the research

Modern tourism is increasingly dependent on digital platforms and technologies, which significantly shape the decision-making process of respondents. In this context, e-promotion has become a key factor in attracting respondents and deciding on the choice of destinations. E-promotion has a similar role to traditional promotion in the sale of goods and services, providing information about a product, such as its price, features, and functions, while also informing consumers who are unfamiliar with the product of its existence (Wenjuan et al., 2015). It also represents the practice of sending marketing messages to users via the internet, either through email or through services provided on the web. According to data, the world's 4.3 billion email users send more than 333 billion email messages daily (Kotler et al., 2023).

With the development of the internet and mobile technologies, tourism organizations have new tools for communicating with potential visitors. The main forms of e-promotion today are online display ads and search-related ads (Kotler et al., 2023). To innovate, anticipate demand trends, and surprise and satisfy the expectations, needs, and desires of customers are fundamental steps in tourism, and digital marketing can be an "excellent foundation in this process." (Santos & Silva, 2020). Today, websites providing tourist services are very popular and useful both for tourists who want to book their vacation quickly and easily, and for suppliers who want to facilitate and automate the process. E-promotion represents the digital means through which companies attempt to inform, persuade, and remind consumers, directly or indirectly, about the products and brands they offer. It includes advertising, personal selling, sales promotion, public relations, exhibitions, sponsorships, and direct mailing of promotional materials. Promotion in the tourism industry helps build credibility and increase consumer confidence, develops product awareness, arouses interest and desire, thereby influencing purchase decisions and enhancing business success.
Internet e-business services in tourism represent a set of digital tools and services that enable the management and enhancement of business operations. They include:

- Web hosting and website development – "creating and maintaining internet presentations that serve as the primary source of information and contact with tourists." (Ke & Wu, 2020).
- Online booking and payment platforms – "Booking, Airbnb, Expedia, and similar platforms enable real-time reservations and payment processing, significantly simplifying the stay process" (Ankur et al., 2023).
- SEO and Google tools (Analytics, My Business, Ads) – "used to enhance visibility and analyze user behavior" (Sharma et al., 2022).
- Cloud services – "for storing data, photos, documentation, and for communication with collaborators (e.g., via Google Drive, Dropbox)" (Verma & Sahu, 2022).

The research aims to examine how electronic promotion, including virtual audio and video materials, influences the attitudes and choices of respondents, with an emphasis on demographic differences such as gender, education, and age.

1. Methodological framework of the research

1.1. Problem and subject of the research

The goal of the research is to determine the influence of e-promotion on the choice of tourist destinations and to analyze the attitudes of respondents towards different forms of digital communication. The research problem is reflected in determining whether there are statistically significant differences in the attitudes of respondents towards the use of virtual audio and video materials, as well as towards the use of mobile devices, computers, and the internet in the context of improving relationships with tourism companies. Furthermore, the research analyzes how demographic variables such as gender, education level, and age influence the attitudes of respondents. The subject of the research comprises the attitudes of respondents from different demographic groups regarding the use of e-promotion. The research includes an analysis of attitudes concerning: the application of virtual audio and video materials as more modern forms of tourism promotion, the use of mobile devices, computers, and the internet in communication with tourism companies, and the possibilities of e-business models in enhancing the traditional marketing mix.

1.2. Research goals, tasks, and hypotheses

The primary goal of the research is to analyze the influence of e-promotion on the choice of tourist destinations and to examine differences in the attitudes of respondents based on demographic characteristics. The research tasks include: analyzing the attitudes of respondents towards different types of digital media, assessing the influence of e-promotion on respondents' decisions, and

investigating differences in the attitudes of respondents based on gender, education, and age structure. The research hypotheses are:

- H01: There is no statistically significant difference based on the gender of respondents in the attitude towards the belief that virtual audio and video materials on a tourism company's website are a better form of promotion and advertising than other forms.
- H01: There is no statistically significant difference based on the gender of respondents in the attitude towards the belief that virtual audio and video materials on a tourism company's website are a better form of promotion and advertising than other forms.
- H02: There is no statistically significant difference based on the educational level of respondents in the attitude towards the belief that virtual audio and video materials on a tourism company's website are a better form of promotion and advertising than other forms.
- Ha2: There is a statistically significant difference based on the educational level of respondents in the attitude towards the belief that virtual audio and video materials on a tourism company's website are a better form of promotion and advertising than other forms.
- H03: There is no statistically significant difference based on the age of respondents in the attitude towards the belief that virtual audio and video materials on a tourism company's website are a better form of promotion and advertising than other forms.
- Ha3: There is a statistically significant difference based on the age of respondents in the attitude towards the belief that virtual audio and video materials on a tourism company's website are a better form of promotion and advertising than other forms.

2. Research

The research was conducted using a quantitative method, with surveys as the main data collection tool. The sample included tourists from different age groups, education levels, and genders, and data were collected through an online survey distributed via social networks. The survey consisted of two parts and was set up using Google Forms. The sample included 377 respondents, which allowed for reliable conclusions to be drawn. The survey was conducted in accordance with precise instructions and procedures, ensuring the credibility of the obtained data.

All responses were saved on Google Drive. The data were then transferred to an IBM SPSS Statistics 28 database (Appendix 1) for further processing and analysis. The first part of the questionnaire contains questions related to the sample structure and demographic characteristics of the respondents, who were classified according to the following parameters: Respondent's Gender (divided into two categories: male and female); Respondent's Education Level (divided into two categories: high school and higher or high school); and Respondent's Age (divided into three groups: 18-35, 36-55, and older than 55 years) out of 15 questions that covered various aspects of respondents' attitudes: internet use in travel planning, perception of e-promotion, and the influence of electronic media on destination choice. In the second part of the e-Questionnaire, respondents were asked to state their agreement or disagreement with given statements, with the option to choose one of the following positions: 1 (disagree), 2 (neutral), or 3 (agree). The data were analyzed using descriptive statistics and χ^2 tests.

3. Research results

The research included respondents of different genders, age groups, and educational levels, which allowed for a detailed analysis of the influence of demographic factors on the attitudes and behavior of respondents in the context of e-promotion. The data are presented in (Table 1), which contains the distribution of respondents by gender, age, and education level.

Table 1. Respondent profile

Gender of Respondent											
Male						Female					
Educational attainment of Respondent						Educational attainment of Respondent					
Primary or Secondary school			College or University			Primary or Secondary school			College or University		
Age of Respondent			Age of Respondent			Age of Respondent			Age of Respondent		
from 18 to 35	from 36 to 55	over 55	from 18 to 35	from 36 to 55	over 55	from 18 to 35	from 36 to 55	over 55	from 18 to 35	from 36 to 55	over 55
54	26	18	14	20	22	57	68	30	32	25	11

- Gender and Education: The data shows that respondents are divided by gender (male and female) and education (primary or secondary school, higher school or university). In both genders, the majority of respondents have a higher level of education. Among men, the largest number of highly educated respondents is in the 36 to 55 age group (68 respondents). Among women, a similar trend is present, but with a smaller number of highly educated individuals, especially in the 18-35 age group (32 respondents), where men predominate with 54 respondents.
- Age Groups: The largest number of respondents belongs to the 18-35 age group, indicating the most active group in the research. In this age range, 54 men and 32 women constitute the majority. This group is dominant in both education categories, with most having completed a higher degree. The age groups of 36-55 and over 55 have a smaller number of respondents, but the highly educated remain well-represented in these groups, indicating increasing use of the internet and e-promotion among the middle-aged and older population.
- Educational Attainment of Respondents: Highly educated respondents represent a technologically savvy group that is more likely to use the internet and e-promotion strategies. Respondents are important for tourism companies that want to target their users with digital tools, such as video and audio materials on websites, to increase awareness of their offerings.

In the second part of the research, the attitudes of respondents regarding different aspects of e-promotion, which plays a significant role in the choice of tourist destinations, are analyzed. The results are presented using: mean values, standard deviations, and variances for each stated claim. Table 2 provides an overview of the values obtained from the respondents, enabling the determination of agreement or disagreement with specific statements related to the effectiveness of e-promotion in the tourism sector.

Table 2. Statements

Statements	Mean Value	Standard Deviation	Variance
I enjoy watching or listening to e-promotion messages and feel that they contribute to promoting various tourist destinations.	2.048	0.814	0.663
After I see an e-promotion message, I usually visit the website of that tourist destination.	2.199	0.531	0.282
Before I go to a tourist destination's website, I regularly consult with friends.	2.629	0.68	0.463
When I am shown boring e-advertisements for tourist destinations on the site I am currently browsing, I often switch to another site.	2.764	0.551	0.303
If someone recommends a tourist destination, then I visit the provider's website to find out more about it.	2.467	0.722	0.521

I believe that e-promotion is not effective for tourism companies and does not benefit them.	2.459	0.729	0.531
I believe in e-promotion messages that involve celebrities.	2.48	0.677	0.458
I think that only the highest quality examples of e-promotion can adequately represent a tourist destination.	2.286	0.898	0.806
I believe that if a tourist destination is frequently advertised, it is a sign that it is good.	2.546	0.801	0.642
I believe that tourism companies can use their website to collect data on the popularity of their offerings.	2.186	0.78	0.609
I believe that tourism companies can determine the profile of future visitors using data from their websites.	2.599	0.637	0.406
I believe that social networks can facilitate research for tourism companies about their products or services.	2.255	0.896	0.802
I believe that virtual audio and video materials on a tourism company's website are a better form of promotion and advertising than other forms.	2.048	0.814	0.663
I think the relationship between a tourism company and a tourist is better when using: mobile phones, computers, and the Internet.	2.252	0.791	0.625
I believe that e-business models can improve a provider's traditional marketing mix.	2.111	0.837	0.7

Key conclusions from the data analysis:

- Mean Values: Enjoyment of e-promotion messages: a mean value of 2.048 indicates that most respondents have a positive attitude towards e-promotion as a means of promoting tourist destinations, but not an entirely positive one (spanning the range between disagree and agree). Visiting websites after e-promotion: a mean value of 2.199 shows that a significant number of respondents react to e-promotion messages by visiting the websites of tourist destinations, but again, not all responses are categorical. Consulting with friends: with a mean value of 2.629, respondents indicate that they consult with friends before visiting tourism websites, highlighting the importance of social networks and recommendations in the decision-making process.
- Diversity of Responses (Standard Deviation): The standard deviation values show that there is a relatively large diversity in responses to most claims, particularly for questions such as the influence of celebrities in e-promotion and belief in the effectiveness of e-promotion for tourism companies. For example, the standard deviation for attitudes about celebrities in e-promotion is 0.677, indicating a significant number of respondents who do not believe in the effectiveness of such messages, alongside positive responses from others.
- Variance: The variance for most claims shows moderate diversity in responses, but it is particularly high for the claim related to the quality of e-promotion examples, where the variance is 0.806, indicating greater disagreement among respondents regarding the effectiveness of different types of e-promotion.
- Influence of E-promotion on Respondents' Attitudes: E-promotion as an attraction tool: Respondents generally believe that e-promotion messages positively influence the choice of tourist destinations, but to a lesser extent. For example, the claim that frequent e-advertising of a tourist destination is a sign of quality received a mean value of 2.546, showing that respondents are inclined to believe in the effectiveness of such advertising activities.

- Resolving conflicts with ads: A value of 2.764 for the claim that respondents often switch to another site when they see boring ads indicates that the majority of respondents disengage from interacting with pages that present boring or excessive e-promotion messages.

Table 3 provides the cross-tabulated data for Respondent's Gender regarding the statement *"I believe that virtual audio and video materials on a tourism company's website are a better form of promotion and advertising than other forms."*. Distribution of Responses: Male Respondents: Out of 154 male respondents, 53 expressed disagreement with the claim that virtual audio and video materials are the best form of e-promotion. 51 men were neutral, while 50 respondents from this group expressed agreement with the claim. Female Respondents: Among women (223 respondents), 63 disagreed with the claim, 76 were neutral, and 84 agreed with it. The data shows that the number of agreeing responses among women (84) is more prominent compared to men (50), indicating a greater number of women who consider virtual audio and video materials on tourism company websites to be a better form of e-promotion. On the other hand, men were somewhat more neutral or disagreed with the claim.

Table 3. Cross-tabulated data for Respondent's Gender according to the statement "I believe that virtual audio and video materials on a tourism company's website are a better form of promotion and advertising than other forms."

Gender of Respondent	I believe that virtual audio and video materials on a tourism company's website are a better form of promotion and advertising than other forms.			Total
	Disagree	Neutral	Agree	
Male	53	51	50	154
Female	63	76	84	223
Total	116	127	134	377

Table 4 provides the value for the Chi-square test for the cross-tabulated data for Respondent's Gender regarding the claim about virtual audio/video materials. Pearson Chi-Square: A p-value of 0.398 is greater than the standard significance level (0.05), meaning there is no statistically significant difference between the analyzed variables. Therefore, we cannot reject the null hypothesis that there is no significant association between these variables. Likelihood Ratio: A p-value of 0.399 confirms the same assumption and indicates that there is no statistically significant difference between the variables. Linear-by-Linear Association: A p-value of 0.183 is also greater than 0.05, meaning there is no significant linear association between the analyzed variables.

Table 4. Chi-Square Test for Respondents' Gender according to the statement "I believe that virtual audio and video materials on a tourism company's website are a better form of promotion and advertising than other forms."

	Value	Degrees of Freedom	Asymptotic Significance (2-sided)
Pearson Chi-square	1,843	2	0,398
Likelihood ratio	1,838	2	0,399
Linear-by-Linear Association	1,776	1	0,183

H_{01}: There is no statistically significant difference based on the gender of respondents in the attitude towards the belief that virtual audio and video materials on a tourism company's website are a better form of promotion and advertising than other forms.

Table 5 provides the cross-tabulated data for Respondent's Education Level regarding the claim about virtual audio/video materials. Distribution of Responses: Respondents with primary or secondary education: Disagree: 63 respondents; Neutral: 94 respondents; Agree: 96 respondents. Respondents with higher education: Disagree: 53 respondents; Neutral: 33 respondents; Agree: 38 respondents. The results indicate that respondents with primary or secondary education show a higher degree of agreement with the claim that virtual audio and video materials are a better form of promotion for tourist destinations,

while respondents with higher education show a higher number of neutral responses and less agreement. This may indicate that highly educated individuals may be more critical and skeptical regarding the effectiveness of this type of marketing compared to those with lower education, who are more open to these types of promotions.

Table 5. Cross-tabulated data for Respondent's Educational Attainment according to the statement "I believe that virtual audio and video materials on a tourism company's website are a better form of promotion and advertising than other forms."

Educational attainment of Respondent	I believe that virtual audio and video materials on a tourism company's website are a better form of promotion and advertising than other forms.			Total
	Disagree	Neutral	Agree	
Primary or Secondary school	63	94	96	253
College or University	53	33	38	124
Total	116	127	134	377

Table 6 provides the value for the Chi-square test for the cross-tabulated data for Respondent's Education Level regarding the claim. Pearson Chi-Square test: A p-value of 0.002 is less than the significance level of 0.05, meaning there is a statistically significant difference between the tested categories. It indicates that the educational level of respondents has a significant influence on their attitudes towards virtual audio and video materials as a form of e-promotion. Likelihood Ratio: A p-value of 0.002 confirms that the difference between the categories is statistically significant. The test confirms the results of the Pearson Chi-Square test and indicates a significant difference between the attitudes of respondents with different education levels. Linear-by-Linear Association: A p-value of 0.005 also indicates a significant linear association between educational attainment and attitudes towards virtual audio and video materials. There is a linear relationship between the education of respondents and their perception of e-promotion.

Table 6. Chi-Square Test for Respondents' Educational Attainment according to the statement "I believe that virtual audio and video materials on a tourism company's website are a better form of promotion and advertising than other forms."

	Value	Degrees of Freedom	Asymptotic Significance (2-sided)
Pearson Chi-square	12,600	2	0,002
Likelihood ratio	12,317	2	0,002
Linear-by-Linear Association	7,937	1	0,005

H_{a2}: There is a statistically significant difference based on the education attainment of respondents in the attitude towards the belief that virtual audio and video materials on a tourism company's website are a better form of promotion and advertising than other forms.

Table 7 provides the cross-tabulated data for Respondent's Age regarding the claim about virtual audio/video materials. Distribution of Responses: Age group 18-35 years: Disagree: 45 respondents; Neutral: 63 respondents; Agree: 49 respondents. Age group 36-55 years: Disagree: 42 respondents; Neutral: 49 respondents; Agree: 48 respondents. Age group over 55 years: Disagree: 29 respondents; Neutral: 15 respondents; Agree: 37 respondents. Younger Age Group (18-35 years): In the 18-35 group, more than a third of respondents (49) agree that virtual audio and video materials are the best form of promotion, but a large group (63 respondents) is neutral, indicating a greater openness towards this type of promotion, but they do not express a negative stance. Middle Age Group (36-55 years): In the 36-55 group, the distribution is similar, but with fewer respondents agreeing with the claim (48). A larger number of people in this group are neutral (49), which may indicate more pronounced skepticism or a lower level of engagement with these forms of promotion compared to the younger group. Older Age Group (over 55 years) Shows a more decisive split. It has the highest proportion of respondents

who "Agree" with the statement, but also a significant number who "Disagree," with very few remaining "Neutral." This indicates more formed and polarized opinions.

Table 7. Cross-tabulated data for Respondent's Age Groups according to the statement "I believe that virtual audio and video materials on a tourism company's website are a better form of promotion and advertising than other forms."

Age of Respondents	I believe that virtual audio and video materials on a tourism company's website are a better form of promotion and advertising than other forms.			Total
	Disagree	Neutral	Agree	
from 18 to 35	45	63	49	157
from 36 to 55	42	49	48	139
over 55	29	15	37	81
Total	116	127	134	377

Table 8 provides the value for the Chi-square test for the cross-tabulated data for Respondent's Age regarding the claim. Pearson Chi-Square test: A p-value of 0.020 is less than 0.05, indicating that there is a statistically significant difference between the analyzed categories. We can reject the null hypothesis and conclude that there is a significant association between the examined categories (e.g., age groups and attitudes towards virtual audio/video materials). Likelihood Ratio: A p-value of 0.014 also confirms that the difference between the categories is not random and that there is a statistically significant difference. Since this p-value is less than 0.05, we can again confirm that the results are significant. Linear-by-Linear Association: A p-value of 0.530 is greater than 0.05, indicating that the linear association between the analyzed categories is not significant. Thus, although there is statistical significance in the overall test, there is no clear linear dependence between some of the variables.

Table 8. Chi-Square Test for Respondents' Educational Attainment according to the statement "I believe that virtual audio and video materials on a tourism company's website are a better form of promotion and advertising than other forms."

	Value	Degrees of Freedom	Asymptotic Significance (2-sided)
Pearson Chi-square	11,684	4	0,020
Likelihood ratio	12,473	4	0,014
Linear-by-Linear Association	0,394	1	0,530

H_{a3}: There is a statistically significant difference based on the age of respondents in the attitude towards the belief that virtual audio and video materials on a tourism company's website are a better form of promotion and advertising than other forms.

Research conclusions

The research showed that e-promotion plays an important role in the choice of tourist destinations, especially when it comes to visual and audiovisual content. The results indicate different attitudes of respondents from different demographic groups towards digital media, which requires the adaptation of marketing strategies. Future research should analyze specific demographic groups and their relationship with new technologies in tourism.

Higher school or university are the most prevalent educational levels, and this trend is most pronounced in the 36-55 age group, where the number of highly educated respondents is significantly higher. Highly educated respondents are likely more familiar with technology and e-promotion, making them important for marketing strategies.

