Edited by
Vladan Pantović
Dušan Starčević

INFOTECH

Powered by ASIT

XL International Conference

Infotech 2025 Proceedings

Aranđelovac, June 4-5, 2025

XL International Conference

INFOTECH 2025

PROCEEDINGS

Edited by

Vladan Pantović

Dušan Starčević

Aranđelovac, 4 – 5, June, 2025

XL International Conference

INFOTECH 2025

Aranđelovac, 4 – 5, June, 2025

Organizer

ASIT - *Association for Computing, Informatics, Telecommunications and New Media of Serbia*

Co-organizers of the scientific part of the conference:

- Faculty of Project and Innovation Management prof. dr Petar Jovanović, Belgrade
- Faculty of Information Technology and Engineering, Belgrade
- Faculty of Business Economy and Entrepreneurship, Belgrade
- Laboratory for multimedia communication, FON, Belgrade
- University "Bijeljina", Bijeljina, Bosnia and Herzegovina
- "Dositej" Faculty of Economics and Informatics, Belgrade

INFOTECH 2025 Proceedings

Edited by Vladan Pantović & Dušan Starčević

Publisher: ASIT, Belgrade, Nikola Mirković, President

Co-Publisher: Faculty of Project and Innovation Management prof. dr Petar Jovanović, Belgrade

Cover Design**:** Vladimir Jablanov / Digital printing: GRAFOPAN doo / Circulation: 200

ISBN-978-86-900491-3-4

CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

004(082)
007:004(075.8)(082)

INTERNATIONAL Conference INFOTECH (40 ; 2025 ; Aranđelovac)
Proceedings / XL International Conference INFOTECH 2025, Aranđelovac, 4 – 5, June, 2025 ; edited by Vladan Pantović, Dušan Starčević ; [organizer] ASIT [i. e.] Association for Computing, Informatics, Telecommunications and New Media of Serbia ; [co-organizers Faculty of Project and Innovation Management ... [et al.]]. - Belgrade : ASIT : Faculty of Project and Innovation Management, 2025 (Beograd : Grafopan). - 138 str. : ilustr. ; 30 cm

Tiraž 200. - Str. 5: Preface / Nikola Mirković, Vladan Pantović. - Bibliografija uz svaki rad.

ISBN 978-86-900491-3-4 (ASIT)

1. Pantović, Vladan, 1961- [urednik] [autor dodatnog teksta] 2. Starčević, Dušan, 1949- [urednik]
a) Информациона технологија -- Зборници b) Информациони системи -- Зборници

COBISS.SR-ID 169843977

Table of Contents

P R E F A C E

This year marks the 40th edition of INFOTECH, a regular annual international scientific and professional conference in the field of the development and application of information technologies.

INFOTECH has always followed trends in the development of information and communication technologies, and this year is no different; the obvious dominant theme, addressed in more than half of the papers, is the application of artificial intelligence (AI). Due to the importance of this current topic, a special AI Panel, AI Workshop and AI Keynote were organized.

A total of 23 accepted papers by 58 authors are published in the Proceedings. They are classified according to their subject matter into four sections: Artificial Intelligence, Information Security, Information Technology and Applications, and Management and Information Systems. The tradition continues, and this year INFOTECH also featured authors from abroad (Italy, Canada, United Kingdom, Germany and Bosnia and Herzegovina).

ASIT - the Association for Computing, Informatics, Telecommunications and New Media of Serbia, the organizer of the conference, on the occasion of the important jubilee, published, in cooperation with the Co-Publisher the “Faculty of Project and Innovation Management prof. dr Petar Jovanović“, two additional special editions edited by prof. dr Vladan Pantović and prof. emeritus dr Dušan Starčević:

- INFOTECH 2020 – 2024 Selected Papers
- INFOTECH 1995 – 2000 Proceedings: Digital version the classic printed proceedings

We would like to thank everyone who actively participated in the preparation of the INFOTECH 2025 conference, and we expect good cooperation in the coming years as well.

Chairman of the Organizing Board

Nikola Mirković

Chairman of the Scientific Program Board

Prof. dr Vladan Pantović

PROGRAM COMMITTEE

- Dr Vladan Pantović, Faculty of Project and Innovation Management, Belgrade

PROGRAM COMMITTEE MEMBERS

- Dr Dušan Starčević, Faculty of Organizational Sciences, Belgrade
- Dr Aca Aleksić, "Dositej" Faculty of Economics and Informatics, Belgrade
- Dr Maja Anđelković, Faculty of Information Technology and Engineering, Belgrade
- Dr Zoran Avramović, University of Belgrade, Belgrade
- Dr Olja Arsenijević, Institut for serbian culture, Priština – Leposavić
- Dr Robin Singh Bhadoria, *Hindustan College of Science and Technology, Mathura, India*
- Dr Zoran Bojković, Faculty of Transport and Traffic Engineering, Belgrade
- Dr Milan Brković, Association of Serbian Banks, Belgrade
- Dr Vladimir Brusić, *University of Doha for Science and Technology, Qatar*
- Dr Miodrag Brzaković, Faculty of Applied Management, Economics and Finance, Belgrade
- Dr Maja Cogoljević, Faculty of Business Economy and Entrepreneurship, Belgrade
- Dr Danijela Ćirić-Lalić, Faculty of Technical Sciences, Novi Sad
- Dr Anastasios Dagiuklas, *London South Bank University, London, United Kingdom*
- Dr Velimir Dedić, Faculty of Information Technology and Engineering, Belgrade
- Dr Vlado Delić, Faculty of Technical Sciences, Novi Sad
- Dr Gordana Djordjević, Faculty of Business Economy and Entrepreneurship, Belgrade
- Dr Viviana Fernández Marcial, *Universidade da Coruña, España*
- Dr Jovan Filipović, Faculty of Organizational Sciences, Belgrade
- Dr Pawan Fowdur, University of Mauritius, Republic of Mauritius
- Dr Borko Furht, *Florida Atlantic University, Boca Raton, USA*
- Dr Gordana Gardašević, Faculty of Electrical Engineering, Banja Luka
- Dr Milan Gligorijević, Alfa BK University, Belgrade
- Dr Zagorka Gospavić, Faculty of Civil Engineering, Belgrade
- Dr Zvezdan Horvat, *Adizes Institute Worldwide, Santa Barbara, USA*
- Dr Miloš Jelić, Foundation for Quality Culture and Excellenc, Belgrade
- Dr Emil Jovanov, *University of Alabama, Huntsville, USA*
- Dr Filip Jovanović, Faculty of Project and Innovation Management, Belgrade
- Dr Siniša Jovanović, Imtel Komunikacije, Belgrade
- Dr Marina Jovanović-Milenković, Faculty of Project and Innovation Management, Belgrade
- Dr Asutosh Kar, *Indian Institute of Information Technology, Kancheepuram, Chennai, India*
- Dr Tihomir Katulić, University of Zagreb, Croatia
- Dr Jelena Kočović, Faculty of Economics, Belgrade
- Dr Petar Kočović, Faculty of Information Technology and Engineering, Belgrade
- Dr Bojan Kostandinović, Mokra Gora School of Management, Belgrade
- Dr Boro Krstić, University "Bijeljina", Bijeljina, Bosnia and Herzegovina
- Dr Dejan Kršljanin, Center for Applied Mathematics and Electronics, Belgrade
- Dr Goran Lazarov, Higher Colleges of Technology, Dubai, United Arab Emirates
- Dr Dragan Lončar, Faculty of Economics, Belgrade

- Dr Zoran Marjanović, Faculty of Organizational Sciences, Belgrade
- Dr Vera Marković, Faculty of Electronic Engineering, Nis
- Dr Miodrag Mesarović, Energoprojekt Entel, Belgrade
- Dr Danijela Milošević, Faculty of Technical Sciences Čačak
- Dr Mladen Milošević, Faculty of Security Studies, Belgrade
- Dr Miloš Milovanović, Faculty of Organizational Sciences, Belgrade
- Dr Miroslav Minović, Faculty of Organizational Sciences, Belgrade
- Dr Cvetko Mitrovski, Faculty of Technical Sciences, St. Kliment Ohridski University – Bitola, North Macedonia
- Dr Vojislav Mišić, *Ryerson University, Toronto, Canada*
- Dr Vladimir Mladenović, Faculty of Technical Sciences Čačak
- Dr Boško Nikolić, Faculty of Electrical Engineering, Belgrade
- Dr Srđan Nogo, University of East Sarajevo, Bosnia and Herzegovina
- Dr Deasún Ó Conchúir, *Scatterwork GmbH, Switzerland*
- Dr Mladen Opačić, Metropolitan University, Belgrade
- Dr Miroslav Perić, Singidunum University, Belgrade
- Dr Vladimir Petrović, *Robert Bosch GmbH, Germany*
- Dr Milan Prokin, Faculty of Electrical Engineering, Belgrade
- Dr Jelica Protić, Faculty of Electrical Engineering, Belgrade
- Dr Zoran Radojičić, Faculty of Organizational Sciences, Belgrade
- Dr Milan Radosavljević, Faculty of Business Studies and Law, Belgrade
- Dr Radoslav Raković, Engineering Academy of Serbia (EAS), Belgrade
- Dr Muthu Ramachandran, *Leeds Becket University, United Kingdom*
- Dr Marko Savković, Studiopro, Belgrade
- Dr Dejan Simić, Faculty of Organizational Sciences, Belgrade
- Dr Svetozar Sofijanić, Technical Academy for Applied Studies, Belgrade
- Dr Svetlana Stevović, Faculty of Mechanical Engineering, Belgrade
- Dr Velimir Štavljanin, Faculty of Organizational Sciences, Belgrade
- Dr Vladimir Terzija, *University of Manchester, United Kingdom*
- Dr Ana Trbović, FEFA, Belgrade, Grid Singularity, Berlin, Germany
- Dr Mladen Veinović, Singidunum University, Belgrade
- Dr Dejan Vidojević, Academy of Professional Studies Sumadija, Kragujevac
- Dr Nikola Vojtek, Daon, Belgrade
- Dr Slađana Vujičić, Faculty of Business Economy and Entrepreneurship, Belgrade
- Dr Dušan Vujošević, School of Computing, Belgrade
- Dr Ivan Vulić, Faculty of Project and Innovation Management, Belgrade
- Mr Dragorad Milovanović, School of Computing, Belgrade, Program Committee Secretary