Young respondents (18-35 years) are the most represented in the sample, indicating greater use of the internet and e-promotion strategies in this group. Men predominate in this age range, but women, especially those with higher education, also show significant representation.

Differences in gender representation are noticeable, with more men in the young and middle-aged groups, while women are more numerous in the over-55 group, but with a smaller number of highly educated respondents.

The 18-35 age group shows greater interest in e-promotion, making them a target group for travel agencies applying digital marketing strategies.

Results indicate that most respondents believe that e-promotion can contribute to the choice of a tourist destination, but not entirely. Respondents are open to ads featuring celebrities but are more critical of boring and aggressive advertisements. Tourism companies should avoid such e-advertisements and provide quality and informative content.

Women have a greater tendency to agree with the claim that virtual audio and video materials on tourism company websites are a better form of promotion compared to men. Tourism companies can consider adapting their e-promotion strategies for a female audience.

Respondents with primary or secondary education more frequently agree with the claim that virtual materials are an effective form of promotion, while highly educated individuals have a more critical stance. The results show that education plays an important role in attitudes towards e-promotion, with highly educated respondents being more prone to criticism.

Younger respondents (18-35 years) have a more positive attitude towards virtual audio and video materials as an effective form of promotion, while older respondents (over 55 years) show greater skepticism and more neutral responses or disagreement. The results indicate the need to adapt strategies to different age groups.

There is a statistically significant difference in attitudes based on age and education, but the difference is not linear. Marketing strategies should be tailored to specific demographic factors to successfully attract consumers.

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Ethical Behaviour in Professional Football: Attitudes of Professional Players and the Challenges of Fair Play

Etično ponašanje u vrhunskom nogometu: stavovi profesionalnih igrača i izazovi *fair play*-a

Neda Lukić[1], Dominik Mulac[2]

[1]*PAR University of Applied Sciences, Rijeka, Croatia, neda.lukic@par.hr*
[2]*PAR University of Applied Sciences, Rijeka, Croatia, mulacdominik10@gmail.com*

Abstract: *Ethics and leadership represent core values in professional football. Preserving fair play goes beyond rule compliance—it reflects the responsibility of players and coaches as leaders who shape team culture and social values through their actions. The aim of this study was to examine professional football players' attitudes toward ethical behavior, responsibility, and leadership by example. A survey conducted among 55 players from the top three tiers of Croatian football revealed that most respondents recognize ethical behavior as a key element of leadership, while performance-related and financial pressures may cause moral dilemmas. The results suggest that ethical conduct on the field is closely related to perceived authority, self-control, and team cohesion, confirming the importance of moral leadership in professional sport.*
Keywords: *Ethics, football, fair play, leadership, professional sport, moral leadership.*

Sažetak: *Etičnost i leadership predstavljaju temeljne vrijednosti sporta i profesionalnog nogometa. Očuvanje fair play-a ne odnosi se samo na poštivanje pravila igre, već i na odgovornost igrača i trenera kao lidera koji svojim ponašanjem oblikuju timsku kulturu i društvene vrijednosti. Cilj ovog istraživanja bio je ispitati stavove profesionalnih nogometaša o etičnom ponašanju, odgovornosti i utjecaju vođenja kroz primjer. Istraživanje provedeno među 55 nogometaša prva tri ranga hrvatskog nogometa pokazalo je da većina ispitanika prepoznaje važnost etičnog ponašanja kao ključnog elementa liderstva, ali i da pritisci rezultata i nagrađivanja mogu dovesti do moralnih dilema. Rezultati upućuju na to da je etično ponašanje na terenu povezano s percepcijom autoriteta, samokontrolom i utjecajem na timsku koheziju, što potvrđuje važnost moralnog vodstva u profesionalnom sportu.*
Ključne riječi: *Etika, nogomet, fair play, leadership, profesionalni sport, moralno vođenje*

Introduction

Ethics in sport serves as the cornerstone of trust, sporting integrity, and public reputation. Football, recognized as the most widely followed sport across the globe, not only reflects prevailing societal values but also exposes inherent contradictions within them (Butić, 2021). While the principles of fair play are formally embedded within the cultural fabric of football, empirical observations indicate that the pressures to achieve results and respond to market demands frequently generate moral dilemmas, prompting pragmatic, and at times ethically ambiguous, decisions. This paper seeks to explore the perceptions of ethics and fair play among professional football players in Croatia, with particular attention to the degree to which external factors—ranging from organizational expectations to societal pressures—influence their behavioral choices on and off the pitch.

1. Methodology

1.1. Research problem

Ethical behavior reflects adherence to societal norms and the moral evaluation of actions. Morality, in its broadest sense, represents a form of social consciousness and encompasses a set of unwritten rules, traditional customs, habits, and norms accepted within a community (Mužić, 2003).

In the context of football, ethical conduct can be examined on two levels: the behavior of players on the field and the actions of club management and other football stakeholders. On the field, ethical behavior includes gestures such as offering a hand to an opponent, alerting referees to mistakes, and respecting the rules of the game. Unethical behavior, conversely, encompasses practices such as doping, violent play, and the use of psychological tactics that fall outside the framework of fair play.

Off the field, unethical actions include match manipulation for betting purposes, bribery of referees, and corrupt practices in the allocation of major tournament hosting rights—for instance, the 2022 FIFA World Cup in Qatar (Enciklopedija.hr, 2023).

The aim of this study is to investigate how ethical considerations influence the integrity of the game and the behavior of football players, while testing the following hypotheses:

H1: Higher rewards for victory are associated with an increased likelihood of unsportsmanlike behavior.

H2: Public expectations and pressure elevate stress levels among athletes, which may subsequently affect their sporting performance.

1.2. Purpose and objectives of the study

The purpose of this study was to analyze the attitudes of professional football players regarding ethical behavior in sport and to identify the sources of moral compromise. The objectives included examining players' awareness of the importance of fair play, analyzing the influence of financial and performance-related motives on behavior, and investigating perceptions of the integrity of Croatian football and the role of the media.

The study sought to address the following research questions:

- What constitutes ethics?
- What is considered ethical behavior?
- How are ethical behaviors applied on the field?
- Why do not all football players adhere to ethical rules?
- How can violations of fair play principles be reduced?
- Is it more effective to punish unethical behavior or to reward ethical conduct?

1.3. Research methods

The study was conducted using a combination of desk research and a survey-based approach. Initially, professional literature, ethical codes (FIFA, UEFA), and relevant media examples were analyzed to identify key concepts of ethics, fair play, and leadership in football. Based on these insights, a questionnaire was developed and administered to 55 professional football players across three tiers of Croatian football.

Data analysis was carried out using descriptive and comparative methods to present respondents' attitudes and to enable comparisons across leagues and age groups. Patterns in behavior and perceptions of moral leadership were identified inductively, while conclusions were cautiously generalized to the studied sample. This methodological combination allows for the integration of

theoretical insights with empirical data and provides a comprehensive understanding of the influence of ethics and leadership on professional football players.

1.4. Structure of the study

The study is organized into six interconnected sections, each addressing a specific dimension of the research problem:

1. Introduction – Outlines the research problem, objectives, and significance of the study, establishing the theoretical and practical context of ethics in football.
2. Ethics through History – Examines the evolution of ethical thought and moral principles, providing a theoretical framework for understanding ethical behavior in sport.
3. History of Football – Presents the development of football as a global sport, highlighting historical milestones that shaped its culture and ethical standards.
4. Ethics and Contemporary Football – Analyzes modern ethical challenges in football, including fair play, governance, and leadership, with reference to recent cases and regulations.
5. Analysis of Data Obtained from the Survey – Reports the findings of the empirical research, comparing players' attitudes across leagues and age groups, and identifying patterns of moral perception and behavior.
6. Conclusion – Summarizes key insights, evaluates the implications for practice and policy, and suggests directions for future research on ethics and leadership in football.

2. Ethics through history

Ethics as a philosophical discipline emerged in ancient Greece. The Sophists were the first to emphasize the human being as the measure of all things (Protagoras), while Socrates grounded ethics in self-knowledge and virtue as the path to the good. His student, Plato, reflected on the "idea of the good" as the highest value, whereas Aristotle, in the Nicomachean Ethics, developed the concept of the "golden mean" – a balance between extremes as the foundation of moral action (Guthrie, 2007).

Subsequent philosophical movements – Stoicism, Epicureanism, Utilitarianism, and Deontology – shaped contemporary understandings of morality. According to Kantian deontological ethics, morality arises from duty and good will, while utilitarianism (Mill) grounds morality in utility and the well-being of the community (Jurić, 2010).

In modern society, ethics emphasizes the responsibility of individuals and institutions toward the community, the environment, and future generations. The boundaries between ethical and unethical behavior often become blurred, particularly in contexts characterized by pressures of profit and power (Mužić, 2003).

3. History of football

The earliest ball games appeared in China and ancient Greece, while modern football developed in England during the mid-19th century. In 1863, the English Football Association was founded, and the first official rules of the game were established, marking the beginning of football's institutionalization (Enciklopedija.hr, 2023). In Croatia, the first football match was played in 1873 in Rijeka, initiated by Robert Whitehead, while Franjo Bučar, in 1893, popularized football and translated the first official rules into Croatian (Nogomet.lzmk.hr, 2023).

Today, football has a global character. FIFA has organized the World Cup since 1930, making it the largest sporting event in the world. The commercial dimension of football is evident in its extraordinary revenues—for example, the 2022 World Cup in Qatar generated $7.5 billion in revenue for FIFA (Businesstoday.in, 2023).

4. Ethics and contemporary football

Ethics in sport defines the moral standards governing the behavior of individuals and institutions, with the aim of ensuring fair competition and the integrity of the game (McNamee, 2018). Fair play goes beyond mere compliance with the rules—it encompasses honesty, respect for opponents, and self-control. In contemporary sport, however, professionalization and commercialization often jeopardize these principles, subordinating them to the demands of success (Butić, 2021).

Modern football exemplifies many ethical challenges of a globalized sport. Massive financial interests, commercial pressures, match manipulation, corruption, and unethical player transfers threaten the fundamental values of the game. According to the rankings of the highest-paid players in the Saudi league, some athletes earn over £150 million per year (90min.com, 2023). Such figures highlight the growing imbalance between sporting spirit and market interests.

Ethics in football encompasses not only fair play but also social responsibility—engaging youth, combating discrimination and corruption, and respecting the dignity of all participants. FIFA's Code of Ethics (2020) establishes the fundamental principles of conduct: respect for integrity, fair play, and the social responsibility of all officials, players, and intermediaries. Violations of the code are punishable by warnings, fines, suspension, or bans from participation.

Examples from world football illustrate the tension between ethics and the performance imperative. In 2012, Miroslav Klose admitted to scoring a goal with his hand, leading to the goal being disallowed—an example of exceptional ethical awareness (FIFA, 2020). In contrast, repeated incidents by Luis Suárez (e.g., biting Giorgio Chiellini) have made him a symbol of impulsive behavior under pressure (BBC Sport, 2014). Media pressure also exerts a psychological impact: cases involving Dele Alli and Jadon Sancho demonstrate how negative media narratives can exacerbate mental health challenges and influence players' decisions (The Guardian, 2023).

5. Analysis of data obtained from the survey

The analysis of the survey results focuses on the attitudes and perceptions of players from three tiers of Croatian football (first, second, and third leagues), encompassing a total of 55 respondents, regarding adherence to fair play principles, ethical dilemmas in football, and social pressures in elite sport.

Key findings:

General information about respondents

- All respondents are active football players aged 16 to over 36 years, with the most represented age group being 21–25 years (50.9%).
- Participants compete across three tiers: primarily in the second league (47.3%) and third league (32.7%), with the smallest proportion in the first league (20%).
- Most have played at the first- and second-league levels, while a small number have experience in national teams and international leagues.

Attitudes toward fair play and ethics

- 89.1% of respondents believe they partially or fully adhere to fair play principles.
- 78.2% consider football without fair play to be irregular, though some disagreement exists.
- Most players respect opponents both on and off the field, although some division persists on this issue.
- Opinions on respect for referees are mixed, with a significant proportion expressing neutral or partially disagreeing views.

- More than half (56.4%) are willing to breach fair play if it benefits their team, indicating moral compromises under performance pressure.
- 54.6% agree, to some extent, that "the end justifies the means."
- Over 76% consistently adhere to the rules of the game.
- 87.2% believe that wealthier clubs receive preferential treatment in football.

Perception of the integrity of Croatian football

- None of the respondents consider the competitiveness of football in Croatia to be at a high level; 90.9% believe there is significant room for improvement.

Behavior on the field

- Conflicts with opponents or referees are varied, with a large group of neutral responses.
- Provoking opponents is seen as common but within the limits of sporting rivalry, except in cases of racist or ethnically motivated provocation.
- 80% of respondents do not support intentionally injuring opponents, though a small number expressed the opposite view, which is concerning.

Impact of rewards and public pressure

- Elite football is financially powerful, influencing player decisions and often motivating rule violations.
- Public, media, and social media pressure on players is substantial and negatively impacts mental health, as evidenced in cases such as Dele Alli and Jadon Sancho, who repeatedly faced negative commentary online and in the media, affecting their performance and overall psychological well-being.
- Racism and inappropriate social media comments remain serious issues.

Conclusion of finding

The results indicate that although most players consciously accept and strive to uphold fair play principles, external pressures—such as performance expectations, financial incentives, and competitive ambitions—frequently lead to moral compromises and deviations from ethical standards. Respondents express the view that Croatian football requires higher levels of integrity, transparency, and consistent application of rules, while also highlighting the strong influence of public opinion, media, and social networks on players' behavior and decisions. These factors further complicate the maintenance of professional integrity in sport.

Such an analysis can serve as a foundation for player education, the development of ethical standards, and programs supporting the mental health of athletes in football and beyond.

Conclusion

The results of the conducted study, involving 55 football players from the top three tiers of Croatian football, demonstrate that ethical conduct is strongly associated with personal integrity and leadership, both on and off the field. The majority of respondents consider adherence to fair play and ethical norms a prerequisite for successful collective performance, emphasizing that leadership in a sporting context arises not solely from hierarchical position but from moral authority and personal example.

The findings support both of the study's hypotheses. The first hypothesis (H1)—that the desire to win and high material motivation may lead to unsportsmanlike behavior—is partially confirmed. Players are aware of the pressures and competitive environment, yet most highlight that long-term success and reputation stem from fair play and an ethical approach. The second hypothesis (H2)—that public

expectations and constant exposure can increase stress affecting behavior—is fully confirmed. This stressful context has emerged as a significant challenge in maintaining consistent ethical principles.

The analysis of responses suggests that the concept of leadership in football extends beyond formal leaders, such as captains or coaches, to include any player whose behavior can influence team ethics, atmosphere, and mutual trust. Players who demonstrate honesty, self-control, and a willingness to assume responsibility are perceived as moral leaders within the team. Such individuals contribute to cultivating a culture of respect and trust, which, over time, enhances team cohesion and sporting performance.

In professional football, where pressures of results, financial interests, and media attention are particularly pronounced, a systematic development of ethical and moral leadership is essential. This entails education on sports ethics, support for the psychological development of athletes, and the creation of institutional frameworks that reward ethical conduct alongside sporting achievements.

In conclusion, the study confirms that ethics and leadership in sport constitute an inseparable whole. Leadership in football entails the ability to inspire and motivate others through personal example, while ethics provides the foundation that ensures success is achieved without compromising moral values. In this context, every player becomes a potential agent of change—an ambassador of fair play and moral leadership—thereby preserving the social and educational value of sport.

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Challenges and Innovations in Digital Recruitment and Technological Human Resources Training

Izazovi i inovacije u digitalnoj regrutaciji i tehnološkom treningu ljudskih resursa

Sara Tomašević[1], Svetlana Vukotić[2], Vuk Mirčetić[3]

[1]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, sara.tomasevic@mef.edu.rs*

[2]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, svetlana.vukotic@mef.edu.rs*

[3]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, vuk.mircetic@mef.edu.rs*

Abstract: *E-business is increasingly reshaping the way organisations approach hiring and training employees, setting new standards and challenges in the field of human resources management. The manuscript analyses contemporary challenges in the context of implementing digital recruitment of candidates and technological training for employees. Additionally, the paper also considers new and innovative training models, such as e-learning, hybrid platforms, and virtual classrooms, that enable better synchronisation between the organisation and employees. The analysis spans the period during which the accelerated digital transformation, following the COVID-19 pandemic, was reflected in all aspects of employee management, with a focus on e-commerce in Serbia. Research results indicate that the proper design of digital processes in human resource management can significantly enhance efficiency, and that the human factor and human resource experts remain crucial in shaping the strategic direction of digital transformation. The paper has theoretical and practical implications. Contributions to theory can be best observed through enriching existing respectable literature regarding the digital transformation of human resource management. Additionally, human resource professionals can use research results to navigate digital transformation more effectively, ensuring their adaptability and proactive approach.*
Keywords: *Digital transformation, e-business, e- learning, recruitment, employee attitude analysis.*

Apstrakt: *Elektronsko poslovanje sve više oblikuje način na koji organizacije pristupaju zapošljavanju i usavršavanju zaposlenih, postavljajući nove standarde i izazove u oblasti upravljanja ljudskim resursima. Rad analizira savremene izazove u primeni digitalne regrutacije kandidata i tehnološkom treningu zaposlenih. Takođe, rad obuhvata nove i inovativne modele treninga, kao što su elektronsko učenje, hibridne platforme i virtuelne učionice koji omogućavaju bolju sinhronizaciju organizacije i zaposlenih. Analiza obuhvata period kada se ubrzana digitalna transformacija, nakon pandemije COVID-19, odrazila na sve aspekte upravljanja zaposlenima, sa posebnim fokusom na elektronske trgovine u Srbiji. Rezultati istraživanja pokazuju da pravilan dizajn digitalnih procesa u upravljanju ljudskim resursima može značajno poboljšati efikasnost, ali da ljudski faktor i stručnjaci za ljudske resurse ostaju ključni u strategijskom usmeravanju digitalne transformacije. Rad ima teorijske i praktične implikacije. Doprinos teoriji se najbolje ogleda u obogaćivanju postojeće relevantne literature u oblasti digitalne transformacije upravljanja ljudskim resursima. Pored toga, stručnjaci za ljudske resurse mogu koristiti rezultate istraživanja kako bi efikasnije upravljali procesom digitalne transformacije, osiguravajući svoju prilagodljivost i proaktivan pristup.*
Ključne reči: *Digitalna transformacija, elelktronsko poslovanje, elektronsko učenje, regrutacija, analiza stavova zaposlenih.*

Introduction

The contemporary business environment has been undergoing intensive changes in recent years, primarily driven by rapid technological advancement and the digitalization of almost all aspects of economic activities (Sima et al., 2020). The digital transformation of the work environment has brought significant changes to the way organizations approach the process of integrating new employees. In an increasingly complex and dynamic business environment, organizations continuously strive to adapt their operations. This also includes improving the theoretical understanding of the role and effects of digital innovations in the employee integration process, as the concept of change management is closely linked to the concept of innovation management, since innovations both rely on change and actively stimulate it (Momčilović et al., 2022).

The increased use of ICT (information and communication technologies) has significantly changed the way we live, learn, and work, transforming the direction of interaction between individuals, business systems, and public institutions (Magnusson & Hermelin, 2019). The development of information technologies and the advancement of internet technologies enable the progress of existing enterprises and the opening of new ones, leading to the growth of electronic business and the digital economy (Zhang & Chen, 2023). Organizations no longer function in a static and predictable environment, but rather in a dynamic, digitally connected, and globalized market, where competitiveness depends on the ability to quickly adapt to new technologies and changing consumer demands (Strohmeier, 2020).