INFOTECH 2025 INVITED KEYNOTE LECTURE

Trust in the Age of AI: Decoding the Future of Data-Driven Insights

Nikola Vojtek, Smart Consulting Agency | Daon, nikola@smartconsulting-agency.com
Vladan Pantović, Faculty of Project and Innovation Management, vladan@pantovic.rs

Abstract:

In today's fast-paced world, where data-driven decisions are integral to success, organizations face an increasing need to process vast amounts of information in real time. From early human survival strategies to modern corporate environments, the necessity of making informed decisions has evolved, and now, more than ever, it relies on the power of artificial intelligence (AI) and data analytics. As businesses race to stay ahead in a competitive landscape, the real challenge lies in establishing trust in both the decision-making process and the data itself.

This keynote explores how AI, particularly synthetic data generation, plays a pivotal role in overcoming data scarcity and optimizing decision-making. While synthetic data offers a faster and more reliable alternative to traditional data augmentation, it also raises questions of data authenticity, integrity, and reliability. Comparison between synthetic data generation and data augmentation is available in a separate paper: "*Tackling Data Scarcity in AI: Synthetic Data Generation in Project Management*".

We also highlight the importance of ISO/IEC 42001 in managing AI data processes and ensuring the ethical use of AI in decision-making. By adhering to these standards, organizations can safeguard the trustworthiness of their data and AI systems, ensuring that their decision-making is both efficient and accountable. The insights and methodologies discussed in this keynote, including those from our paper *"Protecting Organizations with ISO/IEC 42001: A Framework for AI Data Supervision,"* provide a comprehensive strategy for navigating the complexities of AI data management in the modern era.

Introduction:

From the beginning, humans have gathered data to make decisions. Whether for hunting, farming, or navigating the complexities of society, data has always been a cornerstone of our decision-making processes. Even though centuries have passed, one thing remains constant: the need to make informed decisions. However, over time, the ways we approach decision-making have drastically evolved. When we say "better," we mean faster, more accurate, automated processes that rely on a broader range of data. With advancements in technology, we've moved from simple observations to processing large datasets, using predictive models and probabilities to forecast outcomes.

The Evolution of Decision-Making:

In the early days, our decisions were driven by the most basic of needs—survival. We needed to make quick, life-or-death decisions—whether to seek shelter from an incoming storm, gather food before the season changed, or protect our families from predators. In those days, it was a matter of survival. Today, while the stakes may have shifted, the essence remains the same: the need to make timely and well-informed decisions is just as important. Only now, the scale has changed. We face an increasingly complex world where markets are evolving rapidly, and timely decisions are paramount to success.

The Corporate Landscape Today:

This brings us to the modern corporate world. Today, companies, no matter their size, are not competing in a marathon—they are competing in a sprint. The pace of business has accelerated to a level that we could scarcely imagine just a few decades ago. The distinctions between small, medium, and large enterprises are beginning to blur. In fact, even traditionally larger organizations are strategically targeting niche markets to increase profitability. The boundaries between industries are becoming less defined. We are no longer limited by the size of our company or the industry we operate in. Instead, the need to be agile, adaptable, and quick to respond to market changes has become critical.

The Role of Technology in Modern Decision-Making:

In this sprint-like environment, technology plays a crucial role. With the emergence of artificial intelligence, machine learning, and advanced analytics, companies can process vast amounts of data, enabling faster decision-making and more accurate forecasts. AI-driven decision-making tools provide companies with the power to automate complex processes, predict future trends, and continuously optimize operations. This ability to act quickly and intelligently is not just a competitive advantage—it has become a necessity.

Quality of data:

The real challenge—both historically and now to an even greater extent—lies in establishing trust in the decision-making process and, more importantly, in the data itself. From a data perspective, how can we be confident that the data we're using in our decision-making models accurately reflects the real world? Is the data authentic? Is it fit for the intended purpose? And, perhaps most critically, do we have enough quality data to ensure that our decisions are made with minimal error?

As we explore these challenges, we are evaluating and addressing them from both academic and practical perspectives. We recognize that establishing trust in data isn't just about having more data—it's about having the right data, aligned with ethical guidelines and standards that ensure its integrity and reliability. In our academic work, we have delved deeper into these issues, researching frameworks and methodologies to tackle data trustworthiness.

Some of this work is outlined in our paper published in the conference proceedings, titled "**Tackling Data Scarcity in AI: A Comparative Analysis of Data Augmentation and Synthetic Data Generation**" where we propose a structured approach to AI data supervision. This framework provides organizations with a guideline for ensuring that their AI-driven decision-making processes are based on secure, authentic, and high-quality data, helping them build trust in both the models and the outcomes they produce.

The need for data:

In the past, the process was simpler. We relied on our own judgment, along with statistical models, to draw conclusions based on the data available to us. However, with the rise of artificial intelligence, machine learning, and large-scale learning models, the need for more data has grown. These models require vast amounts of data to be properly calibrated, enabling them to generate reliable conclusions and actionable insights.

Synthetic data generation:

We've reached a point where virtually everyone is gathering data, analyzing it, and investing substantial resources into the data collection process. However, this process is neither cheap nor quick—it can consume considerable time and money. Where time and resources are limited, automation steps in to save both. This is where AI comes into play, particularly through synthetic data generation. Synthetic data offers a solution to the challenge of data scarcity, providing a faster and more reliable alternative to the more conventional approach of data augmentation.

Ensuring Trust in AI: The Role of ISO/IEC 42001:

As we continue to embrace AI-driven solutions, it's essential that we don't lose sight of the importance of data integrity and security. While synthetic data generation offers an efficient way to overcome data scarcity, we must ensure that the data used in decision-making is not only abundant but also trustworthy. This brings us to the role of frameworks like ISO/IEC 42001, which provides a structured approach to AI data supervision. By adhering to these guidelines, organizations can safeguard the ethical use of AI, ensuring that the data fueling their decisions is secure, authentic, and fit for purpose. Some of the insights and methodologies we've developed in this area are outlined in our paper "**Protecting Organizations with ISO/IEC 42001: A Framework for AI Data Supervision**." This framework offers a comprehensive strategy for organizations to manage their AI data processes, helping them not only improve decision-making but also build trust with stakeholders, ensuring that their AI initiatives remain robust, transparent, and accountable in the future.

1.

Artificial Intelligence

APPLICATION OF ARTIFICIAL INTELLIGENCE TECHNOLOGIES IN AUTONOMOUS VEHICLES – ADVANTAGES AND CHALLENGES

Radoslav Raković, Engineering Academy of Serbia, Belgrade, rrakovici@gmail.com

Abstract: *Autonomous vehicles i.e. vehicles without the active participation of a human as a driver were, until recently, in the realm of science fiction. The development of modern technologies, and especially artificial intelligence (machine learning, computer vision and sensor integration) have contributed to the fact that this is no longer the case. Many global car manufacturers work intensively in this area. The paper provides a concise overview of the role that artificial intelligence plays in the development and application of autonomous vehicles.*

Keywords: *Artificial Intelligence (AI), Autonomous Vehicles (AV).*

1. INTRODUCTION

Autonomous vehicles, i.e. vehicles without the active participation of a human as a driver, were, until recently, in the realm of science fiction. The development of modern technologies, and especially artificial intelligence, has contributed to this no longer being the case. Artificial intelligence technologies have become the driver of significant changes in industrial areas, including the automotive industry. Many global car manufacturers are working intensively on developing solutions that, day by day, increase the level of vehicle automation, from basic driver assistance (e.g., when parking), through the levels of partial, conditional, high, and full automation - autonomy. This process will, in the not-so-distant future, lead to the application of fully autonomous vehicles. The paper provides a brief overview of the role that artificial intelligence (AI) plays in the development and deployment of autonomous vehicles (AV), including the challenges in this regard.

2. AUTOMATION vs AUTONOMY

The concepts of automation and autonomy are defined in the ISO/IEC 22989:2022 standard [1], which systematizes the terminology and concepts of artificial intelligence. *Automation*, definition 3.1.7 [1], is a characteristic of a process or system that, under certain circumstances, functions without human intervention, and *autonomy*, definition 3.1.5 [1], represents a characteristic of a system that is capable of modifying its intended application domain or goal without external intervention, control, or supervision. It can be concluded that autonomy is the highest level of automation, as evidenced by point 5.13 of the relevant standard [1], which provides a special table defining autonomy and heteronomy, which includes different levels of automation - autonomy is located on one side of the spectrum, at the highest level (level 6), while heteronomy encompasses systems with a certain level of human control and has levels from 0 (no automation) to 5 (full automation).

In practice, the classification of autonomous vehicles established by the Society of Automotive Engineers (SAE) [2] has prevailed, ranking them from level 0 (no automation) to level 5 (full automation), which corresponds to autonomy, Figure 1 [2]. Levels 0-2 are predominantly oriented to driver assistance, and levels 3-5 represent a significant step forward in automation, towards full autonomy, with a significant reduction in human involvement.

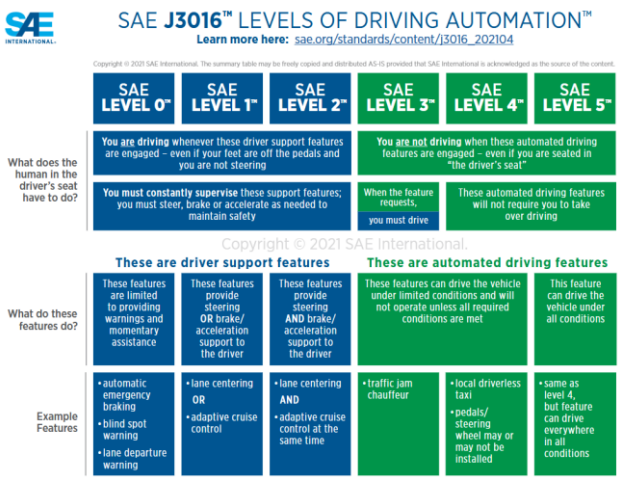


Figure 1: SAE Levels of driving automation [2]

Related to AV terminology, the concept of *computer vision* is very important - it represents, definition 3.7.1 [1], ability of a functional unit to collect, process and interpret data representing images or video, which involves the use of appropriate sensors.