Digital transformation in human resource management can be understood as a systematic reconfiguration of HR processes through the integration of digital tools, data analytics, and automated workflows (Bondarouk & Brewster, 2016). It not only enables higher efficiency and standardization of HR procedures, but also requires organizations to redesign their internal structures, competencies, and organizational culture to support continuous technological adaptation (Marler & Parry, 2015). Human Resource Management (HRM) is gaining a new dimension, as traditional models of employment, selection, and employee training are giving way to innovative, digitally-based solutions (Bondarouk & Brewster, 2016). The development of electronic business, especially after the COVID-19 pandemic, has significantly accelerated organizations; transition to online work and communication channels (Carnevale & Hatak, 2020). Remote work has become the new norm (Kniffin et al., 2021). Video interviews and online candidate testing enable more objective evaluation of competencies (Basch et al., 2021).

Educational programs based on e-learning platforms, virtual classrooms, and hybrid training models enable continuous development of employee skills (Saleh & Ali, 2024). This paper builds on the research of Tomašević and Mirčetić (2025) presented at an international conference in Turkey, which analyzed contemporary challenges of digital candidate selection and technological employee training in the context of accelerated digital transformation following the COVID-19 pandemic. The aforementioned work highlighted the need for deeper study of the theoretical gap in the domain of digital HR process implementation in the electronic commerce sector, particularly in local economies such as Serbia, where the digitalization of the human resources function is still developing.

This work aims to fill precisely that gap through an expanded analysis of specific challenges and limitations of digital transformation in human resource management in e-commerce. While global companies have adopted these models relatively quickly, small and medium-sized enterprises, especially in developing countries such as Serbia, have faced specific challenges in the process of digital transformation of human resource functions, including the lack of integrated systems and limited use of structured online tools (Nikolić, 2023). Although there is a significant number of works dealing with the digitalization of human resource management at the global level, there is relatively little research analyzing the implementation of these processes in the context of electronic commerce (Bindra et al., 2025). The goal of the research is to identify key challenges through analysis of existing literature and secondary data, and to offer recommendations for improving HR practices in electronic business in Serbia, as well as to compare the results with experiences from other countries.

The existing gap in the literature is addressed through the identification and analysis of contemporary technological solutions and their implications for employee integration efficiency, employee engagement, and organizational performance. As Strohmeier (2020) states, although digital transformation in HRM encompasses only a limited set of functions, there remains a lack of a clear theoretical foundation for understanding its implementation and further development, which highlights the need to conceptually and empirically fill this gap. Social exchange theory emphasizes the importance of reciprocity in the relationship between the organization and the employee, where a positive employee integration experience generates greater commitment and engagement (Armstrong & Taylor, 2023). Research consistently shows a strong connection between the quality of employee integration and key organizational outcomes.

1. Virtual and augmented reality

The structure of the paper includes: following introductory considerations, a review of relevant literature, the methodological framework of the paper, presentation of results, discussion, and concluding considerations. The method of scientific study is applied as the primary method in this paper, as the research represents a literature review and data analysis. This method involves the theoretical study of the research subject, whereby significant data is collected for drawing conclusions about the challenges and possible solutions in the field of digital human resource management. The method of scientific observation is applied as a supplementary method and involves the planned collection of data on the research subject through observing contemporary trends and practices of digital human resource management. Within this method, observation of trends in practice is applied, which includes monitoring current trends in the application of digital HR tools in the e-commerce sector, observing the development of new technologies in the field of recruitment (AI tools for candidate assessment, video interview platforms), identifying innovative training models, tracking changes in organizational practices after the COVID-19 pandemic.

The development of information technologies, and especially the advancement of internet technologies, enables the improvement of existing enterprises and the establishment of new ones, which leads to the growth of e-business and the digital economy (Sandberg & Hakansson, 2020). The modern human resources (HR) technological ecosystem consists of integrated platforms and specialized tools that support various aspects of talent management (Kavanagh & Johnson, 2017). Applicant Tracking Systems (ATS) and employee management platforms expand their functions from recruitment to employee integration, creating a seamless transition between processes (Nikolaou, 2021). Learning Management Systems (LMS) enable the creation, distribution, and monitoring of training programs. Also informal learning provided by interactions with coworkers may develop expertise and other job resources (Zia et al. 2024). Contemporary LMS platforms integrate microlearning, mobile applications, gamification, and AI-based personalization (Marler & Boudreau, 2017).

The use of Virtual Reality (VR) and Augmented Reality (AR) technologies for training and familiarization with the work environment improves information retention and increases the sense of organizational belonging among remote employees (Li et al., 2024). AR/VR systems in education face significant challenges in terms of hardware limitations, development complexity, and the need for improved human-computer interaction (Tan et al., 2020). The chapter is divided in two subchapters. The first segment is dedicated to virtual reality, and the second elaborates on augmented reality. VR and AR technologies create immersive experiences that transform traditional training and orientation (Li et al., 2024). These technologies are particularly valuable for remote employees who cannot physically visit offices or work locations.

1.1. Virtual reality in employee integration

Over the past decade, VR adoption in corporate learning has expanded across industries such as aviation, retail, logistics, and healthcare. For example, Walmart uses VR simulations to train employees

in handling customer service and high-pressure retail scenarios, resulting in improved consistency and confidence.

These findings align with research demonstrating that VR supports complex learning and increases engagement by replicating realistic social and task environments (Pan & Hamilton, 2018). Virtual reality enables new employees to explore the workplace, offices, production facilities, or retail environments as if they were physically present (Li et al., 2024).

Thanks to the use of the VR system, training can be conducted at any time, as long as employees have access to a computer and VR peripherals (Zawadzki et al., 2020).VR simulations provide a safe environment for practicing critical skills, client interactions, or crisis scenarios without real-world risk (Flavián et al., 2019). Virtual social events use VR spaces to organize informal meetings, team-building activities, and networking events, improving relationship-building within remote teams (Li et al., 2024). Virtual Shadowing is effective because it entails remote workers to follow peers who are currently involved with key projects and assignments similar to the new employee's profile. It is the process that ensures that new hires will show their work progress of jobs to preferably established and older team members (Varshney, 2022).

1.2. Augmented reality in training

Augmented reality (AR) is a transformative technology that offers enhanced and immersive user experience. Its applications span diverse domains, such as education, medicine, and various industries. By superimposing digital information onto the real world, AR holds considerable potential to significantly improve the user experience in both learning and professional settings, especially within training and instructional environments. AR is used to deliver information and provide an immersive method for knowledge assessment in education and cultural training.

AR training overlays digital information onto the physical environment through mobile devices or AR glasses, enabling real-time, hands-on training with guided instructions (Li et al., 2024). Unlike VR, which immerses users in a fully virtual environment, AR enhances the real workspace by adding digital guidance or contextual cues. AR enhances user engagement by creating interactive and immersive learning experiences, which can increase motivation and participation among employees.

Applications of AR are not limited to technical tasks, they can also support soft-skill training by simulating customer interactions or collaborative scenarios in the real workplace. Integration of AR into HR and employee integration processes helps new hires understand complex procedures and organizational workflows more quickly than traditional manuals or e-learning alone. While AR presents significant advantages, successful implementation requires adequate IT infrastructure and employee digital literacy, as well as change management strategies to ensure acceptance across all generations of employeees. Even aviation industry use AR for aerospace component assembly to ensure precision and reduce training time (Palmarini et al., 2018).

The advantages of VR/AR technologies include increased information retention, higher engagement, standardized training experiences, and reduced physical training costs (Li et al., 2024). However, challenges include high initial investments, the need for technical infrastructure, and potential barriers to technology acceptance among employees of different generations.

2. Social aspect of digital employee integration

The social aspect of employee integration is critical for successful integration, and it is particularly challenging in remote and hybrid work contexts (Li et al., 2024). Digital employee integration platforms focus on facilitating interpersonal connections and relationship building. Research by Sani and colleagues shows that digital employee integration significantly impacts employee outcomes, accompanied by perceptions of decreasing social connectedness (Sani et al., 2023). Tools include video calls, virtual groups, mentoring, interactive sessions, and gamification elements. The results of a study

by Bolli and Pusterla suggest that digitalization has a rather negative impact on employee job satisfaction. The increased time pressure caused by digitalization has a slight negative impact on job satisfaction, and the deteriorating work-life balance negatively affects job satisfaction (Bolli & Pusterla, 2022).

Education is an inevitable and pivotal component of a person with integrity, who has a strong theoretical background and the ability to use it to respond to practical challenges (Mirčetić et al., 2024). The key challenges and failures in digital transformation are based on various socio-technical factors, both internal and external such as the nature of digital technologies involved, actors such as employees, leadership, and vendors, and aspects like organizational structure (Mehmood, 2024). For example, Pappas (2023) highlights that one-on-one meetings and the role of mentors are crucial in digital employee integration. Platforms that support network- building in digital workplaces help new hires connect with colleagues and gain insight into organizational networks (Li & Zhao, 2022).

Digital mentoring programs enable structured connections between new hires and experienced organizational members (Allen et al., 2017). Platforms automate mentor matching based on role, location, interests, and availability and support regular check-ins and monitoring of mentoring progress. Virtual social hubs create digital spaces where new employees can meet colleagues, participate in discussions, share experiences, and build informal relationships. Research shows that socially integrated employees are more likely to stay in the organization, develop a sense of belonging faster, and achieve higher productivity (Li et al., 2024).

3. Contemporary challenges and solution proposal

All organizations, regardless of the size, educational, age or gender structure of employees have various challenges within their business. (Mirčetić & Vukotić, 2020). Studies examine the effects of digital employee integration on outcomes such as employee satisfaction, engagement, productivity, intention to leave, and leader satisfaction. For example, Sani et al. (2023) found that digital employee integration has a significant impact on employee outcomes but may reduce social connectedness if human aspects are not adequately included. Similarly, Li and Sandino (2018) demonstrated that Information Sharing Systems positively influence employee creativity and engagement, particularly enhancing performance outcomes in digitally integrated environments. The results of Mosquera and Soares (2025) research indicate that in order to retain employees, organizations should combine the three types of activities when designing onboarding programmes (Corporate Welcome, Managers' Welcome, and Coworkers' Welcome). However, organizations face challenges in implementation (Barbau et al., 2025). Many small and medium-sized organizations lack the necessary IT infrastructure. Employees and management may resist new technologies. Successful implementation requires a comprehensive change management strategy that includes communication, training, and support. Excessive automation may result in a cold and impersonal experience that fails to build emotional connection (Armstrong & Taylor, 2023). Balancing technological efficiency with human interaction is critical. Not all employees have the same level of digital literacy (Barbau et al., 2025). Additionally, digital channels may overwhelm new employees with information (Kapp & DeFelice, 2019). A hybrid model that balances digital tools with face-to-face interactions provides both efficiency and the human connection needed for successful employee integration.

Conclusion

The purpose of this research was to identify key challenges of digital transformation in human resource management within the context of e-business, with a focus on the employee onboarding process. The goal was to provide recommendations for improving HR practices through the analysis of literature and secondary data, and to compare these findings with experiences from other countries.

The analysis showed that the digital transformation of the HR function requires a systematic reconfiguration of processes through the integration of VR/AR technologies, LMS platforms, and ATS systems. A key finding is that technological efficiency must be balanced with human interaction in order to avoid a cold and impersonal experience. The social aspect of digital integration, including mentorship and virtual social hubs, proved critical for successful onboarding in remote work environments. The results confirm social exchange theory: a positive onboarding experience generates higher employee commitment.

The scientific contribution of this study lies in filling the theoretical gap regarding the implementation of digital HR processes in the e-commerce sector, particularly in local economies such as Serbia, where HR digitalization is still developing. The practical contribution is reflected in recommendations for gradual implementation, interactive training, monitoring of key performance indicators, development of digital competencies, and adapting HR models to the specific characteristics of e-business.

The limitations of the paper, as the research relies on literature review without primary empirical data (such as surveys or interviews with HR managers). Additionally, there is a lack of longitudinal observation of the effects of the proposed solutions. Practical limitations include the inability to access internal company data regarding their digital HR practices. Recommendations for future research include conducting empirical studies with HR managers in Serbian e-commerce companies to evaluate the applicability of the proposed recommendations, research to track the effects of implementing digital HR solutions over time, comparative analysis across Balkan countries, and quantitative measurement of the impact of specific digital tools on key indicators (retention, productivity, employee satisfaction). Digital transformation of the HR function in e-business represents an inevitable process that, when approached properly, can bring significant benefits to both organizations and employees.

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Artificial Intelligence in Education: Application, Challenges and Aspects of Cyber Security in Bosnia and Herzegovina

Vještačka inteligencija u obrazovanju: primjena, izazovi i aspekti kibernetičke sigurnost u Bosni i Hercegovini

Ružica Đervida[1], Jovo Marković[2], Igor Dugonjić[3], Mirko Sajić[4]

[1] *Independent University of Banja Luka, Banja Luka, Bosnia and Herzegovina, ruzica.djervida@gmail.com*
[2]*Ministry of the Interior of the Republic of Srpska, Banja Luka, Bosnia and Herzegovina, jovo.markovic@hotmail.rs*
[3] *University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, igor.dugonjic@mef.edu.rs*
[4]*Independent University of Banja Luka, Banja Luka, Bosnia and Herzegovina, mirko.sajic@gmail.com*

Abstract: *Artificial intelligence (AI) is becoming a defining feature of contemporary education, reshaping how we learn, teach, and assess knowledge. Its applications enable personalized learning, automated assessment, and more efficient data analytics, while simultaneously raising questions of ethics, security, and privacy protection. This paper examines the impact of AI technologies on educational processes, with a particular focus on Bosnia and Herzegovina. The analysis foregrounds the need to develop digital infrastructure, strengthen information (digital) literacy, and safeguard personal data as key preconditions for the responsible and sustainable adoption of AI in education. The aim is to present the challenges, opportunities, and recommendations for securely integrating artificial intelligence into the education systems of the future.*
Keywords: *Artificial intelligence, education, digital security.*

Apstrakt: *Vještačka inteligencija (AI) postaje jedno od ključnih obilježja savremenog obrazovanja, mijenjajući načine na koje učimo, podučavamo i procjenjujemo znanje. Njena primjena donosi mogućnost personalizovanog učenja, automatizacije ocjenjivanja i efikasnije analize podataka, ali istovremeno otvara pitanja etike, sigurnosti i zaštite privatnosti. Rad analizira uticaj AI tehnologija na obrazovne procese, s posebnim osvrtom na stanje u Bosni i Hercegovini. Fokus je stavljen na potrebu za razvojem digitalne infrastrukture, jačanjem informacione pismenosti i zaštitom ličnih podataka kao ključnim uslovima za odgovornu i održivu primjenu AI u obrazovanju. Cilj je da se prikažu izazovi, prilike i preporuke za sigurno uključivanje vještačke inteligencije u obrazovne sisteme budućnosti.*
Ključne reči: *Vještačka inteligencija, obrazovanje, digitalna sigurnost.*

Introduction

Artificial intelligence (AI) is one of the most significant achievements of the modern era, transforming how society functions across nearly all domains of human activity—from medicine and finance to industry, media, and everyday digital services (www.unesco.org). At the center of this transformation is education, a sector that directly shapes a country's social future and economic development.

Thanks to its ability to analyze, learn, and adapt, AI is increasingly viewed as a key tool of modern education (www.unesco.org). Its applications enable personalized learning, faster data analysis, and the automation of administrative tasks, thereby reducing teachers' workloads and improving the efficiency of educational processes. This, in turn, creates room to prioritize creativity, develop critical thinking, and strengthen students' social and emotional competencies (www.education.ec).

Contemporary education systems face numerous challenges—from unequal access to digital resources and teacher overload to insufficient digital literacy and a lack of personalized approaches to learners. In this context, artificial intelligence should not be seen as a threat but as a support to teachers, making the learning process more dynamic, accessible, and equitable (www.eurlex.eurora.eu)

In practice, there is a growing trend of experimenting with digital assistants and robot teachers, particularly in STEM education. Even so, the teacher's role remains irreplaceable: while AI provides analytical support and content personalization, the human factor ensures empathy, a moral framework, and pedagogical intuition (www.oecd.org).

At the same time, the rapid digitalization of the education sector brings risks. According to the European Union Agency for Cybersecurity (ENISA), the number of cyberattacks on educational institutions in Europe increased by more than 40% between 2020 and 2024, with e-learning platforms and virtual classrooms among the most frequent targets (www.enisa.europa.eu). These data clearly indicate that the development of AI in education must be considered in the context of cybersecurity and personal-data protection.

Bosnia and Herzegovina, like most Western Balkan countries, is undergoing intensive digital transformation. However, the lack of specialized personnel, limited technical resources, and low levels of digital literacy among teaching staff are significant obstacles to the full integration of AI technologies into the education system (www.mcp.gov.ba). It is therefore essential that digital transformation proceed in parallel with the development of data-protection policies, user education, and the construction of infrastructure that provides a secure environment for AI deployment.

The aim of this paper is to analyze how artificial intelligence will reshape education over the next decade, with a focus on technological, ethical, and security aspects, and to highlight the opportunities and challenges of its application in the context of Bosnia and Herzegovina. The study employs an analytical-descriptive approach based on a review of relevant literature, international guidelines, and research on the role of AI in education.

1. Application of artificial intelligence in education – global and regional context

Artificial intelligence in education is no longer a theoretical concept but a reality that is gradually changing how students acquire knowledge and how teachers plan and assess instruction (www.unesdoc.unesco.org). Its applications include personalized learning platforms, automated assessment, virtual assistants, and analytics tools that help identify educational needs and risks.

Globally, AI is used to create individualized learning plans, automate routine tasks, and develop virtual mentors. According to the UNESCO Digital Learning Report (2023), more than half of higher-education institutions in Europe use at least one AI tool in their operations, whereas in the Western Balkans the share remains significantly lower, though it is steadily increasing (www.unesco.org).

One of the key advantages of AI technologies is the ability to personalize learning. By analysing data on students' progress, pace, and interests, systems generate content aligned with their abilities and learning styles. In this way, advanced learners can move through material more quickly, while others receive additional support through tailored explanations and assignments. Such an approach increases students' motivation and autonomy and gives teachers a more detailed insight into each learner's progress.

Virtual assistants and intelligent tutor bots provide continuous access to help and feedback, which particularly contributes to the inclusivity of education. These tools are increasingly used in STEM disciplines and as support for students with special educational needs through speech interfaces and adaptive learning modules.

Automation of assessment enables faster and more objective evaluation of knowledge. Contemporary AI systems are no longer limited to multiple-choice tests; they also analyse essays, coding tasks, and

presentations, providing students with real-time feedback. Nevertheless, the evaluation of creativity, critical thinking, and interpretation remains within the teacher's domain, confirming that a balance between technology and human judgement is a basic precondition for high-quality education.

Predictive analytics adds further value to the introduction of AI in education. Based on students' behaviour patterns and outcomes, systems can detect early signs of underperformance or risk of dropping out, enabling timely teacher intervention. In some advanced environments, AI is also used to detect digital threats within educational networks, thereby enhancing data security and user protection (www.ibm.com; www.checkpoint.com).

Successful deployment of artificial intelligence requires appropriate infrastructure and teachers' digital competencies. Technology alone is not sufficient—stable networks, reliable platforms, and continuous professional-development programs are essential. Without adequate support and training for teachers, education systems risk remaining at an experimental stage without long-term impact (weforum.org).