3. AI APPLICATION vs AUTONOMOUS VEHICLES

Chapter 10.3 of the ISO/IEC 42001:2023 standard [3] related to Artificial Intelligence Management System (AIMS) defines that automated vehicles are one form of application of AI systems. The process of implementing AI in autonomous vehicles essentially involves a number of steps [4]:

Step 1: Data collection. The autonomous vehicle journey begins with the collection of a large amount of data from on-board sensors and other sources. The key data sources on the vehicle are, Figure 2 ([4],[5]):

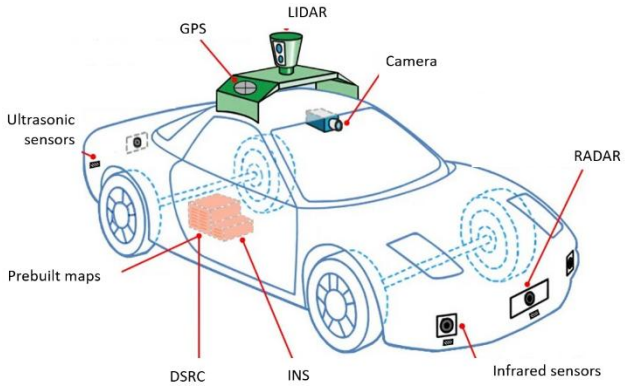


Figure 2: AI technologies in vehicles (Author, as per [4])

- GPS (*Global Positioning System*) provides information about the vehicle's position and helps with navigation. Its accuracy is lower than other sensors, at around 1m.
- LIDAR (*Light Detection and Ranging*) system by emitting laser beams and reflecting them off obstacles, forms a 3D map of the vehicle's surroundings, including the distances to nearby objects.
- High-resolution *cameras* collect visual information such as lane markings, traffic lights, pedestrian crossings, cyclists/motorcyclists and other vehicles.
- RADAR (*Radio Detecting and Ranging*) sensors use radio waves to detect objects and their speeds, which provides very important information, especially in conditions of reduced visibility.
- *Infrared sensors* collect visual information such as lane markings, traffic lights, pedestrian crossings, cyclists/motorcyclists and other vehicles in low-visibility conditions.
- *Ultrasonic sensors* are used to detect nearby objects, helping with parking or maneuvering the vehicle.
- INS (*Inertial Navigation System*), in combination with GPS, improves the accuracy of determining the vehicle's position, orientation and speed. It uses gyroscopes and accelerometers.
- *Prebuilt maps* are used for navigation, in cooperation with GPS and INS, with restrictions on roads and surfaces on which it is possible to drive.
- DSRC (*Dedicated Short-Range Communication*) enables communication with other vehicles (Vehicle-to-Vehicle, V2V) and road infrastructure (Vehicle-to-Infrastructure, V2I), providing information about road conditions, congestion, collisions, as well as ensuring communication between a group of vehicles traveling together.

Step 2: Data processing. The "raw" data collected from the sensors are processed using AI algorithms. It includes fusing of data from different sensors to form a meaningful picture of the vehicle's environment, eliminating noise and errors through filtering, and performing sensor calibration to ensure accurate and consistent measurements.

Step 3: Perception. Represents the process by which an autonomous vehicle interprets processed data obtained from sensors to understand its environment. This includes object detection (road users and non-structural obstacles), image segmentation (differentiating between roads, pedestrian/bicycle paths, buildings, etc.), lane detection (with markings and other elements of road geometry), and precise vehicle location on the map.

Step 4: Modeling the environment. After step 3, the AI algorithm forms a detailed model of the environment that includes object tracking and predicting their movement, map integration (to accurately determine the vehicle's position), and recognition of traffic lights and traffic signals (to comply with traffic rules and regulations).

Step 5: Decision Making. This step is a critical one, as the AI system makes real-time decisions based on the environment model, which relate to path planning (taking into account the vehicle's position, the movement of other vehicles and road users, objects on the road, etc.), behavior planning (how the vehicle will behave in different situations, such as respecting the right of way, changing lanes or merging into traffic) as well as maneuvering in emergency situations (unexpected events or obstacles, to implement braking or turning).

Step 6: Control. The control algorithm translates the decisions made into precise commands for the actuators ("executive organs") in the vehicle, including algorithms for steering (the angle of the steering wheel that allows for the planned path), acceleration and braking (throttle and brake control), and sensor and actuator integration (so that the actuators respond accurately and safely to the commands).

Step 7: Monitoring and Feedback. Throughout the autonomous driving process, the vehicle continuously monitors its environment and checks for deviations from the planned path. The AI system uses feedback from sensors to make adjustments to its steering and decision-making.

Step 8: Redundancy and safety. When it comes to autonomous vehicles, safety is the most important. In this regard, the system implements multiple levels of redundancy, manifested in duplicate sensors, data processing units, and safety mechanisms that play a role in ensuring that the vehicle can safely overcome unexpected situations or system failures.

Based on steps 1-8, it is clear that AVs rely heavily on machine learning algorithms to process and interpret sensor data. The following AI technologies are used:

- *Deep learning*, primarily in object recognition and path planning.
- *Computer vision*, which analyzes camera images and videos, allowing the vehicle to recognize objects, lanes, and road markings
- *Sensor Fusion*, because the AI algorithm combines data from various sensors to create a comprehensive understanding of the environment in which the vehicle is located
- *Machine Perception*, because AI systems understand and interpret data from sensors to form the basis for decision-making.

So far, most autonomous vehicles are at levels 2 or 3, meaning they require some supervision and intervention from a human. Of course, level 5, which would mean that the vehicle can operate without human intervention in all conditions, remains a long-term goal. According to some forecasts [6], it is expected that after 2045, about 50% of new vehicles should belong to level 5 (autonomous vehicles). Given that the main drivers of these activities are renowned companies and research centers such as Waymo (Google), Tesla, General Motors Cruise Automation, Aptiv (formerly Delphi Automotive), as well as Uber and Lift, this forecast does not seem unattainable. At the same time, this also implies other major changes in the transport sector, the most striking of which are the reduction in the number of vehicles and their better use by abandoning the concept of ownership and individual use in favor of shared use, which is more rational from the point of view of parking space, fuel consumption, emissions of greenhouse gases (GHG), etc.

4. ADVANTAGES AND CHALLENGES OF AI APPLICATION IN AUTONOMOUS VEHICLES

Traffic is a very complex system, because its safe operation depends on many factors. Nowadays, the human factor is certainly at the forefront, which, according to all statistics, is the cause of more than 90% of traffic accidents, followed by weather conditions, vehicles and their condition, the number of vehicles and the organization of traffic (especially in large cities), road quality, traffic signals, traffic regulations, etc.

There is no doubt that AI systems, as an essential component of AVs, help to the greatest extent in the human factor segment, which is practically the only subjective component of traffic. A person as a traffic participant can be tired, its moods can fluctuate in a wide range, he/she can have problems with vision or reaction speed, ability to drive decreases in difficult conditions (reduced visibility due to darkness, fog or heavy rainfall, slippery road surfaces, etc.), may be under the influence of alcohol and psychoactive substances, etc. AI systems overcome all these situations better, they are useful for easier navigation in an unfamiliar environment, when you need to determine which route to take (avoiding traffic jams), when you need to park, etc.

In summary, the advantages of applying AI in autonomous vehicles are as follows ([6]-[10]):

- *Increased traffic safety* due to reduced accidents caused by human error. An analysis of references [7] indicates that 81% believe that AI increases the safety of autonomous vehicles, while 19% believe that AI potentially threatens it. The first group consists mainly of authors from the world of AI and autonomous vehicle manufacturers, and the second group consists of authors from the safety sector. The greatest contribution to safety is made by AI technologies connected to sensors and environmental perception, because of collision avoidance, lane departure warning, and detection of traffic signs and other traffic signals.
- *Improving traffic flow*, through optimization of traffic routes to avoid traffic congestion.
- *Increasing accessibility and mobility*, especially for people who are unable to drive (young people, due to legal restrictions, older people and the disabled, due to limitations in their physical ability to drive).
- *Productivity and convenience*, as the passenger can use the travel time in a more productive way, given that he/she is not engaged in driving the vehicle.

- *Economic effects* through increased employment in the automotive sector, especially for AI and control systems engineers.
- *Reduced fuel consumption and reduced emissions of GHGs*, which contributes to reducing air pollution.

When it comes to the challenges of applying AI in autonomous vehicles and autonomous vehicles themselves, they can be systematized into the following areas ([6]-[10]):

- *Technical obstacles*. For autonomous vehicles to operate successfully in a highly variable environment, it is necessary to solve technical problems related to sensor accuracy and reliable communication between vehicles and each other and between vehicles and infrastructure, in order to avoid traffic accidents, it is necessary to develop algorithms for the different situations in which a vehicle may find itself, especially in terms of the necessity of making decisions in a period that is sometimes measured in fractions of a second.
- *Public acceptance and trust*. Through various forms of informing and educating people, it is necessary to ensure that they gain confidence that autonomous vehicle technologies are safe and reliable, which is especially important in the case of their widespread application in public transport.
- *Safety and liability*. It has already been mentioned that the key issue with autonomous vehicles is driving safety. Unfortunately, incidents – traffic accidents are an unavoidable element in traffic. In this regard, the question of liability for incidents involving an autonomous vehicle also arises, especially for the consequences that arise from it (material damage, injuries or fatalities). Insurance companies are a significant participant in all this, so it is necessary to find appropriate solutions in this segment as well.
- *Ethical and moral issues*. Autonomous vehicles may face situations where accidents cannot be avoided, so ethical decisions need to be made, e.g. whether vehicle passengers or pedestrians have priority in safety, etc. Algorithms must provide that in all situations, the priority is primarily the preservation of human lives, while material damage to vehicles or infrastructure must be secondary.
- *Cybersecurity*. Cyberattacks can threaten the functionality and security of a vehicle and its environment. For example, hacking into a system and taking control of a vehicle can have very serious consequences, and a particular danger in such situations is the possibility of using these vehicles as weapons in a terrorist attack.
- *Infrastructure and connectivity*. For autonomous vehicles to function successfully, they require advanced infrastructure, such as smart traffic lights and roadside equipment that enables precise detection of traffic lanes and road boundaries. In addition, good connectivity and high-speed communication with other vehicles (Vehicle-to-Vehicle – V2V) and with infrastructure (Vehicle-to-Infrastructure – V2I) are also essential.
- *Regulatory framework*. The use of autonomous vehicles requires that all relevant issues be regulated by laws and other regulations. In many areas, there are significant differences in the legislation of different countries, and regulatory harmonization is necessary here to reduce the differences to the smallest possible extent, especially in the case of the use of autonomous vehicles on international roads.
- *Cost and availability*. The development of autonomous vehicles and their cost are high, therefore these vehicles are not easily available and this may be an obstacle to wider use. In this sense, there will inevitably be a change in approach, where ownership will gradually decrease in favor of sharing vehicles as a resource.
- *Impact on employment*. Autonomous vehicles may have a negative impact on employment in the transport sector, in terms of reducing the need for drivers. This of course requires retraining of personnel, which can be problematic, especially in the transition period.