At the regional level, the use of artificial intelligence in education in the Western Balkans is still in its early stages. While EU Member States already have developed strategies for digital transformation, countries such as Bosnia and Herzegovina, Serbia, and Montenegro face infrastructure constraints and uneven access to resources. According to reports by international organizations, most educational institutions in Bosnia and Herzegovina use basic digital tools, whereas more advanced AI systems appear primarily through individual projects and initiatives (www.eun.org). (Lee & Kwon 2024) recommend developing customized curricula for artificial intelligence, teaching strategies, and appropriate tools and resources with the aim of integrating AI across different school subjects.

Positive examples come from Slovenia and Croatia, where programs to integrate AI into secondary and higher education have already been launched alongside simultaneous efforts to strengthen the digital skills of teachers and students (www.eurlex.europa.eu).

2. Cyber security and personal data protection

The development of digital technologies and the use of artificial intelligence (AI) in education open new possibilities for improving teaching and learning, while at the same time creating complex challenges for personal data protection and information security. Educational institutions process large volumes of information on students, teachers, and administrative staff on a daily basis—from test results and attendance records to the digital traces generated by the use of e-learning platforms and virtual assistants. In the context of AI systems, these data become particularly sensitive because they are used for behavior analytics, knowledge assessment, and the creation of personalized educational profiles.

Protecting privacy and information security is the foundation of the responsible use of AI in education. In Bosnia and Herzegovina, this area is governed by the Law on the Protection of Personal Data of BiH (Official Gazette of BiH, nos. 49/06, 76/11, 89/11), under which the Personal Data Protection Agency was established (www.azlp.ba).

The law stipulates that personal data may be processed only with consent and for clearly defined purposes; in practice, however, many educational institutions lack the capacity and technical conditions to ensure consistent compliance. An additional challenge is reliance on foreign educational platforms (such as Google Workspace, Microsoft Teams, or Moodle Cloud), where data are stored outside the territory of BiH, raising questions of jurisdiction and international safeguards.

Compared with European Union member states that apply the **GDPR**, BiH has not yet fully aligned its regulations, although the principles of lawfulness, transparency, and data minimization should be integral to education policies (www.edpb.europa.eu).

During the COVID-19 pandemic and the shift to e-learning, an increase in attacks on educational networks and platforms was observed, further underscoring the need to strengthen security architecture and users' digital literacy (www.enisa.europa.eu; www.ibm.com; www.checkpoint.com).

The most common threats include phishing, ransomware, and DDoS attacks, which can lead to system outages, data loss, or disruption of instruction (www.enisa.europa.eu; www.ibm.com; www.statista.com).

Accordingly, educational institutions are advised to develop internal data-protection protocols, implement multi-factor authentication, and regularly train teachers and students in the safe use of digital tools (www.eun.org).

Cyberattacks can have serious consequences for educational institutions—from the loss of confidential information and financial damage to interruption of teaching and reputational harm. Practice shows that most incidents end with the compromise of students' and employees' personal data, directly endangering their privacy and security.

Educational institutions in BiH should establish internal privacy policies that clearly define how personal data are collected, stored, and erased, as well as staff responsibilities in the event of a breach. It is also recommended to appoint Data Protection Officers (DPOs) to monitor legal compliance, advise staff, and serve as contact points with the Personal Data Protection Agency (www.edpb.europa.eu).

Comparative practice shows that countries such as Germany, the Netherlands, and Finland have developed comprehensive data-protection protocols and mandatory staff-training programs. In BiH, however, the level of protection often depends on the individual initiatives of schools and IT departments, in the absence of a unified strategy or national standard (www.eurlex.europa.eu).

Therefore, the following is recommended:

1. Align the BiH Law on the Protection of Personal Data with the GDPR framework;
2. Develop national guidelines on the use of AI tools in education;
3. Provide continuous training for teachers and students on digital security;
4. Build technical protection systems (encryption, authentication, secure backups);
5. Involve IT experts in shaping education policies and curricula.

The application of artificial intelligence must be grounded in the principles of transparency, accountability, and trust. Only by ensuring a high level of privacy and information security can educational institutions fully realize the potential of AI technologies to improve instructional quality and create a secure digital environment (www.education.ec.europa.eu).

3. Ethical challenges and the responsible use of artificial intelligence in education

The application of artificial intelligence in education brings numerous benefits, but also challenges that cannot be viewed solely from a technical perspective; they must also be examined through an ethical lens. Questions of trust, transparency, the protection of students' rights, and the role of teachers become central to shaping contemporary education. How these challenges are understood and addressed will determine the extent to which AI technologies contribute to improving learning quality and developing a digital culture. According to (Čehić et al..2025) the introduction of AI technologies, whether formally through the curriculum or informally through personal use, requires adaptation from both teachers and students.

Unlike conventional digital tools, AI systems have the capacity to learn and adapt autonomously, meaning their behavior is not always fully predictable. Ethical considerations must therefore be as important as technological ones. According to the Ethical Guidelines for Educators on Using AI and Data in Education (www.education.ec.europa.eu), the core principles for responsible AI use in education include fairness, transparency, reliability, and respect for human dignity. This implies that every AI-generated decision or recommendation must be understandable, explainable, and subject to human review.

One of the greatest challenges concerns the transparency of algorithms that analyze student data. If teachers and students do not understand how AI arrives at particular conclusions, trust is undermined. Educational institutions should therefore deploy tools that enable explainability - the ability to clearly see which parameters led the system to a given assessment. It must also be clearly defined who bears responsibility for potential errors—the teacher, the institution, or the technology provider.

AI systems learn from existing data; if those data are one-sided or contain social biases, there is a risk that the algorithm will replicate the same patterns of discrimination. For example, a grading system may disproportionately disadvantage certain groups if it was not trained on representative samples. This is why it is recommended to involve interdisciplinary teams—pedagogues, psychologists, IT specialists, and ethicists—in the development and oversight of AI solutions. The European Commission also encourages periodic audits of algorithms used in educational settings, as well as independent assessments of their fairness and reliability (www.education.ec.europa.eu).

Unequal access to technology also raises the issue of the digital divide. Students from rural areas or lower-income families often lack the same technical opportunities as their peers, which can deepen existing inequalities. Ethical responsibility in education therefore entails ensuring equal access to digital resources and tools for all students, regardless of socioeconomic status.

The teacher remains the central figure in the educational process, even in environments dominated by digital systems. The role is evolving—from lecturer to mentor and guide. AI can analyze data, but it cannot replace pedagogical intuition, empathy, and emotional intelligence. According to the OECD Education Policy Outlook (www.oecd.org), the teacher in the digital age becomes a key intermediary between students and technology, responsible not only for knowledge but also for developing critical thinking and an ethical stance toward digital tools.

Newer approaches are also developing the concept of digital empathy, which concerns understanding students' emotional responses in virtual environments. Some AI tools already enable the detection of fatigue, stress, or lack of concentration, but such systems must be used strictly as support—not as a substitute for pedagogical judgment.

Today, digital literacy means more than technical know-how; it also encompasses the capacity for critical reflection on technology. Students must be aware that every online activity leaves a trace and that using AI tools requires responsibility, respect for intellectual property, and the protection of personal data. As emphasized in the UNESCO Recommendation on the Ethics of Artificial Intelligence (www.unesco.org), the goal of the education system should be to foster a digital ethical culture that teaches students to recognize manipulation, misinformation, and algorithmic bias.

Responsible AI use in education also requires institutional support. Educational institutions should develop ethical codes and clear policies on the use of digital technologies, data governance, and user rights. Establishing ethics committees at universities and ministries of education would help create a culture of trust and accountability. The European Commission's Digital Education Action Plan (wwweurlex.europa.eu) recommends precisely such mechanisms as a way to increase transparency and reduce the risk of misuse.

Ultimately, the ethical use of artificial intelligence does not depend solely on legal norms, but on a culture of learning and value awareness. Only through cooperation among educational institutions, teachers, students, and regulatory bodies is it possible to build a system in which AI enhances knowledge and creativity without replacing human integrity and freedom.

4. Implementation phases and success metrics

Introducing artificial intelligence into education should not be abrupt but planned and gradual, with clearly defined objectives and methods for verifying results. Success depends on coordination among policymakers, teachers, students, and IT experts, as well as on a strategy that aligns technological

progress with ethical standards and privacy protection. In this context, over a period of up to 10 years, the following phases can be considered:

Phase 1 – Preparation and Pilot Projects. Define national and institutional policies for AI adoption, with an emphasis on data protection and digital security. Launch pilot projects in selected schools and faculties, identify the areas of greatest benefit (administration, assessment, personalized learning), and organize basic training for teachers and administrative staff. In this phase, develop "AI mentorship"—tools that help teachers with lesson planning, task design, and evaluation—to build trust and reduce resistance to technology (www.eurlex.europa.eu).

Phase 2 – Expansion and Standardization. Scale successful pilot practices and build institutional support: introduce automated grading for routine tasks, use predictive analytics for early identification of at-risk students, and establish centers for digital support and AI resources within institutions. Set clear technical and pedagogical standards, internal data-processing protocols, and full compliance with national regulations and the GDPR. In hybrid learning models, the teacher remains the intermediary and interpreter of AI system outputs.

Phase 3 – Integration and Sustainability. AI becomes an integral part of the curriculum; digital literacy and digital ethics become mandatory competencies. Develop interoperable systems for data exchange between schools and universities with a high level of information security. It is recommended to establish a national center for digital education and security to coordinate efforts, support schools, and continuously align guidelines with European practice. The focus is on continuous monitoring, evaluation, and improvement, while preserving the balance between technology and pedagogy. As noted by (Kučina et al., 2021), digital technologies can be used for a wide range of innovative pedagogies.

To track progress objectively, it is necessary to combine quantitative and qualitative indicators as instruments of success measurement.

- Quantitative: student progress (pre/post AI implementation), reduction in dropout rates, number of trained teachers, time required for grading and administration, and the volume of digital-resource usage (www.weforum.org).
- Qualitative: student and teacher satisfaction, the quality of feedback and individualized support, the degree of integration of ethical and security standards, perceptions of transparency and trust in AI tools, and levels of digital and information literacy.

International indices such as DERI and DESI can serve as a broader comparative framework; according to the latest reports, BiH remains below the EU average in digital readiness, confirming the need for additional investments in infrastructure and staff training (www.eurlex.europa.eu).

Decision-makers at the national and local levels should ensure stable financing, a legal framework that encourages innovation, and mandatory professional-development programs. Partnerships among institutions, academia, the private sector, and civil society are crucial to ensure that AI in education evolves beyond project-based enthusiasm into a sustainable reform that enhances the quality, accessibility, and equity of learning.

Conclusion

The development of artificial intelligence in education represents one of the greatest opportunities—yet also challenges—of contemporary society. Its impact goes beyond the mere digitalization of learning processes: it changes how individuals approach knowledge, develop critical thinking, and collaborate in virtual environments. Over the next decade, education systems worldwide will face the task of finding a balance between technological efficiency and the preservation of the human dimension of education.

Bosnia and Herzegovina, as a country in the midst of digital transformation, has a real opportunity to harness the potential of artificial intelligence. However, this process must be planned, responsible, and aligned with international standards. The key preconditions for success include investment in infrastructure, strengthening digital literacy, developing the ethical and legal framework, and protecting privacy and personal data. It is particularly important to build a strong link between the education and technology sectors so that innovations from domestic IT companies directly contribute to improving instruction and students' digital competencies.

Artificial intelligence is not a substitute for the teacher but an ally. The teacher's role in the digital age becomes even more important, not only transmitting knowledge, but also developing critical thinking, fostering ethical reflection, and guiding students to use technology responsibly and purposefully. AI should be viewed as a tool that supports pedagogy, not as an end in itself.

The ultimate goal of integrating AI into education in Bosnia and Herzegovina is to create a sustainable, equitable, and humane model of learning in which technology and the human element are in balance. Such a system contributes not only to instructional efficiency but also to the development of a society grounded in knowledge, transparency, and accountability. To achieve this, it is necessary to institute ongoing evaluation of the effects of AI tools, analyze their impact on students and teachers, and continuously adapt policies to new technological and social conditions. If ethical and legal principles are consistently upheld, education in BiH can become an example of the successful integration of advanced technologies in the service of people and communities. Used thoughtfully and responsibly, artificial intelligence can become a driver of positive change and the foundation of the education of the future.

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Analysis of the Serbian Labour Market Between Economic Crises and Employment Perspectives

Analiza tržišta rada Srbije između ekonomskih kriza i perspektive zaposlenosti

Pavle Jeremić[1], Pavle Brzaković[2], Vuk Mirčetić[3]

[1]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, pavle.jeremic@mef.edu.rs*
[2]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, pavle.brzakovic@mef.edu.rs*
[3]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, vuk.mircetic@mef.edu.rs*

Abstract: *This paper presents an analytical review of employment in Serbia over the past decades, during which various complex socio-political circumstances shaped the labour market. Numerous authors have highlighted the connection between fluctuations in national labour markets and global economic crises. Transition and the liberalisation of the labour market have affected employment in different ways during various periods. Serbia faced challenges such as the "transition gap" and structural unemployment. The outbreak of the 2008 global financial crisis led to new trends in employment dynamics and posed significant challenges for governments worldwide. In the previous period, the research literature has increasingly focused on the impact of the COVID-19 pandemic on employment, as well as the effects of accelerated digitalisation in the contemporary business environment. Flexible working hours have become an integral part of the work culture of many companies, and simultaneously provide motivation for further academic investigation into what has led to this. Based on a systematic review of labour market trends in the previous period, as conducted in this paper, and global tendencies in employment types, the paper identifies prospects for the domestic labour market. These implications can also be considered as the contribution of the study.*
Keywords: *Business environment, instability, employment dynamics, unemployment, digital transformation, workforce.*

Apstrakt: *Kroz rad je izvršen analitički pregled zaposlenosti u Srbiji u prethodnim decenijama, u kojima je tržište rada oblikovano različitim složenim društveno-političkim okolnostima. Mnogi autori su istakli povezanost turbulencija na nacionalnim tržištima rada i globalnih ekonomskih kriza. Tranzicija i liberalizacije tržišta rada su uticali na zaposlenost na različite načine u različitim periodima. Srbija se suočila sa problemima poput „tranzicionog gepa" i strukturne nezaposlenosti. Izbijanje svetske ekonomske krize 2008. godine dovelo je do novih trendova u kretanju zaposlenosti i postavilo veliki izazov pred vlade svih zemalja. U prethodnom periodu se istraživačka literatura značajno bavila i uticajem COVID–19 pandemije na zaposlenost, kao i efektima koje izaziva ubrzana digitalizacija u savremenom poslovnom okruženju. Fleksibilno radno vreme postalo je neizostavan deo radne kulture mnogih kompanija, a istovremeno predstavlja i motiv da se studioznije istraži šta je dovelo do toga. Na osnovu sistematizacije kretanja na tržištu rada u prethodnom periodu koja je izvršena u radu, kao i na osnovu globalnih tendencija u vidovima zaposlenosti, proističu perspektive i domaćeg tržišta rada. Ove implikacije ujedno se mogu označiti kao doprinos rada.*
Ključne reči: *Poslovno okruženje, nestabilnost, dinamika zapošljavanja, nezaposlenost, digitalina transformacija, radna snaga.*

Introduction

The international economic environment in the past decades has been characterised by the emergence of frequent and unpredictable crises that have significantly affected countries' labour markets. Despite a large number of studies by respectable authors addressing the impact of crises on employment worldwide (Johnstone et al., 2016; Oulton & Sebastia-Barriel, 2017), there remains a theoretical gap that has not sufficiently examined the correlations between these crises and their implications for the labour market.

Employment is one of the fundamental macroeconomic categories and has been studied and analysed by various authors. The role of the government in each country is to design policy strategies that create favourable conditions for raising employment rates. Employment is a very important issue in both developed and developing countries (Abdullah et al., 2011).

In addition to global economic crises that have affected economies and employment worldwide, crises can also be generated by internal economic and political processes, such as transition. The process of transforming property relations brought with it the problem of unemployment in post-socialist countries such as Serbia. The initially high unemployment rates were considered a potential obstacle to effective reforms (Bah & Brada, 2014).

The global financial crisis of 2008 introduced new instabilities into the labour market and led to changes in employment and unemployment rates. Even the most developed economies experienced negative effects and rising unemployment. Within the European Union, only Luxembourg increased employment during the crisis period, by 1.3% (Hijman, 2009).

With the outbreak of the COVID-19 pandemic, all world economies faced new challenges and obstacles. Gašić and Berber (2021, p. 2) stated: "The COVID-19 pandemic has significantly transformed the work environment as well as the work responsibilities of many individuals who started working from home or remotely". These trends were strongly reinforced by digitalisation, which affects all business aspects in the contemporary work environment. This implies that new skills are required to perform tasks effectively, introducing the risk of structural unemployment.

The growing influence of digital transformation and the development of artificial intelligence have clearly shaped contemporary employment trends. Digitalisation has reached such proportions that it has entered almost all major economic sectors and significantly influenced the structure of the labour market (Charles et al., 2022).

Apart from the introductory and concluding considerations, this paper is structured into two chapters. The first chapter provides an analysis of the Serbian labour market prior to the onset of the 2008 global economic crisis, as well as the key consequences of that crisis for employment in Serbia. The second chapter examines the implications of the crisis caused by the COVID-19 pandemic for the Serbian labour market, while also addressing potential prospects for future employment development in Serbia.

1. The state of the Serbian labour market before the 2008 crisis and the effects of the crisis on employment

Economic crises and their consequences significantly shape the labour market and alter employment trends, as they determine the employment policies implemented by governments across the world. Global economic crises have a profound impact on the number of employed and unemployed individuals, both globally and nationally. The analysis of the impact of crises on employment in Serbia has been the subject of research by several respected authors (Kosanović & Paunović, 2009; Uvalić et al., 2020).

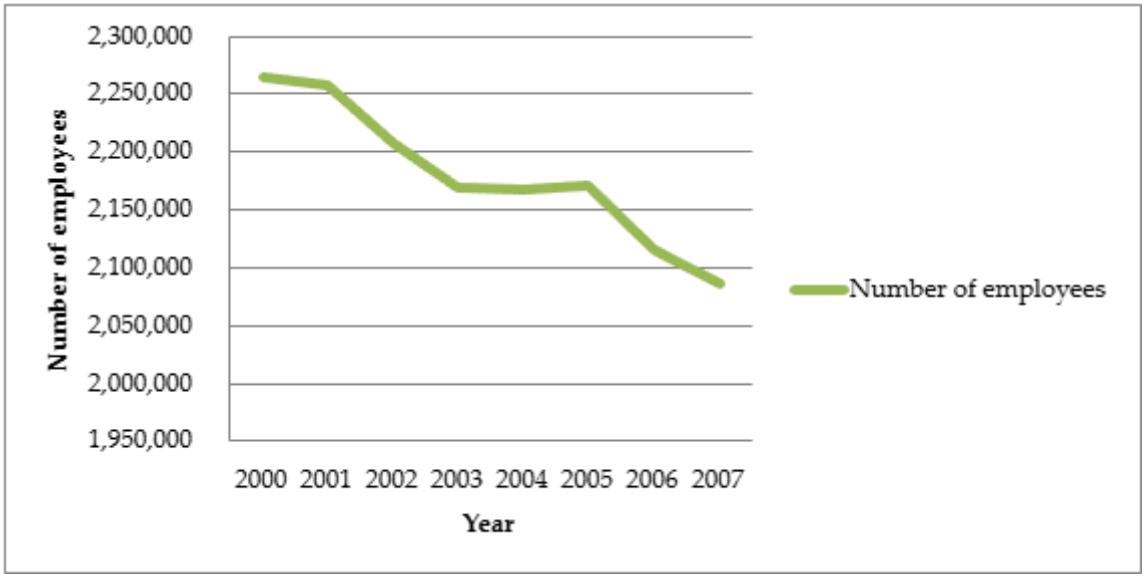
Crises bring about the problem of unemployment and introduce greater uncertainty into an already uncertain contemporary business environment. Some respected authors identify various factors

contributing to increased uncertainty, including financial and health crises, wars, and migratory processes (Andrijić, 2024). Political instability is directly linked to adverse developments in employment trends and prevents the creation of a long-term state policy framework that would stimulate employment. The view that political instability has long-term consequences for employment is supported by several notable authors (Rashid & Rashid, 2024).

The political and economic turbulence that culminated with the fall of the Berlin Wall marked the beginning of a gradual transition of formerly socialist countries towards a market-oriented economic system. In Serbia, this transition was additionally burdened and slowed down by the disintegration of the Socialist Federal Republic of Yugoslavia (SFRY), the imposition of international sanctions, and the civil war. The disintegration of what had once been a unified labour market also had a substantial effect on the formation of new economic flows. From the beginning of the dissolution of the SFRY until 2001, nearly half a million young people left the country, while, conversely, a large influx of refugees placed additional strain on the labour market (Marjanović, 2016).

Following the political changes of 2000, Serbia entered a second, more intensive wave of transition. Several authors assess its effects as similar to those observed in other post-socialist countries, where total employment declined and unemployment increased (Gligorov et al., 2011).

Graph 1 shows the number of employees in Serbia between 2000 and 2007. This period reflects the state of the Serbian labour market between the democratic changes of 2000 and the onset of the 2008 crisis.



Graph 1. Number of employees in Serbia (2000-2007)
Source: Authors, based on data from the Statistical Office of the Republic of Serbia

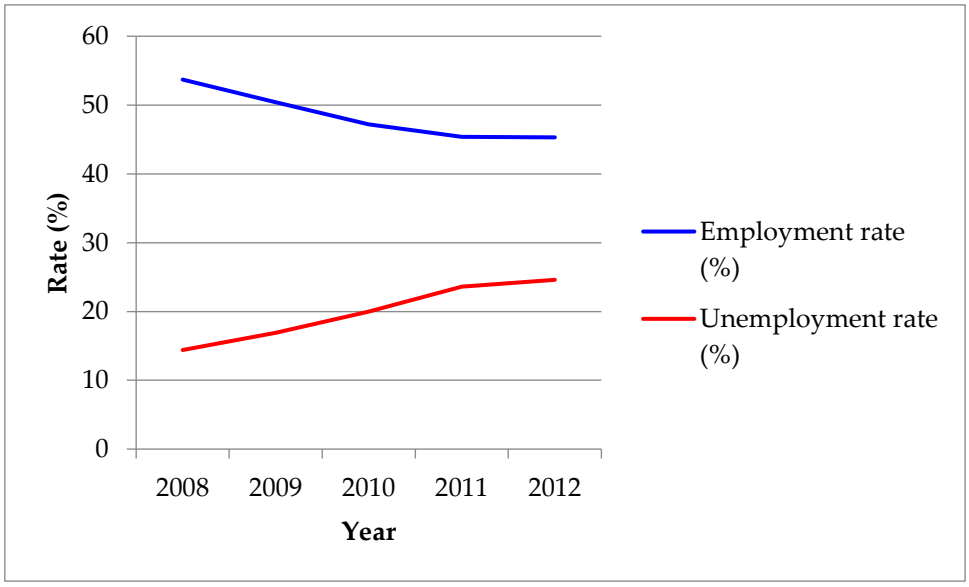
By the end of the observed period, there were approximately 179,000 fewer employees, representing a 7.9% decrease compared to the initial year. The largest decline was recorded between 2005 and 2006, when the number of employees fell by around 2.6%, while a slight increase (0.2%) was recorded only between 2004 and 2005.

In 2008, the world was struck by a major economic crisis, which introduced a new era of uncertainty in the labour market. Several respected authors describe the period preceding the crisis as one of general employment growth across all industries, accompanied by historically low unemployment rates (Goodman & Mance, 2011). Different countries attempted to apply various models of response to the crisis: Germany and Denmark shortened working hours, while the United Kingdom reduced public sector wages (Lallement, 2011). Despite the different strategies, all countries experienced a decline in employment. Within the European Union, Latvia recorded the most significant drop in employment - a dramatic 13.1% decrease by the second quarter of 2009 (Hijman, 2009).

The adverse effects of this crisis also encompassed Serbia, pushing its economy into recession and leading to an increase in public debt (Hanić et al., 2014). Serbia entered the global economic crisis already burdened by the negative trends that had emerged during the transition period, while simultaneously facing political instability due to the unilateral declaration of independence by the province of Kosovo and Metohija. Under such conditions, unemployment in Serbia rose sharply, reaching 17.4% in just one year (Arandarenko, 2010).

The scale of the crisis is further illustrated by the fact that the number of individuals applying for social assistance increased by one-third during this period (Anić & Mladenović, 2014). Unemployment trends also varied among different age groups. Several notable authors have pointed out the existence of a long-term youth unemployment problem in Serbia, with the unemployment rate among young people reaching as high as 41.6% in 2009 (Gligorov et al., 2011). According to certain respected scholars, the Serbian economy entered a state of stagnation in 2009, due to a wide range of factors, including a reduction in investment levels (Petrović et al., 2024).

Graph 2 shows the trends and relationship between unemployment and employment rates during the period from 2008 to 2012.



Graph 2. Employment and unemployment rates in Serbia (2008-2012)
Source: Authors, based on data from the Statistical Office of the Republic of Serbia

The total decline in employment amounted to 8.4% over the observed period, while unemployment increased by 10.2%. The largest yearly drop in employment occurred between 2009 and 2010, amounting to 3.2%, whereas the sharpest increase in unemployment was recorded between 2010 and 2011, at 3.6%.

2. An analytical overview of the labour market after COVID-19 and employment prospects

Economies around the world faced the problem of unemployment following the outbreak of the COVID-19 pandemic, which led to a decline in employment worldwide. The unemployment consequences of this crisis, expressed in numbers, were greater than those of the 2009 financial crisis (Su et al., 2021). Some authors describe this crisis as the largest to have struck the world since the Great Depression of 1929 (Alrefai, 2020; Li et al.,2021).

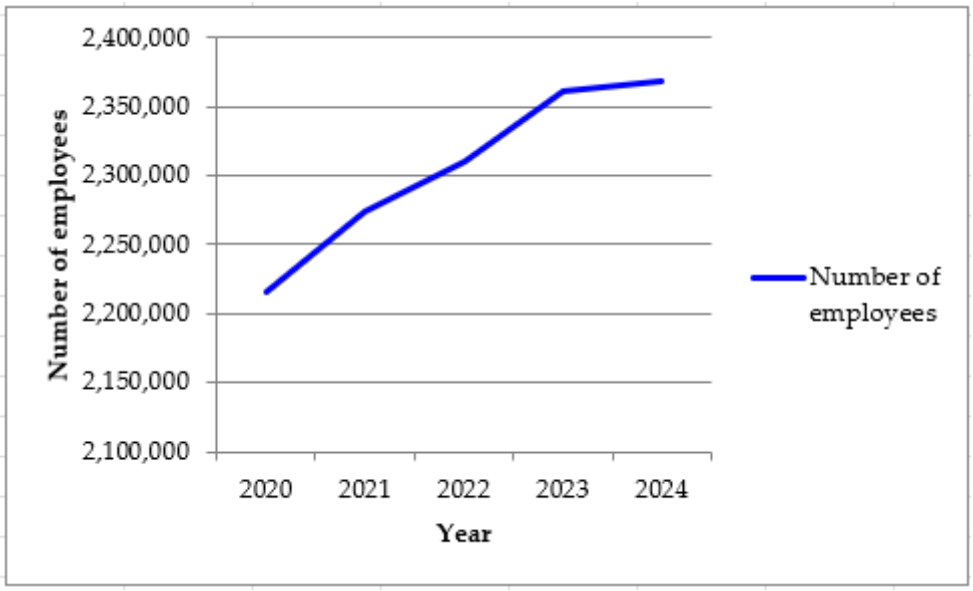
The new global economic crisis transformed the previous trends of employment and unemployment. The lack of demand for workers caused by the crisis not only reduced employment but also prevented those already unemployed from seeking and obtaining new jobs (Smith et al., 2021).

The crisis triggered by the COVID-19 pandemic, much like that of 2008, demonstrated that such crises have a particularly negative impact on youth employment. In some European countries, the number of unemployed young people doubled, and this problem also affected countries where youth employment had previously been at high levels (Lambovska et al., 2021).

Several respected scholars have analysed the impact of this crisis on the labour markets of European Union countries (Žak & Garncarz, 2020; Privara, 2022; Markowska & Sokolowski, 2023). As was the case globally, the outbreak of the pandemic also led to an increase in unemployment in the EU labour market (Gubatova, 2021).

The impact of the global economic crisis was also evident in the Serbian labour market. The positive macroeconomic effects resulting from government reforms initiated in 2014 were particularly visible until 2019, when Serbia's labour market faced the challenge of a new crisis (Pavlović et al., 2020). Some authors argue that the effects on employment and unemployment during this period were noticeably different from those observed at the broader macroeconomic level (Vuksanović & Aleksić, 2025). The COVID-19 crisis, in addition to its impact on the economy as a whole, has consequently affected individual economic sectors such as tourism. Several respected authors have assessed that the crisis had particularly negative effects on this sector (Mirčetić et al., 2021).

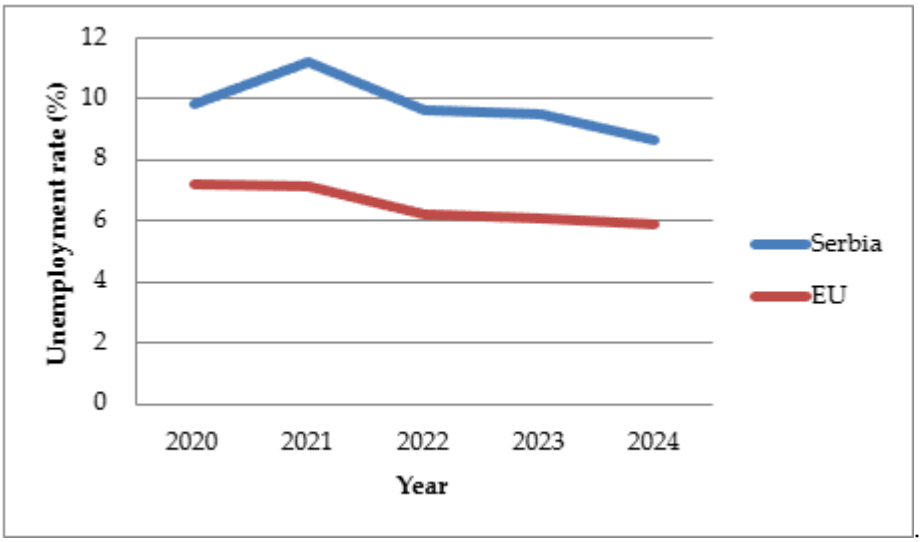
Graph 3 illustrates the number of employees in Serbia from 2020 to 2024.



Graph 3. Number of employees in Serbia (2020-2024)
Source: Authors, based on data from the Statistical Office of the Republic of Serbia

Graph 3 shows that the number of employees in Serbia continuously increased during the period from 2020 to 2024. The total increase in employment during this period amounted to more than 153 thousand newly employed persons, representing a growth of 6.9%. The upward trend in employment slowed after 2021, with the growth rate declining to 0.35% in 2024 compared to 2023.

Graph 4 presents a comparative analysis of the unemployment rate trends in Serbia and the European Union for the period between 2020 and 2024.



Graph 4. Unemployment rate in Serbia and EU (2020-2024)
Source: Authors, based on data from Eurostat

The data show differences in unemployment trends between Serbia and the European Union during this period. At the beginning of the observed period, unemployment in Serbia was significantly higher than in the EU, standing at 9.8%, compared to 7.2% in the EU. The most significant increase in unemployment in Serbia occurred between 2020 and 2021, when it rose to 11.2%, while in the EU it decreased to 7.1%. Subsequently, unemployment in Serbia gradually decreased, reaching 8.6% in 2024, while in the EU it also declined, reaching 5.9%.

The COVID-19 pandemic significantly accelerated the transformation of the labour market and the shift to hybrid work models, as companies and governments were forced to operate under lockdowns and health crises. Some authors argue that this crisis was the main catalyst for the acceleration of digitalisation in the business environment (Amankwah-Amoah et al., 2021). The crisis also created a need for companies to adapt their existing organisational models to new circumstances (Pelaez et al., 2021). Certain respected authors have addressed the impact of the crisis on public services provided by the state and how governments organised remote work for employees in the public sector (Fischer et al., 2021).

A company's ability to quickly adapt to changes in the market is one of the prerequisites for survival in the contemporary business environment. Some authors claim that companies that adapted faster to sudden changes and shifted to remote work during the wave of work digitalisation triggered by the COVID-19 pandemic were better able to withstand the effects of the crisis (Yahmed et al., 2025). Even though over 49% of today's work tasks can be automated, this process should contribute to employee upskilling rather than job loss (Horvath et al., 2021).

Conclusion

Employment is one of the fundamental macroeconomic categories. Countries worldwide face challenges in implementing long-term policies that would stimulate employment. The contemporary business environment, characterised by a high degree of uncertainty, places governments before challenges when defining objectives and goals of economic policy in general, including strategies aimed at raising employment levels. In addition to economic factors, it is essential to consider political factors, which can serve as additional sources of instability and obstacles to national and local labour market development.

Economic crises significantly influence labour market trends. Global economic crises also have implications for national labour markets, transforming pre-existing employment flows. Major economic

crises, such as the one in 2008 and the crisis caused by the COVID-19 pandemic, in addition to increasing global unemployment, also impacted unemployment rates in Serbia. Beyond crises arising from external factors, national labour markets can also be affected by internal political instability. Employment trends in Serbia have long been shaped by internal challenges caused by the dissolution of the SFRY, war events, and hyperinflation, followed by the transition process in the early 21st century.

This paper aimed to explore the impacts of crises on the Serbian labour market in the previous period. Despite a large number of respectable authors having studied the effects of transition and economic crises on employment in Serbia, a theoretical gap remained, leaving room for further research. The paper also analysed the prospective trends in unemployment and employment conditioned by the accelerated process of digitalisation. The scientific contribution of this study can also be reflected in the quantitative analysis of employment and unemployment trends between 2000 and 2024, through which key patterns of change in the Serbian labour market have been identified. For example, the study's analysis shows an increase of more than 153,000 newly employed persons during the 2020–2024 period. The study may be of value to the scientific and research community, the public sector, the business community, and educational institutions.

Although the study consulted a significant number of authors, certain limitations regarding the literature remain. These limitations can be viewed in terms of the need to consult an even larger number of reputable authors who have conducted research in the areas analysed in this paper. Moreover, these limitations can serve as a basis for future research and for narrowing the existing theoretical gap. In the future, it would be beneficial to examine the impacts of global economic crises on the labour markets of other countries in more depth and subsequently compare these findings with the results related to Serbia. The study provides an analysis framework that may serve as a foundation for further research on the influence of digitalisation on employment prospects in Serbia. The trends indicate that, despite periods of crisis, the Serbian labour market shows a tendency toward employment growth, which provides grounds for optimism regarding future economic development.

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Monitoring and Application of Technological Tools for the Protection of Intellectual Property and Copyright in the Era of Artificial Intelligence

Praćenje i primena tehnoloških alata za zaštitu intelektualne svojine i autorskih prava u eri veštačke inteligencije

Svetlana Marković[1], Miodrag Brzaković[2], Marko Marković[3]

[1]*University Business Academy in Novi Sad, Serbia, office@privrednaakademija.edu.rs*
[2]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, miodrag.brzakovic@mef.edu.rs*
[3]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia,, marko.markovic@mef.edu .rs*

Abstract: *This paper aims to find a way and a method in seeking an answer to the question "Who is the author in the age of artificial intelligence?" , which is not only a legal question, but also a question of the future of human creativity. The answer to it requires an open mind, an innovative approach and a willingness to redefine our foundations in light of the technological revolution that has already begun. Artificial intelligence is not only a technology, but also a mirror of modern society that reflects our values, fears and hopes. The development of artificial intelligence and the digitalization of creative content bring not only legal challenges, but also the need for innovative technological solutions that will enable effective copyright protection. Traditional protection systems are often not adapted to the speed and complexity of modern digital flows, which is why new technologies are gaining an increasing role in this domain.*
Keywords: *Intellectual property, copyright, artificial intelligence.*

Apstrakt: *Ovaj rad ima za cilj da nađe put i način u traženju odgovora na pitanje „Ko je autor u doba veštačke inteligencije?", koje nije samo pravno pitanje, već i pitanje budućnosti ljudskog stvaralaštva. Odgovor na njega zahteva otvoren um, inovativan pristup i spremnost da redefinišemo naše temelje u svetlu tehnološke revolucije koja je već krenula. Veštačka inteligencija predstavlja ne samo tehnologiju, već i ogledalo savremenog društva koje reflektuje naše vrednosti, strahove i nade. Razvoj veštačke inteligencije i digitalizacija kreativnih sadržaja donose ne samo pravne izazove, već i potrebu za inovativnim tehnološkim rešenjima koja će omogućiti efikasnu zaštitu autorskih prava. Tradicionalni sistemi zaštite često nisu prilagođeni brzini i kompleksnosti savremenih digitalnih tokova, što je razlog da nove tehnologije dobijaju sve veću ulogu u ovom domenu.*
Ključne reči: *Intelektualna svojina, autorsko pravo, veštačka inteligencija.*

Introduction

The growing influence of artificial intelligence on the creation of copyrighted, patented, and proprietary works has numerous implications. These implications are potentially catastrophic due to the growing capabilities of artificial intelligence and its ability to mimic the characteristics of human intelligence. These capabilities at least resemble the creativity and originality of human thought. It is therefore reasonable to ask who should own inventions created with the help of artificial intelligence, in general, and in particular, under the laws relating to the protection of intellectual property and copyright.

In the rapidly evolving field of intellectual property, the integration of artificial intelligence into the creative process has become a significantly influential factor, altering the very nature of original works and introducing a multitude of complex legal issues (Greenstein, 2022). Legal systems are struggling to

understand the transformative impact of artificial intelligence on intellectual property. At the heart of these effects lies the unique ontology of artificial intelligence, and more precisely, its autonomy, which enables artificial intelligence to produce creative and original works without any, or at least critical, human intervention. Although this legal issue has only recently emerged, numerous court decisions have already been made in various legal systems worldwide.

1. Ontology of artificial intelligence and the meaning of its autonomy

Laws of artificial intelligence defines artificial intelligence as "a system designed to operate with a certain level of autonomy and which, based on information and inputs provided by a machine and/or a human, determines how to achieve a given set of goals defined by a human using machine learning and/or reasoning and knowledge-based approaches, and produces system-generated outputs such as content (generative AI systems), predictions, recommendations or decisions that affect the environments with which the AI system interacts (Pokrovskaya, 2024). This is one of the definitions related to artificial intelligence and applies to a wide range of AI outputs, including decision-making and content creation. This ontology itself raises the question of regulating the works created by artificial intelligence.

The very concept of artificial intelligence was initially based on the desire to create machines that could imitate human intelligence or its aspects, or, in other words, reproduce human learning procedures and aspects of human intelligence through machine learning. Alan Turing's vision was that a computer replicates the thinking, methodology and development of a child (Turing, 2007).