It should be emphasized that there is a difference in the functioning of autonomous passenger vehicles and freight vehicles - trucks. Autonomous passenger vehicles are generally used more in urban areas and are oriented towards creating conditions for passenger safety and travel comfort. On the other hand, autonomous cargo vehicles are more oriented towards non-urban driving, the safety of the cargo carried is in the foreground (e.g. adequate conditions for transporting food), and the task of the algorithms is to optimize the route between the starting point and the destination and minimize fuel consumption, which is related to the weight of the cargo.

5. SOCIAL ACCEPTABILITY OF AVs IN SERBIA

In the previous part of the paper, it was pointed out that the application of artificial intelligence in the field of autonomous vehicles has a technological and social component, because the application of modern technologies in practice faces many dilemmas and challenges. In this sense, the Republic of Serbia is no exception. That is why it is very interesting to consider the social acceptability of those technologies in our conditions.

Below are the results of the research conducted on that topic, which is an integral part of the Erasmus project PELMOB (Partnership for Promotion and Popularization of Electrical Mobility). The research was conducted in the period March-April 2025 with the aim of assessing the attitude of the citizens of the Republic of Serbia towards the application of autonomous vehicles [11].

The survey was conducted online on a sample of 112 respondents, and contained 6 questions [11]:

- *How familiar are you with the term autonomous vehicles?* The results show that 19.6% of respondents have never heard of this term, 33.9% of respondents know some basic things and only 1.8% are well acquainted with it. It can be concluded that the term is not sufficiently known, which is probably the result of insufficient media coverage.
- *Would you ride in a fully autonomous vehicle, without a driver?* The results indicate that 7.1% of respondents would not drive an autonomous vehicle at all, 37.5% believe that they would not feel safe, 26.8% of them would perhaps drive if the safety measures were explained to them beforehand, and 22.3% would drive but with a certain amount of caution. These results are expected, given that people have no experience with these vehicles.
- *What, in your opinion, are the main advantages of autonomous vehicles?* The largest number of respondents, i.e. 36.6% see the main advantage in reducing stress while driving, while 17% see the advantage of reduced fuel consumption, or the availability of vehicles for the elderly and people with disabilities. Almost a quarter of respondents (22.3%) had no opinion or did not see any advantages.
- *What are your biggest fears about autonomous vehicles?* Two-thirds of respondents (67.9%) are afraid of losing control over the vehicle, and a third (35.7%) are afraid of software failures and technical errors.
- *Do you believe that autonomous vehicles can reduce the number of traffic accidents?* A third of respondents (34.8%) are not sure whether these vehicles can reduce the number of traffic accidents, and 45.5% of them believe that this is possible to some extent.
- *When do you think autonomous vehicles will become commonplace on the roads?* The largest number of respondents, two-thirds of them (68.8%) believe that it will happen in the period of 10-20 years, about 12.5% that it will happen in 5-10 years, while 9.8% believe that this technology will never be common.

The authors of the research concluded that the awareness of the existence of autonomous vehicles is quite high, but that the degree of trust in this technology is still at a low level.

6. LEGAL FRAMEWORK FOR AVs IN SERBIA

Autonomous vehicles have also found their place in the current legislation of the Republic of Serbia - the Law on Road Traffic Safety, the Regulation on the Conditions for Performing Autonomous Driving, and the Regulation on Vehicle Testing.

The Law on Road Traffic Safety [12] in Article 7, definition 105, defines an autonomous vehicle as "a manufactured or modified motor vehicle, with an automated driving system, which meets technical and other prescribed conditions and which enables the movement of that vehicle in road traffic, with partial control by the driver, or with the complete absence of control by the driver." Definition 106 defines autonomous vehicle testing as "a set of activities carried out for the purpose of technical and functional verification of the automated autonomous vehicle system".

Article 122a) of the Law explicitly states that "driving an autonomous vehicle on the road (hereinafter: autonomous driving) is permitted solely for the purpose of testing that vehicle and is carried out on the basis of a particular permit issued by the Ministry responsible for internal affairs. Autonomous driving may only be carried out at the time and in the manner prescribed by the permit. The detailed conditions for autonomous driving and the procedure for issuing the permit shall be prescribed by the minister responsible for internal affairs."