1.1. What is machine learning?

"Machine learning" refers to an AI's ability to "learns" how to produce specific results. The goal of machine learning in AI is to discover natural patterns of development and, therefore, to obtain solutions to a wide range of unspecified problems without the need for human intervention (Bostrom, 2014). "Machine learning" takes place by collecting and using large amounts of data to train algorithms. AI learns from our shared data generated by the entire community, and in this sense, the autonomy of AI is essentially (at least partially) a social outcome. AI does not yet possess all these characteristics as humans do, because it lacks self-reflective intelligence; however, in many areas, it already produces results that are a prerequisite for such intellectual abilities in humans.

Machine learning also explains why, as AI develops, its ontology becomes probabilistic, nonlinear, complex, and opaque, leading to fundamental uncertainties that have been described as the "black box effect." This means we cannot be certain of the output of machine learning and AI actions.

The question of whether AI can exhibit creativity and originality or whether these are purely human traits is an interdisciplinary one and remains largely unanswered. To a certain extent, AI – at least the kind that currently exists – simply guesses patterns and can therefore never be creative and original. On the other hand, this approach is deeply unfair, as it fails to take into account that even in its limited form, AI mimics the characteristics of the human mind, including aspects of creativity. A partial way to circumvent this ontological contradiction (but also to provide a legal answer) is the fact that, regardless of whether we consider artificial intelligence ontologically creative or not, it creates works that, if created by humans, would be considered creative and therefore protected by copyright.

2. Fundamentals of intellectual property rights and the impact of artificial intelligence

To understand artificial intelligence and intellectual property law, it is first necessary to briefly review the fundamentals of intellectual property law. First of all, intellectual property "...in a broad sense means the legal rights arising from intellectual activity in the industrial, scientific, literary and artistic fields"

(Moerland & Kafrouni, 2022). Intellectual property law is fundamentally straightforward: it transforms knowledge and its practical application into economic value.

From the point of view of intellectual property law, scientific works fall within the scope of copyright, while inventions fall within the scope of industrial property. The fundamental element of intellectual property is the combination of a creative, non-obvious, original idea or invention with its practical application in industry. Determining whether each specific criterion is met is a legal challenge.

Intellectual property rights in all legal systems must always be balanced against the broader public interest to avoid abuse; public access cannot be unfairly restricted in favour of any person or entity. This requirement becomes even more critical when considering artificial intelligence and its gradual replacement of humans in this chain.

One common element of all legal systems is that they exclude intellectual activity from the scope of intellectual property protection. This issue has been clarified by numerous case laws, which have drawn an important distinction between intellectual activity in itself and intellectual activity with industrial applications.

The protection of the author's identity is a fundamental principle of copyright law, as evident in several provisions: the work may not be altered or distorted without the author's permission, regardless of any transfer of copyright ownership. It must be associated with the name of the author; publication of the work without the author's permission is prohibited; The author reserves the right to withdraw his work.

3. Intellectual property protection in the digital age

Digital technologies are fundamentally changing the way intellectual property is protected, but artificial intelligence may eventually become the author of inventions. According to international practice, intellectual property rights are legal rights to works, ideas and inventions created by humans. Such intellectual property may include:

- Copyrights for literary, musical, artistic and other works;
- Patents for inventions;
- Trademarks and rights to trademarks;
- Rights to utility models and industrial designs;
- Rights to software and hardware;
- Rights to databases and other intellectual property.

According to generally accepted practice in our country and internationally, protection of one's own intellectual property rights is possible only if the owner has supporting documentation. Otherwise, there will be no infringement, because the attacker is copying code or illegally using a brand that is not officially owned.

Intellectual property rules are not absolute. They must be balanced with the public interest and the rights of competition. Although the precise scope of intellectual property protection, both at the constitutional level and under ordinary law, varies between countries, the need for a balanced approach is undeniable. Intellectual property protection must be fair to the author (rewarding individual achievements) and proportionate to the public interest, which requires the broadest possible access to knowledge, creations and their industrial applications.

4. What if intellectual property is actually created by artificial intelligence (AI)?

The idea of this article is that AI, when creating a work, can be ontologically creative, even though its inventions cannot be protected by copyright law. AI is not just a machine; it is a unique, autonomous entity with the capacity for autonomous creativity. Therefore, blocking public access to its works is unfair, disproportionate, and offensive under intellectual property law, both in domestic copyright law and international copyright law. A new set of norms and regulations is needed, a kind of standard and reference point for the autonomy of AI, which will help determine when AI has become so autonomous that its results should be freely available to everyone. Universal accessibility of works generated by AI must be a basic requirement. This must become the new guiding principle in the new era of AI-generated work.

4.1. Originality and copyright in AI-generated software

In the field of programming, artificial intelligence is increasingly playing the role of a creative collaborator. Software engineers today use tools based on large language models to write, optimise, and even automatically generate entire functions, applications, or websites.

Tools such as:

- GitHub Copilot (powered by OpenAI Codex),
- Amazon CodeWhisperer,
- Tabnine,
- Replit Ghostwriter,

have become a daily part of the work of hundreds of thousands of developers worldwide.

However, their ability to generate functional code raises legal questions about ownership, liability, and permissible use.

Under the laws of most countries, software is protected as a work of authorship. However, when an artificial intelligence creates code:

- Who is the author? – the developer, the company that trained the AI, or no one?
- Who is liable if the code causes harm? – e.g. if an AI writes insecure code that causes a security flaw.

Currently, the end user (programmer) is considered responsible for checking and validating the code, even if they did not directly write it.

In order for software code to be protected by copyright, it must meet the condition of originality. This means that it must be:

1. the result of human work and
2. a reflection of creative choice and arrangement, not just mechanical functionality.

When an AI generates code that has already been seen or is a derivative of someone else's work, this becomes legally questionable.

Examples from practice:

1. Lawyers from the Software Freedom Conservancy argue that AI code that "frequently uses patterns from popular repositories" is actually reproducing fragments that are legally protected.
2. Example: GitHub Copilot under legal pressure

In 2022, a group of developers filed a class action lawsuit against Microsoft, GitHub, and OpenAI, alleging that Copilot:

- uses open-source code without respecting its licenses (such as the GNU GPL, MIT, Apache),

- generates code similar or identical to the originals without attribution,
- infringes the copyrights of developers who have published their work for the community.

The lawsuit is still ongoing, but it already has far-reaching consequences:

- GitHub has introduced an option to turn off suggestions that overlap with publicly available code.
- The questions are open: Does training AI on open-source code infringe copyright? Moreover, is the AI-generated code original?

Industry implications and practice:

- Startups are increasingly using AI to rapidly prototype software – reducing costs and the number of engineers they employ.
- Freelancers are using tools to complete large amounts of code in a short time.
- Large companies are investing in their own internal models, further protecting data and reducing the risk of legal consequences.

An interesting fact is that although software is closest to "algorithmic logic", it is in this area that copyright is most often used as protection. Artificial intelligence has now turned this system against itself – future law reforms are expected to more precisely determine who claims the rights to "algorithmic code that writes the algorithm" (Kaminski & Midgli, 2023).

Conclusion

This requires a regulatory framework that provides step-by-step guidance. Just as the EU Law on Artificial Intelligence was adopted, a law on artificial intelligence and intellectual property could be developed and implemented. Before undertaking such a legal development, it is necessary to consider what might lead to its emergence.

Artificial intelligence law is facing increasing challenges regarding the impact of new technologies, particularly artificial intelligence, on intellectual property rules. Legal systems worldwide are facing such challenges. Artificial intelligence poses new challenges for both legislators and courts, which, particularly in the context of artificial intelligence law, have played a significant role in shaping intellectual property rules. There is no doubt that artificial intelligence is transforming the field of intellectual property in unprecedented ways.

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Smart Systems for Sustainable Destination Management

Pametni sistemi upravljanja održivim turističkim destinacijama

Predrag Todorov[1], Adriana Radosavac[2], Dušan Rajčević[3]

[1]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, and Ministry of Tourism and Youth, Serbia, predrag.travel@gmail.com*

[2]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, adriana.radosavac@mef.edu.rs*

[3]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, dusan@mef.edu.rs*

Abstract: *Contemporary tourist destinations face complex coordination challenges that require balancing visitor experience, sustainability, and local community welfare. Traditional Tourist Destination Management Systems (TDMS) are typically static and fragmented, lacking the capacity to integrate real-time data and adaptive decision-making mechanisms. This paper introduces a conceptual model of Smart Systems for Sustainable Destination Management (STDMS), integrating Artificial Intelligence (AI), data interoperability, and principles of ethical and responsible governance. Drawing on systems thinking, smart tourism, and responsible AI literature, the model proposes four interconnected layers data fabric, intelligence, orchestration, and experience that together enable context-aware forecasting, optimization, and transparent decision-making aligned with sustainability principles. Rather than presenting empirical results, the paper introduces this framework as a foundation for future implementation and validation in real-world destinations. The contribution is both theoretical and practical: it formalizes STDMS as an adaptive socio-technical system, identifies research gaps in existing smart tourism literature, and outlines directions for the sustainable digital transformation of tourist destinations.*

Keywords: *Smart tourism, sustainable destination management, artificial intelligence, systems thinking, sustainability, digital transformation.*

Apstrakt: *Savremene turističke destinacije suočavaju se sa složenim izazovima koordinacije koji zahtevaju balansiranje između iskustva posetilaca, održivosti i dobrobiti lokalnog stanovništva. Tradicionalni sistemi za upravljanje turističkim destinacijama (TDMS) obično su statični i fragmentisani, bez kapaciteta da integrišu podatke u realnom vremenu i primene adaptivne mehanizme za donošenje odluka. Ovaj rad predstavlja konceptualni model pametnih sistema upravljanja održivim turističkim destinacijama (STDMS) koji integrišu veštačku inteligenciju (AI), interoperabilnost podataka i principe etičkog i odgovornog upravljanja. Oslanjajući se na sistemsko razmišljanje, koncept pametnog turizma i literaturu iz oblasti odgovorne veštačke inteligencije, model predlaže četiri međusobno povezana sloja: data fabric, inteligenciju, orkestraciju i iskustvo koji zajedno omogućavaju kontekstno predviđanje, optimizaciju i transparentno donošenje odluka u skladu sa principima održivog razvoja. Umesto prikazivanja empirijskih rezultata, rad uvodi ovaj model kao osnovu za buduću implementaciju i validaciju u realnim destinacijama. Doprinos rada je teorijski i praktičan: formalizuje STDMS kao adaptivni sociotehnički sistem, identifikuje istraživačke praznine u postojećoj literaturi o pametnom turizmu i postavlja smernice za održivu digitalnu transformaciju turističkih destinacija.*

Ključne reči: *Pametni turizam, upravljanje održivom destinacijom, veštačka inteligencija, sistemsko razmišljanje, održivost, digitalna transformacija.*

Introduction

Tourism destinations operate in volatile environments characterized by fluctuating visitor flows, climate variability, digital interdependence etc. Destination Management Organizations (DMO) need to bring together marketing, transport, heritage protection, and stakeholder collaboration, working across systems and data that are often disconnected. Despite advances in "smart tourism" technologies, most existing platforms remain reactive, data-isolated, and non-adaptive (Gretzel et al., 2015; Tussyadiah, 2020).

AI has the power to boost awareness, predict demand, and guide decisions, yet in destination management it's still applied without a clear strategy. The Smart Tourist Destination Management System (STDMS) proposed in this paper conceptualizes destinations as adaptive service ecosystems governed by data flows, feedback loops, and human oversight (Buhalis & Amaranggana, 2015). This paper's objective is to synthesize existing knowledge into a structured conceptual model that integrates AI capabilities with governance and sustainability principles. It advances three core contributions:

1. A systems-based conceptual framework that formalizes STDMS components and relationships.
2. A synthesis of cross-disciplinary literature on AI, smart tourism, and sustainable management.
3. A research agenda for evaluating STDMS in future empirical work.

The concept of sustainability within contemporary tourism is based on the effort to achieve a balance between economic development, environmental protection, and social responsibility, in order to preserve the opportunities of future generations (UNWTO, 2018). Tourism is therefore viewed not only as an economic activity but as a multidimensional system that integrates the economic, ecological, and socio-cultural components of development (Mowforth & Munt, 2016).

Smart management of tourist destinations implies the integration of digital technologies, data, and sustainable practices with the goal of achieving a balance between tourism development, resource preservation, and the quality of life of the local community. Modern destinations can no longer rely solely on promotion and marketing, but must instead adopt strategic management grounded in data, ethics, and long-term planning.

In this sense, sustainable tourism represents the foundation of smart destination management, as it promotes the rational use of natural and cultural resources and aligns the economic, ecological, and social goals of development (Radosavac & Todorov, 2021:147).

Therefore, the development of smart systems for sustainable destination management requires a multidisciplinary approach that connects technology, ecology, social responsibility, and management. On these foundations lies the theoretical framework presented in the following section of the paper.

1. Background

The concept of smart destinations emerged from the need to make contemporary tourism systems more adaptive, inclusive, and technologically interconnected. Sustainability and digitalization are not opposing but complementary paradigms, the former provides meaning, while the latter offers the tools for its implementation.

The ecological aspects of smart destination management must be grounded in the principles of reducing the negative impacts of tourism on the environment and strengthening the destination's ecosystem (Todorov, et al., 2023:75).

Alongside ecological factors, social and ethical dimensions are equally important. Smart systems must be fair, transparent, and socially responsible, which entails involving the local community in decision-making processes and using technology in the service of the common good.

Responsible business conduct and corporate social responsibility have become key drivers of sustainable development in tourism, as they connect digital innovation with community values and principles of equity (Todorov & Šijan, 2023).

1.1. Smart tourism and destination management

Smart tourism research emphasizes data-driven value co-creation and real-time decision-support infrastructures (Gretzel et al., 2015; Buhalis & Amaranggana, 2015). However, DMOs often lack unified systems integrating predictive analytics, operational orchestration, and visitor experience management (Xiang et al., 2017). Studies highlight a persistent gap between data collection and actionable governance (Li et al., 2018).

1.2. AI and predictive decision support

AI has been applied to tourism forecasting (Abdelhamid et al., 2021), itinerary recommendation (Ricci & Nguyen, 2017), and demand prediction (Law et al., 2020). Yet these applications remain domain-specific. Integrating AI across destination layers such as transport, accommodation, environment requires systems-thinking approaches (Batty, 2013) and explainable models that guarantees transparency and fairness (Ribeiro et al., 2016).

1.3. Systems thinking and adaptive management

Systems thinking conceptualizes destinations as interconnected networks of actors, processes, and feedback mechanisms (Meadows, 2008). Applying this lens to tourism supports adaptive management: continuous sensing, learning, and adjusting policies in response to environmental signals (Koens et al., 2018). By integrating systems thinking with contemporary technological solutions, destinations are transitioning from a phase of static management to one of dynamic adaptation and predictive decision-making. This transition forms the foundation for understanding smart systems of tourist destination management.

1.4. Ethical and inclusive smart systems

Ethical design and accessibility remain critical. Smart systems risk algorithmic bias, data misuse, or digital exclusion if poorly governed (Tussyadiah, 2020; Wobbrock & Kane, 2019). GDPR and WCAG guidelines mandate transparency, informed consent, and universal access to ensure responsible innovation. Social responsibility and the ethical regulation of digital processes are becoming key elements of a sustainable digital ecosystem in tourism (Todorov & Šijan, 2023).

In order to understand the broader context of developing smart systems for managing sustainable tourist destinations, a PESTEL analysis was conducted to identify the key external factors influencing the implementation and effectiveness of such systems. This analysis makes it possible to consider not only the technological and managerial aspects but also the political, economic, social, environmental, and legal frameworks that collectively determine the sustainability and competitiveness of smart destinations.

Table 1. PESTEL Analysis of factors influencing the development of smart systems for sustainable tourist destination management

Factor	Description of the impact on the development of smart destinations
P – *Political*	• There is institutional support through the Tourism Development Strategy of the Republic of Serbia 2016–2025 and local digital transformation strategies. • European initiatives (e.g., EU Smart Tourism Capital) further encourage the implementation of smart and sustainable solutions. • Insufficient coordination between ministries and local governments limits the effective implementation of policies.

E – *Economic*	• The implementation of smart systems requires significant initial investment, but in the long term leads to increased efficiency, competitiveness, and destination revenues. • The use of EU funds and international projects (e.g., Horizon Europe, Interreg) provides opportunities for financial support. In the short term, economic instability may hinder project continuity.
S – *Social*	• Digital transformation affects local communities by increasing access to information and citizen participation. • There is a risk of digital exclusion of the elderly population and small entrepreneurs. Education and community involvement are key to the development of inclusive smart destinations (Todorov, 2025a).
T – *Technological*	• Advances in artificial intelligence, IoT sensors, and predictive analytics enable the creation of adaptive management systems • Key challenges include data interoperability, cybersecurity, and ethical algorithm governance (Todorov, 2025b).
E – *Environmental*	• Smart systems contribute to monitoring and reducing the environmental impact of tourism through sensors for energy consumption control, waste management, and biodiversity protection. • The introduction of green technologies supports the achievement of sustainable development goals (Todorov et al., 2023).
L – *Legal*	• Data protection regulations (GDPR), digital accessibility standards (WCAG), and national tourism laws define the framework for the development of smart systems. • The lack of specific regulations on AI application in tourism poses a legal challenge that requires further institutional regulation (Todorov & Šijan, 2023).

Source: Author's own elaboration

The brief conclusion of the PESTEL analysis (Table 1) indicates that the development of smart systems for managing sustainable destinations in Serbia enjoys strong institutional support, but also faces challenges that require an integrated approach and coordination among all stakeholders. The political framework, defined by the *Tourism Development Strategy of the Republic of Serbia 2016–2025*, provides a foundation for the digital transformation of destinations, while economic factors emphasize the need for diversified funding sources and the inclusion of international programs and partnerships. From a social perspective, the main challenge remains the inclusion of local communities and the improvement of digital competencies to ensure that the transformation process is inclusive and equitable. Technological progress in artificial intelligence, the Internet of Things (IoT), and data analytics offers major opportunities for improving efficiency and transparency in destination management but simultaneously demands responsible data handling and ethical algorithm regulation. Environmental and legal factors further confirm that smart destinations can significantly contribute to the preservation of the environment and the reduction of tourism pressure on natural resources—provided that technology implementation aligns with the principles of sustainable development and existing legal regulations. In this regard, smart systems can become instruments of long-term destination transformation, not only through digitalization and innovation but also through improving residents' quality of life and promoting the responsible use of natural resources.

2. Conceptual framework for smart tourist destination management systems

The conceptual framework of the STDMS is founded on the combination of systems thinking, analytical methods (AHP), and principles of sustainable management, ensuring greater objectivity in decision-making and more efficient destination development planning. The effective functioning of smart destination management systems requires the implementation of multi-criteria decision-making

models. Such models enable different aspects of sustainability, economic, environmental, social, and technological to be measured, evaluated, and optimized in real time.
The application of the AHP method allows for the objective assessment and selection of priority destinations or development projects, taking into account multiple sustainability criteria (Todorov et al., 2023:184). By integrating such tools into smart systems, the planning process can be improved, subjectivity in decision-making reduced, and a more transparent approach to managing tourist flows ensured.

2.1. Guiding principles

The proposed STDMS model is grounded in four design principles:

- **Modularity:** Independent but interoperable components.
- **Adaptivity:** Continuous adjustment based on context signals.
- **Transparency & Accountability:** Explainable outputs, clear governance.
- **Inclusivity:** Accessibility for all user groups and equitable data representation.

2.2. Architecture overview

The STDMS framework consists of four interconnected layers, inspired by systems architecture models in smart city and service systems research (Batty, 2013; Ricci et al., 2015):

1. **Data Fabric Layer** – integrates heterogeneous sources such as accommodation occupancy, mobility data, event calendars, weather feeds, social media sentiment, and IoT sensors. Data pipelines include anonymization, quality control, and metadata cataloging.
2. **Intelligence Layer** – houses AI modules for forecasting (visitor arrivals, transport demand), optimization (itineraries, time-slotting, resource allocation), and analytics (trend detection, anomaly alerts). Emphasis is placed on explainable and ethically auditable algorithms (Ribeiro et al., 2016).
3. **Orchestration Layer** – converts insights into coordinated actions. It supports policy simulation, dynamic interventions (signage, incentives, alerts), and decision dashboards for operators. Rules incorporate sustainability and resident-wellbeing constraints.
4. **Experience Layer** – interfaces with visitors, residents, and SMEs through personalized mobile apps, kiosks, or APIs. User experience principles ensure clarity, accessibility, and data control (WCAG, 2023).

2.3. Feedback loops and governance

Each layer interacts via feedback loops: visitor behavior informs forecasts; forecasts trigger orchestration decisions; outcomes feed back into learning models. Governance mechanisms oversee these loops through transparent policy settings, audit trails, and participatory boards (residents, local businesses, authorities).

2.4. Theoretical positioning

The STDMS framework bridges gaps between:

- **Smart tourism** (Gretzel et al., 2015; Xiang et al., 2017)
- **AI-driven decision support** (Law et al., 2020)
- **Systems and sustainability theory** (Meadows, 2008; Koens et al., 2018)

It provides a holistic schema for understanding how intelligent, adaptive mechanisms can enhance both efficiency and ethical stewardship in destination management.

3. Discussion

Destination management in the era of digital transformation cannot be viewed in isolation from sustainable development. Smart systems create new opportunities for analyzing, forecasting, and managing tourist flows, but their application must align with the principles of ethics, accessibility, and data protection.

Smart systems enable integrated monitoring of the quality of the tourism product, contributing to more efficient management of sustainable destinations (Todorov, 2025b). Incorporating elements of educational and ecotourism into the planning process of smart destinations enhances awareness of the importance of sustainable tourist behavior and resource preservation (Todorov, 2025a).

Furthermore, the successful implementation of smart destination management systems depends on the ability to foster collaboration among stakeholders, including local communities, tourism organizations, and policymakers. Effective coordination ensures that technological innovation translates into tangible social and environmental benefits. By combining data-driven insights with participatory governance, destinations can achieve a higher degree of adaptability, transparency, and resilience in responding to the challenges of modern tourism.

3.1. Theoretical implications

This conceptualization redefines tourist destination management as a living system instead of a collection of static functions. By integrating AI within systemic governance, STDMS advances theory in three ways:

1. It extends smart tourism frameworks toward real-time, context-adaptive management.
2. It formalizes the feedback and governance structures necessary for ethical AI adoption.
3. It establishes a foundation for evaluating resilience and sustainability outcomes in future empirical studies.

3.2. Practical implications

For practitioners and DMOs, the model serves as a blueprint for system integration:

- Developing interoperable data infrastructures (open standards, APIs).
- Deploying predictive tools for staffing, crowd control, and resource allocation.
- Implementing transparent, participatory decision dashboards.
- Adoption should be incremental and guided by clear governance frameworks.

3.3. Ethical and societal considerations

AI adoption in tourism raises issues of privacy, fairness, and accessibility. The STDMS model embeds ethical safeguards such as consent management, bias audits, and inclusive UX design, to mitigate risks and enhance public trust.

3.4. Limitations and future research

As a conceptual framework, STDMS is theoretical. Empirical validation is needed to test model feasibility, integration costs, and performance under real conditions. Future research should involve prototype implementations in live tourist destinations, mixed-method evaluations (quantitative metrics + stakeholder interviews), comparative analyses across destination types (urban, rural, coastal) etc.

The overall findings confirm that the implementation of smart systems can contribute to the creation of more resilient and sustainable destinations, provided that technological development is aligned with social values and the principles of responsible tourism.

Conclusion

This paper presents a conceptual model of Smart Tourist Destination Management Systems (STDMS) that integrates artificial intelligence, systems thinking, and the principles of responsible innovation as a foundation for sustainable tourism governance. Although the model has not yet been empirically verified, it provides a theoretical and practical platform for future research and implementation. The ultimate goal is the development of tourist destinations that are not only smart but also ethical, inclusive, and resilient.

The paper contributes to the theoretical definition of the relationship between digital transformation and the sustainable development of destinations, emphasizing the importance of ethical, ecological, and managerial principles in the creation of smart tourism systems. The practical contribution lies in the potential application of the STDMS model in the processes of destination planning, management, and evaluation particularly through tools such as predictive analytics, AHP methods, and participatory decision-making. Smart systems for managing sustainable tourist destinations represent a new phase in the evolution of tourism management, one in which technology does not replace humans, but rather empowers them to manage complex systems in ways that preserve nature, identity, and the future of the destination.

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Originality and Copyright in the Era of Artificial Intelligence

Originalnost i autorsko pravo u eri veštačke inteligencije

Svetlana Marković[1], Radovan Vladisavljević[2], Marija Stanković[3]

[1]University Business Academy in Novi Sad, Serbia, office@privrednaakademija.edu.rs
[2]University Business Academy in Novi Sad, Faculty of Economics and Engineering Management in Novi Sad, Serbia radovan.vladisavljevic@fimek.edu.rs
[3]University Business Academy in Novi Sad, Faculty of Law for Commerce and Judiciary in Novi Sad, Serbia, marija.stankovic@pravni-fakultet.info

Abstract: *In an era where technology is developing faster than ever before, artificial intelligence (AI) is not only changing the way we work, communicate, and create, but also challenging the fundamental legal and philosophical postulates that have shaped modern legal systems for centuries. This phenomenon raises one of the most complex and provocative questions in modern law: who is the author of a work that was not created by a human hand, but by a computer? From a legal perspective, copyright serves as an instrument for protecting intellectual property, encouraging innovation and rewarding creators. The aim of this paper is to provide a review through legal analysis and a comparative approach to indicate how the concept of authorship is changing in the age of artificial intelligence.*
Keywords: *Artificial intelligence (AI), copyright, originality.*

Apstrakt: *U eri u kojoj se tehnologija razvija brže nego ikada ranije, veštačka inteligencija (AI) ne samo da menja načine na koje radimo, komuniciramo i stvaramo, već i dovodi u pitanje temeljne pravne i filozofske postulate koji su vekovima oblikovali savremene pravne sisteme. Ova pojava postavlja jedno od najsloženijih i najprovokativnijih pitanja savremenog prava: ko je autor dela koje nije stvoreno ljudskom rukom, već računarom? Sa pravne strane, autorsko pravo služi kao instrument zaštite intelektualne svojine, podstičući inovacije i nagrađujući stvaraoce. Cilj ovog rada jeste da se da osvrt kroz pravnu analizu i komparativni pristup ukaže na koji se način menja koncept autorstva u doba veštačke inteligencije.*
Ključne reči: *Veštačka inteligencija (AI), autorsko pravo, originalnost.*

Introduction

In an era where technology is developing at an unprecedented rate, artificial intelligence (AI) is not only transforming the way we work, communicate, and create, but also challenging fundamental legal and philosophical principles that have shaped modern legal systems for centuries. A significant segment of this development is the emergence of algorithmic creativity – cases in which AI systems, such as machine learning and deep neural networks, independently generate content that has artistic, literary, or commercial value. This phenomenon raises one of the most complex and provocative questions in modern law: Who is the author of a work that was not created by human hands, but by a computer? Traditionally, the author was an individual – a person whose creativity is the result of his imagination, effort, and skill. In accordance with international conventions, the legislation of most countries, and the Law on Copyright and Related Rights of the Republic of Serbia, the author can only be a natural person. However, in recent years, there have been increasing examples of computers, driven by complex algorithms, independently generating images, compositions, texts, and even scientific papers without direct creative intervention from humans. In such cases, it is difficult to determine who should claim the right to authorship and economic gain: should it be the user of the tool, the programmer who created the algorithm, the company that owns the system, or perhaps no one?

From a legal perspective, copyright serves as a tool for protecting intellectual property, encouraging innovation, and rewarding creators. However, AI systems do not possess consciousness, emotions, or the ability to understand social norms, and the question arises as to whether they can even be considered subjects of law. Although some jurisdictions, such as the United States, have clearly taken the position that works created by machines cannot be subject to copyright, other countries leave room for different interpretations and try to find a balance between legal tradition and technological development.

The Law on Copyright and Related Rights of the Republic of Serbia clearly defines the author as a natural person; however, in practice, there are already cases in which artificial intelligence plays a role in creating content that, by all criteria, could be considered a work of authorship. Such a legal gap opens up possibilities for interpretation, but also for legal uncertainty - both for creators and for users, investors and developers.

1. Copyright – definition and basic principles

Copyright is a branch of law that deals with the protection of original intellectual creations, most often in the fields of literature, art, music, science and software. Its essence is to recognise and preserve the rights of authors to their work, thereby encouraging creativity and enabling the creation of cultural and scientific values. In accordance with modern legal standards, copyright encompasses two primary categories of rights: moral rights (the right to recognition of authorship, the right to the integrity of the work, etc.) and economic rights (the right to exploit the work through publication, distribution, public performance, etc.).

In the Republic of Serbia, this area is regulated by the Law on Copyright and Related Rights, which in Article 2 defines a work of authorship as: "An original intellectual creation of the author, expressed in a specific form, regardless of its artistic, scientific or technical value, purpose or form of expression."

An important condition for the legal protection of a work is that it is the result of human creativity, and therefore, created by a natural person.

In addition to domestic legislation, international documents also play an important role, such as:

- Berne Convention for the Protection of Literary and Artistic Works (1886) – which prescribes minimum standards for copyright protection in international frameworks;
- Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) – which further harmonises copyright with international trade;
- European Union Directives – which increasingly seek to encompass issues of digital creativity and AI-generated content.

Copyright, at its core, presupposes the existence of intention, creative contribution, individuality, and conscious choice – qualities that artificial intelligence, in its current form, clearly lacks.

2. Challenges in defining originality in AI works

Understanding originality in the context of copyright is crucial for determining who actually authored a work created using artificial intelligence (AI). Traditional concepts of originality are not readily applicable to works where the creative contribution is primarily made by a machine, which are characterised by:

- Automated production: The AI system uses existing patterns from vast databases to create new content. While the result may appear original, it is actually a combination of learned data.
- Lack of human creative intent: Human creativity involves will, intention, and emotional engagement that AI lacks. The absence of these elements leads to legal ambiguity regarding originality.

- The problem of copying and plagiarism: AI may unintentionally replicate parts of protected works, which raises additional legal dilemmas.

3. Legal standpoints on the originality of AI works

Under current laws in Serbia, the European Union, and the United States, a work is protected that is the result of human creativity and originality. AI, as an entity, does not have legal personality and, therefore, cannot be considered an author. Thus:

- In the United States, the Copyright Office rejects copyright applications for works where there is no evidence of human authorship.
- In the EU, legislation focuses on the author being a natural person.
- Serbia follows a similar approach through its Copyright and Related Rights Law.

4. The role of a human as a co-author

In many cases, AI is used as a tool, and the final result is created in the interaction between a human and a machine. If the human contribution is significant – e.g. in the choice of parameters, additional editing, and creative decisions – it is possible to consider the human as an author or co-author.

Table 1. Human contribution factor and copyright

Human contribution level	Copyright status	Example
High	Human author/co-author	Photograph that uses AI took for editing
Medium	Possible co-authorship	Author that choose AI generic elements and comine them
Low or none	No human authorship	AI generated text without human intervention

Source: Petrović, 2024

5. Legal and ethical dilemmas

Each country approaches copyright regulation in the era of artificial intelligence in its own way, but there are common challenges and directions for development.

Serbia: In Serbia, copyright is regulated by the 2009 Law on Copyright and Related Rights (ZASP), which is in line with international conventions (Berne, TRIPS). The law defines an author as a natural person who created a work. There are currently no specific provisions regulating works created with the help of AI.

- **Problem:** The law does not recognise AI as an author, nor does it clearly define the status of works created with the help of AI.
- **Possible solution:** Amend the law to introduce provisions on co-authorship and tools for creation, including AI.

The European Union (EU) is one of the most active regions in regulating digital rights. Directives and strategies for the digital age attempt to strike a balance between the rights of creators and users.

- **The Copyright Directive in the Digital Single Market (2019)** seeks to strike a balance between copyright and technological innovation.

- **The Green Paper on AI (2020)** and the draft **AI Act address ethics and law**, but have not yet precisely regulated copyright in relation to AI creations.
- **Challenge:** There is no single view on the status of AI among authors.

International legal frameworks: The World Intellectual Property Organisation (WIPO) is the primary international organisation for intellectual property. In relation to AI, the organisation is launching consultations and workshops on the future position of copyright.

- WIPO is launching a discussion on how to regulate rights in works generated by AI.
- It is proposed to create international standards for the recognition and protection of such works.

UNESCO focuses on the ethical and social aspects of AI in culture and the arts:

- Promotes transparency and human control in the use of AI.
- Recommends that countries develop legislation that protects both creators and the public interest.

Legal gaps and challenges:

- **Lack of clarity around authorship:** AI as an entity cannot be a rights holder, and legislation is not harmonised on what is considered sufficient human contribution.
- **Global disagreement:** Different countries have different approaches, making international protection difficult.
- **Rapid technological development:** Law often lags behind technology, so there is a risk of legal conflicts and abuse.

Tabela 2. Examples of regulation in the world

Country	Access to copyright in the AI context	Status	
USA	Human authorship is a requirement for the right, AI is not recognized as an author	Strictly according to the traditional model	
China	Actively developing laws to regulate AI, but authorship is mostly human	Focus on AI control and ethics	
United Kingdom		Explores options for recognizing AI contributions through new legal categories	Adapting to the digital era

Source: Pavlović, 2018

6. A detailed analysis of legal approaches and challenges in the regulation of AI creation

Copyright law is based on the assumption that the author is a human being who possesses creative consciousness and the intention to express his or her personal intellectual contribution. This concept is based on the philosophy that authorship is an expression of human individuality, meaning that without a human author, there is no legal right to a work.

However, in the case of artificial intelligence, this model cannot be directly applied because:

- AI does not have consciousness, intention, or subjective feeling, which are key elements for the traditional recognition of authorship.

- AI generates content based on algorithmic processing of large amounts of data, often using patterns it has "learned" from existing works.
- The absence of a human factor as a driver can lead to a work not meeting the requirements of originality in the legal sense.

These facts raise the question for legislators: Can a work created with the help of AI be protected at all? If so, who is the owner of the rights – the user of the AI, the creator of the algorithm, or maybe no one?

In order to solve the above problems, experts and legislators are considering several legal models:

1. Human authorship model with additional rights - Only a human can be the author, but the law should recognise special categories for works in which AI played a significant role - e.g. the status of co-author or assistant creator.
2. AI as an entity rights model - The proposal that AI systems receive the status of a legal entity with the possibility of owning rights. Requires profound changes in legal theory and practice.
3. Third-party rights model - Copyright belongs to the developers of the AI system or to the persons who control the AI. It provides investment protection, but raises ethical concerns.
4. Public domain model - Works without human contribution are not protected by copyright and remain available to the public. Encourages freedom of access, but may discourage the development of AI technologies.

7. Perspectives and trends in legal development

In light of the above challenges, it is possible to identify several trends that will shape the future of legal regulation in the field of copyright and AI:

- The development of hybrid legal solutions that combine the traditional model of human authorship with new legal categories for AI-works.
- Increasing international cooperation and harmonization of laws, as globalization and digitalization require common standards.
- Introducing mandatory labeling of AI-works for the sake of transparency and protection of end users.
- Considering new forms of intellectual property rights, such as “digital rights” or rights to algorithmic code.

Table 3. Timeline of the development of AI and copyright regulation

Year	Event / Initiative	Description
2009	Copyright Law in Serbia	Human authorship defined, no specificity for AI
2019	EU Directive on copyright in the digital market	Focus on digital rights and justice, but without AI specificity
2020	EU Green Paper on AI	The first official document to discuss the ethics and legal challenges of AI
2021	WIPO consultation on AI and intellectual property	Initiating international discussions on the legal status of AI-parts
2023	The ruling in the case of Thaler vs. U.S. Copyright Office	Confirmed that AI is not an author under current law
2024+	New laws and regulations planned	Working on flexible legal frameworks for AI in different jurisdictions

Source: https://www.wipo.int/about-ip/en/artificial_intelligence/

Conclusion

In the light of global digitalisation, the creative industry is becoming increasingly reliant on automated processes, where algorithms not only assist but also actively participate in the creation of content. This leads to a redefinition of the concept of authorship, as well as the need for normative adaptation of existing legal frameworks. The role of law is no longer limited to protecting copyrighted works, but also to monitoring the dynamic relationship between humans and machines in the creative process. All this requires an interdisciplinary approach, which encompasses law, ethics, philosophy, technology, and economics, in order to find a sustainable solution that will not hinder innovation while preserving the core values of creativity.

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Knowledge as a Driver in Modern Business Conditions in the Age of Artificial Intelligence

Znanje kao pokretač u uslovima savremenog poslovanja u doba veštačke inteligencije

Miloš Grahovac[1], Jovana Ljubisavljević[2], Suzana Doljanica[3]

[1]*Public Prosecutor`s Office for War Crimes, Belgrade, Serbia, m.grahovac@hotmail.com*
[2]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, jovana.ljubisavljevic@mef.edu.rs*
[3]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, suzana.doljanivca@mef.edu.rs*

Abstract: *The importance of knowledge, learning and intellectual capital - how to become a learning organization. As artificial intelligence becomes more pervasive, the value of intellectual capital facilitates the establishment of a connection between the value of intangible resources that are obtained through experience and learning, the application of modern technologies in the function of creating a certain benefit - profit for the organization. The aim of this paper is to contribute to the understanding of the need for improving organizational performance, which is achieved by understanding, predicting and directing the behavior of people in organizations, which is the subject of applied scientific disciplines in modern business.*
Keywords: *Knowledge, intellectual capital, artificial intelligence.*

Apstrakt: *Značaj znanja, učenja i intelektualnog kapitala – kako postati organizacija koja uči. Sve većim prodorom veštačke inteligencije vrednost intelektualnog kapital olakšava uspostavljanje veze između vrednosti nematerijalnih resursa do kojih se dolazi iskustvom i učenjem, primenom savremenih tehnologija u funkciji stvaranja određene koristi - dobiti za organizaciju. Cilj ovog rada je da pruži doprinos u sagledavanju potrebe za unapređenjem organizacionih performansi koje se postignu sa razumevanjem, predikcijom i usmeravanjem ponašanja ljudi u organizacijama, čime se bavi primenjene naučne discipline u savremenom poslovanju.*
Ključne reči: *Znanje, intelektualni kapital, veštačka inteligencija.*

Introduction

Knowledge can be defined in various ways, but the simplest is to see that it has a higher degree of complexity and significance than data and information. Namely, knowledge represents information that is complex, relevant, and placed in a meaningful context, and which can produce a specific action or lead to a significant decision.

To understand the process of knowledge management, it is essential to distinguish between explicit and tacit knowledge, which is the first determinant of one way to categorise knowledge. Explicit knowledge represents a rational part of knowledge that can be expressed and explained in words and numbers.

Tacit knowledge, unlike explicit knowledge, is personal and subjective, making it difficult to formalise and communicate to others, yet it is deeply rooted in the activities and commitments of individuals to a specific context.

One of the key tasks is to ensure that knowledge plays a decisive role in achieving the set business goals in insurance companies, which strive to transform, in various ways, the wealth of data and information at their disposal into practical knowledge. This knowledge should be organised and accessible, whether

there is a need for it at a particular moment or not. In any case, this knowledge is part of the intangible assets of the organisation, which, among other things, can include various data, trade secrets, software codes, brands, know-how, confidential information, patents, licenses and the like that make up intellectual capital.

One of the key problems is that organisations often lack awareness of knowledge as their most valuable resource. In addition, the value created by intangible assets often cannot be directly seen in financial statements, but understanding it is important for the process of value creation within the organisation.

The very concept of intellectual capital facilitates the establishment of a connection between these valuable intangible resources that are acquired through experience and learning, and the creation of certain benefits (gains) for the organisation.

1. Intellectual capital management

Intellectual capital management, encompassing all knowledge within an organisation that provides it with a competitive advantage in the market, is closely related to knowledge management processes within the organisation. Therefore, the successful implementation and application of knowledge management ensures the identification and growth of intellectual capital (Krstić, 2008).

Intellectual capital management includes:

- identifying key sources of intellectual capital that influence the strategic performance of the organisation;
- understanding the flows of value creation in the organisation, which lead to increased satisfaction of users of services and products, employees and other stakeholders;
- establishing indicators and measuring performance in order to determine whether the organisation is successful in achieving its goals;
- nurturing existing intellectual capital through the knowledge management process;
- internal and external reporting on the achieved business improvements that have been achieved through intellectual capital management.

The ability of an organisation to achieve specific performances depends on both the knowledge of individuals and organisational knowledge. An organisation should be viewed in a dynamic relationship with its environment, which is changeable and requires efficient information processing, a combination of information and knowledge, with the ultimate goal of becoming a learning organisation. Knowledge has become a key resource, serving as the primary means of development and competitiveness in the market, thereby affirming the importance and necessity of continuous professional learning as the only path to prosperity and competitiveness in the market. One of the key parameters of a successful organisation is the application of modern solutions, a high level of organisation and employee satisfaction.

The study of organisational behaviour enables individuals to acquire the competencies necessary for success as workers, team leaders, or managers, depending on their role within the organisation. It provides the opportunity to understand human nature and, therefore, predict employee behaviour in certain situations, while also offering insight into how the organisational environment affects employee behaviour (Savić, 2006).

In an organisation in which employees constantly expand their own capacities to create knowledge and achieve desired effects and results as a driver towards solving all problems and tasks facing the organisation.

A learning organisation, one that can attract and retain the most talented individuals, motivating them to create and exchange knowledge in order to acquire and maintain professional skills.

In order to systematise the characteristics of a learning organisation, where knowledge is essential for maintaining competitive advantage and survival in the market, the following characteristics can be distinguished:

- Adaptability to a dynamic environment;
- A sense of belonging and personal and collective responsibility;
- Acceptance of the inevitability of change and meeting it;
- Self-criticism and acceptance of individual and collective mistakes and successes;
- Cultivation of interpersonal relationships, dialogue and mutual respect and trust;
- Ability to confront and find adequate solutions in solving problems;
- The importance of individual and collective learning;
- Regular and proper assessment of self-learning abilities as key personal skills.

The most significant responsibility lies with managers, who are responsible for creating learning opportunities throughout the organisation. It is not enough to recognise the value of accumulated knowledge; it must also be managed (Šušnjar, 2006).

Knowledge management involves establishing a learning culture, where employees systematically acquire knowledge and share it with others to achieve better work performance and results.

2. Knowledge management in modern organisations

Knowledge management is a practice-based field focused on the business problems of a particular organisation, regardless of its industry or activity.

The complexity of knowledge management stems from the need to implement various management activities and the application of multiple scientific disciplines that contribute to the development of knowledge management, including psychology, pedagogy, andragogy, sociology, and others.

It has been determined that most activities to introduce knowledge management are guided by one of the following three goals:

- to make knowledge visible and understand its role in the organisation,
- to develop a culture that encourages the dissemination of knowledge in the organisation, and
- to build an appropriate infrastructure that supports knowledge.

One of the key processes in knowledge management is the process of storing knowledge, or the formation of organisational memory, during which knowledge is formally stored using various conceptual models, in the physical memory of the system, and informally retained in the form of values, rules and beliefs associated with organisational culture and structure.

Organisational memory represents repositories of knowledge and skills that store perceptions and experiences over an extended period, allowing them to be retrieved at any time. In this way, knowledge

becomes accessible to other employees in the organisation without requiring interaction with the person who initially possesses that knowledge.

3. Knowledge management in the age of artificial intelligence

Artificial Intelligence (AI) is rapidly changing business models and the labour market, creating a need for new professions that did not exist just ten years ago. As companies around the world increasingly integrate AI into their processes, completely new professions are emerging that combine technological, analytical, and creative knowledge (Strategy, 2019).

Additionally, technological advances have enabled the use of a wide range of tools that leverage various information and communication technologies, facilitating the successful incorporation of knowledge management into their processes.

For example, artificial intelligence will automate document review, contract analysis, and legal research, radically changing the legal industry. Legal platforms powered by artificial intelligence will be able to analyse vast amounts of legal data, identify patterns, and provide insights to lawyers, who will make faster, more informed decisions. These platforms will increase efficiency, reduce costs, and make legal services more accessible to small businesses and individuals.

Entrepreneurs can develop AI-powered legal tools to support contracts, automate legal research, and even predict case outcomes. Law firms can utilise these platforms to manage cases, streamline administrative tasks, and reduce their workload.

Artificial intelligence (AI) is utilised in business to automate routine tasks, analyse data, make predictions, and personalise services. This helps optimise business processes, reduce costs, and improve efficiency, as well as create new products and services, such as chatbots, voice assistants, and cybersecurity systems. The cost of implementing AI can vary depending on the task and scope, but it is possible to start small.

Examples of AI in business

- Automation and optimisation:
    - Automation of routine and labour-intensive tasks.
    - Optimisation of equipment operation using digital twins.
    - Predictive maintenance of equipment in production.
- Analytics and forecasting:
    - Analysis of big data for more accurate decision-making.
    - Advanced analytics for error-free decisions in any industry.
    - Forecasting demand and customer behaviour.
- Customer service and marketing:
    - Creation of chatbots and voice assistants to process customer inquiries.
    - Personalisation of offers and recommendations for customers.
    - Automation of marketing campaigns.
- Other areas:
    - Computer vision systems for product quality control.
    - Cybersecurity and information protection tools.

- Automated trading in financial markets.

How to get started with AI:

- Start small: You do not have to implement complex systems right away. You can start by testing specific hypotheses and using off-the-shelf tools to solve minor problems.
- Define your goal: Understand the specific problem you want to solve with AI. This will help you choose the right tools and avoid unnecessary costs.
- Use off-the-shelf solutions: There are many platforms and tools to help you get started, such as analytics platforms with natural language search or content creation services.

4. Problems we may encounter

However, despite the great importance of information and communication technologies, as well as the application of artificial intelligence, we encounter challenges in knowledge management that are mainly non-technical in nature, and among them, the following circumstances stand out that can act as a disincentive to knowledge management: 23

- Organisational culture does not encourage knowledge exchange.
- Inadequate understanding of knowledge management and the benefits it brings to the organisation;
- Employees do not have time for knowledge management.
- Inability to measure financial benefits from knowledge management.

In the context of intellectual capital, knowledge management can also be defined as a set of processes and practices that organisations apply to increase their value, thereby improving the effectiveness of generating and applying intellectual capital (Milićević, 2004).

Conclusion

Organisations that invest in knowledge management gain a competitive advantage in the market, either to enhance their own efficiency or effectiveness temporarily or to reduce the competitive edge of other organisations.

Artificial intelligence brings profound transformations to the labour market, changing the way different create a need for new skills and professions. A learning organisation will have one of its key tasks to prepare for the jobs of the future, which the application of AI technologies, automation, and data analytics will shape. Meanwhile, the human factor will remain crucial in areas that require creativity, critical thinking, and ethical decision-making.

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How Artificial Intelligence is Changing Education and its Impact on the Economic Sector

Kako veštačka inteligencija menja obrazovanje i njen uticaj na ekonomski sektor

Svetlana Marković[1], Pavle Brzaković[2], Dragan Doljanica[3]

[1]*University Business Academy in Novi Sad, Serbia, office@privrednaakademija.edu.rs*
[2]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia, pavle.brzakovic@mef.edu.rs*
[3]*University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Serbia,, dragan.doljanica@mef.edu .rs*

Abstract:*This paper provides an overview of how artificial intelligence is changing education and how this is reflected in the economic sector and the development of a society. A new wave of discussion about the role of this technology is increasingly being launched in society. Artificial intelligence (AI) technologies are becoming more and more integrated into the field of education. They have the potential to transform traditional teaching methods and approaches. The possibilities of AI improve educational processes and force us to reconsider our approaches to learning. At the same time, a number of questions arise about the negative impact of AI on education. Society is already looking for answers to these questions.*
Keywords: *Artificial intelligence, education, economic sector.*

Apstrakt: *U ovom radu dat je osvrt kako veštačka inteligencija menja obrazovanje i kako se to reflektuje na ekonomski sektor i razvoj jednog društva. U društvu se sve više pokrenuće nov talas diskusije o ulozi ove tehnologije. Tehnologije veštačke inteligencije (VI) sve više prodiru u obrazovanje. One imaju potencijal da transformišu tradicionalne metode i pristupe nastave. Mogućnosti VI poboljšavaju obrazovne procese i teraju nas da preispitamo pristupe učenju. Istovremeno, pojavljuje se niz pitanja o negativnom uticaju VI na obrazovanje. Društvo već traži odgovore na ova pitanja.*
Ključne reči: *Veštačka inteligencija, obrazovanje, ekonomski sektor.*

Introduction

Artificial intelligence (AI) technologies are increasingly penetrating education every year. They have the potential to transform traditional teaching methods and approaches. AI capabilities enhance educational processes and compel us to reassess our approaches to learning. At the same time, several questions arise regarding the potential negative impact of AI on education. Society is already looking for answers to these questions.

The development of generative AI and the widespread adoption of large-scale language models such as ChatGPT have triggered a new wave of discussion about the role of this technology. Education is a complex and multi-layered process that, in addition to teaching, involves a significant amount of administrative work, including preparing reports, programs, schedules, and attendance records. In traditional education, teachers are expected to spend most of their time interacting with students/pupils.

Intelligent systems make the work of both educational institution administrators and teachers easier. In addition to simplifying routine and bureaucratic tasks, AI-based tools analyse large amounts of data on student performance, attendance, and behaviour. When properly implemented, this helps teachers make more accurate decisions about how to organise the educational process.

Artificial intelligence has been playing a significant role in our lives for many years, often without us even realising it. Tools such as intelligent assistants, recommendations on various platforms, and personalised ads use AI to improve the user experience. However, these and many other digital services that use AI have mostly flown under our "radar" because we often did not pay attention to how they work in the background. It was only with the emergence of advanced language models of generative AI, such as ChatGPT, and direct interaction with these tools that we began to realise the power and potential of AI-based technologies.

The development of new AI language models in the past few years has been astonishingly fast. The aforementioned ChatGPT, developed by OpenAI, reached a million users in the first five days after its launch in November 2022 (for comparison, it took Facebook 10 months to reach its first million users, TikTok 9, and Instagram 2 and a half months).

Such rapid development and the increasing number of users of artificial intelligence indicate that AI is increasingly influencing various aspects of life and becoming an indispensable part of modern society.

1. What is artificial intelligence?

Artificial intelligence (AI) is software that enables computers and machines to perform tasks that typically require human intelligence, such as learning, decision-making, problem-solving, interpreting information, and creating new content. It is utilised in various fields, including finance, healthcare, transportation, and education. AI software enables machines to learn from data, interpret information, and take action based on it. Typical tasks include data analysis (e.g., in market research), disease diagnosis, autonomous vehicle operation, and personalised learning plans. AI has been in development for decades, and today it has become one of the major technological revolutions.

Using data, specific AI systems can be "trained" to make predictions, make recommendations, or make decisions, sometimes without any human intervention (European Commission, 2022).

The rapid development of artificial intelligence requires legal and strategic regulation of this issue. The Republic of Serbia has adopted a Strategy for the Development of Artificial Intelligence in Serbia for the period 2025–2030. To emphasise the importance of the reliable and responsible application of AI technologies in accordance with the highest ethical and security standards, the Ethical Guidelines for the Development, Application, and Use of Reliable and Responsible Artificial Intelligence have also been adopted.

2. Artificial intelligence in education

The application and integration of artificial intelligence in education, unlike its application and impact on economic sectors and various aspects of our lives, have their own specifics. The primary goal of implementing artificial intelligence technology in educational processes is not economic profit, but improving the quality of learning, which is difficult to measure objectively.

Artificial intelligence has great potential for the education industry. First of all, it automates routine tasks that consume a significant amount of time for teachers. Artificial intelligence can become a valuable tool for students and schoolchildren to enhance their learning. Today, a market for applications and tools based on artificial intelligence is emerging, highlighting several key trends.

Technology has penetrated education at different rates and has not yet fundamentally changed it. The "teacher-student" model has existed since ancient times, when the first schools were established. It remained unchanged even after the appearance of computers in educational institutions in the 1960s and 1970s. In the 21st century, the integration of technology into the educational process has become more active, primarily due to the widespread use of communication and the Internet (Figure 1).



Figure 1. AI market growth projections

The global AI market is expected to grow from $621 billion in 2024 to $2.7 trillion in 2032. (The global AI market refers to all companies, products, and services that use or develop AI worldwide, as well as the money that flows through them.)
*Data taken from Exploding Topics - https://explodingtopics.com/blog/ai-market-size-stats.

The alignment of the development of education and upbringing in the Republic of Serbia with the development of artificial intelligence, which is reflected in the implementation of:

1) The Strategy for the Development of Education and Upbringing in the Republic of Serbia until 2030 ("Official Gazette of the Republic of Serbia", No. 63/2021) recognises as one of the indicators the increase in the percentage of students attending study programs in newly identified priority areas on the labour market, which is in correlation with the measures and objectives of this strategy in the context of creating a lifelong learning system in the field of artificial intelligence and introducing content on artificial intelligence into study programs (Strategy, 2025).
2) The Law on Higher Education ("Official Gazette of the Republic of Serbia", No. 88/2017, 73/2018, 27/2018 -other law, 67/2019, 67/2019, 6/2020- other laws, 11/2021 - authentic interpretation, 67/2021,67/2021- other laws and 76/2023), sets as one of its goals the provision of scientific and professional youth as well as the education of a creative population that continuously adopts and creates new knowledge, thus opening up the possibility for the training and advancement of personnel in the field of artificial intelligence (Law).
3) The Strategy for Scientific and Technological Development of the Republic of Serbia for the period from 2021 to 2025 "The Power of Knowledge" ("Official Gazette of the Republic of Serbia", No. 125/2021) identifies steps. It adopts measures that aim to strengthen the scientific research and innovation system of the Republic of Serbia, thereby enabling the development of

artificial intelligence by applying new knowledge in the education, business, and media sectors. While the Strategy "The Power of Knowledge" recognises the importance and sets the foundation for the further development of science and technology, the Strategy of Artificial Intelligence recognises and directs the development of ecosystems through the prism of artificial intelligence as one of the ways to improve economic development and competitiveness (Strategy).

The Institute for the Advancement of Education is publishing a series of texts related to the practical application of artificial intelligence in education. The aim is to familiarise teachers, educators, professional associates, and directors of educational institutions with this topic and offer clear guidelines and instructions on how artificial intelligence can be used practically, ethically, and safely in the teaching process, extracurricular activities, and educational work (ZUOV).

3. Negative impacts of artificial intelligence on education

The introduction of artificial intelligence into education is not without risks.

In addition to the opportunities that artificial intelligence brings, there are concerns about its potential uses. There is concern that the growing influence of artificial intelligence in education could lead to several serious problems due to the reduced human role and increased dependence on technology that result from the excessive use of artificial intelligence in education.

Some of the most significant risks that are considered and believed to be associated with artificial intelligence are:

Reduced socialisation, reduced interactions between students and teachers, i.e. lack of "live" communication, which will negatively affect the acquisition of social skills, impact on emotional intelligence, reduced mental load, degradation and problems with the development of critical thinking, risk of plagiarism and cheating, reduced motivation to learn and laziness.

4. Security, privacy and bias

The use of artificial intelligence in education poses a risk to the privacy of students/pupils and teachers. Training algorithms require vast amounts of data; systems process names, addresses, grades, biometric data, and even behavioural characteristics. Educational solutions based on artificial intelligence must be very secure from hacking. Moreover, the risk of revealing sensitive data through patterns and anomalies that artificial intelligence detects must be eliminated.

A special problem arises not only with information about students/pupils and teachers, but also with the data used to train artificial intelligence. There is considerable discussion today about training generative models using open data. We have a case of several Western media companies filing lawsuits against Microsoft and OpenAI, accusing the companies of using their media content without consent. Artificial intelligence models are trained on openly available Internet data. The Wall Street Journal reported that AI developers will face a shortage of training data within a few years.

UNESCO notes that ChatGPT models are trained on data that primarily reflects values and social norms.

Therefore, the use of artificial intelligence in education, especially generative artificial intelligence, is fraught with risks. Not to mention that models like ChatGPT can invent facts and present non-existent things as real.

5. Perspectives of artificial intelligence in education

The integration of artificial intelligence into education necessitates striking a balance between potential benefits and risks. The World Economic Forum (WEF) report, "Shaping the Future of Learning: The Role

of Artificial Intelligence in Education 4.0," emphasises the preservation of the central role of teachers in the education system. It is necessary to develop literacy in the field of artificial intelligence and critical thinking skills. The forum provided five conditions for balancing benefits and risks:

1) It is necessary to involve educators and industry leaders who should be involved in the development of educational artificial intelligence.
2) Funding an innovative model that will ensure continuous improvement and evaluation of artificial intelligence solutions;
3) Protecting information while implementing robust privacy and security protocols;
4) All users of the education system should be trained in artificial intelligence for efficiency and safety;
5) Apply the principles of equity, which must be key to the development of programs that ensure literacy in the field of artificial intelligence.

UNESCO believes that the education sector is not sufficiently prepared for the effective integration of artificial intelligence. According to a survey conducted by the organisation among schools and universities, only approximately 10% of them have a strategy or formal policy for the use of generative artificial intelligence (UNESCO, 2024).

It is necessary to provide a critical review of the impact of artificial intelligence on the quality of knowledge.

Higher education is facing numerous challenges, and development and changes are inevitable. Considering the complexity of the higher education process itself, it is necessary to ensure that education adapts to these developments (Brejc). Dealing with these changes and the quality of development directly depends on the competencies of the individuals responsible for these activities. Higher education does not focus solely on the transfer of knowledge, but primarily on the development of competencies needed in a modern society that requires training in critical thinking, problem-solving, high-quality digital literacy, and other essential skills. In addition, it is necessary to ensure the ability to deal with uncertainty and develop a sense of responsibility and ethical competence. This requires lifelong learning, continuous and with clear goals related to quality.

Conclusion

Potential and Threats of Artificial Intelligence in Education. Society faces the challenge of finding a balance between restrictive measures and the uncontrolled use of technology. Resolving this issue requires continuous expert discussions, in-depth research, and the development of strategies that minimise risks while preserving the benefits of artificial intelligence.

Additional research is needed on the impact of technology on our cognitive and communicative abilities. The uncontrolled and unjustified use of technology can negatively impact human development.

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