The Regulation on the Conditions for Performing Autonomous Driving [13] defines an automated driving system (ADS) as "a combination of hardware and software components with the help of which, according to the level of automation, the dynamic task of driving a vehicle is realized, within a defined operating range" Vehicle testing is carried out by a legal entity based in the Republic of Serbia (testing organizer) based on a permit, and is carried out for vehicles of categories L7 (with factory-closed bodywork), M1 (passenger vehicle) and N1 (freight vehicle up to 3.5 t). The Regulation defines that testing is carried out up to a maximum of 4th levels of automation, as level 5 is difficult to fit into existing standards.

The Regulation on Vehicle Testing [14], within the framework of Annex 4, deals with the testing of autonomous vehicles for testing purposes. Automation levels range from 0 (no automation) to 5 (fully autonomous driving), vehicle control is tested in the longitudinal and transverse directions, and a separate table defines the operating range of the AVs for individual automation levels (environment and conditions for which it was designed - geographical location, meteorological conditions, time of day, road condition, road category, traffic regime, existence of tunnels, level crossings, work zones, etc.).

It is clear that in the future the legislative framework will have to be significantly adapted to the existence of autonomous vehicles, both in terms of specifying liability and in terms of insuring those vehicles.

7. CONCLUSION

The paper discusses the role that artificial intelligence systems play in the development and implementation of autonomous vehicles, i.e. vehicles without the active participation of a human as a driver. Although at first glance this seems like a long-distant future, the experiences of the past decades have convinced us that technological progress is taking place very rapidly, so it is only a matter of time before autonomous vehicles become a reality. There is no doubt that in technological terms this represents significant progress, but it is necessary to resolve a multitude of organizational, legislative and ethical issues.

REFERENCES

[1] ISO/IEC 22989:2022 *Information technology-Artificial intelligence-Artificial intelligence concepts and terminology* (Ed 1, 2022)

[2] www.sae.org

[3] ISO/IEC 42001:2023 *Information technology-Artificial intelligence - Management System* (Ed 1, 2023)

[4] Ghulaxe V: „Driving the future: The role of Artificial Intelligence in autonomous vehicles“, International Journal of Engineering Technology Research & Management, Vol-08, Issue 09, September 2024, https://www.ijetrm.com

[5] Autonomous vehicles factsheet https://css.umich.edu/publications/factsheets/mobility/autonomous-vehicles-factsheet#references

[6] Litman T: „Autonomous Vehicles Implementation Predictions - Implications for Transport Planning“ (Victoria Transport Policy Institute, October 2024, www.vtpi.org)

[7] Nascimento A.M et all: „A Systematic Literature Review about the impact of Artificial Intelligence on Autonomous Vehicle Safety“ (April 2019) https://www.researchgate.net/publication/332220658

[8] Petrik O: „Autonomous Vehicles and their Implications to Society“, (May 2021) https://www.researchgate.net/publication/351585020

[9] Othman K: „Exploring the Implications of autonomous vehicles: a comprehensive review“ Innovative infrastructure Solutions (2022), 7.165

[10] Garikapati D, Shetiya SS: „Autonomous Vehicles: Evolution of Artificial Intelligence and the current Industry Landscape“ (Big Data and Cognitive Computing, 2024, 8, 42) https://doi.org/10.3390/bdcc8040042

[11] Popović O, Ilić M, Gospić N: „Analisas of Social Acceptability and Challenges for Autonomous Vehicles in Serbia“, Conference „Electrical Mobility for Green Agenda of Western Balcan – Trends and Challenges of sustainable Transport“, Engineering Academy of Serbia, Belgrade, 9th May, 2025, Proceedings, pp 93-99

[12] Law on Road Traffic Safety (Official Gazette of the Republic of Serbia 41/2009, 53/2010, 101/2011, 32/2013 – decision of the Constitutional Court, 55/2014, 96/2015 – other law, 9/2016 – decision of the Constitutional Court, 24/2018, 41/2018, 41/2018 – other law, 87/2018, 23/2019, 128/2020 – other law and 76/2023)

[13] Regulation on the conditions for autonomous driving (Official Gazette of the Republic of Serbia 104/23)

[14] Regulation on vehicle testing (Official Gazette of the Republic of Serbia 8/2012, 13/2013, 31/2013, 114/2013, 40/2014, 140/2014, 18/2015, 82/2015, 88/2016, 108/2016, 129/2021 – other regulations, 110/2022 - other regulations, 83/2023, 7/2024 and 55/2024)

CODE GENERATORS IN THE AGE OF LARGE LANGUAGE MODELS

Mladen Opačić, Belgrade Metropolitan University, mladen.opacic@metropolitan.ac.rs
Nikola Dimitrijević, Belgrade Metropolitan University, nikola.dimitrijevic@metropolitan.ac.rs
Nemanja Zdravković, Belgrade Metropolitan University, nemanja.zdravkovic@metropolitan.ac.rs

Abstract: *Large language models (LLMs) have brought a new era for automatic code generation by changing the architecture of traditional code generators. This paper starts by presenting the state of the art in the field of code generators, from traditional template and rule-based systems to more advanced model-based systems. An overview of fundamental principles underlying LLMs is then provided. On top of this work, how those LLMs have been tailored to code generation is reviewed. Influences of LLMs within the wider community of code generators, observing some new hybrid systems that marry deterministic templates with probabilistic language models were examined. Finally, implications for software engineering practice were presented and future research directions were described. Article concludes by emphasizing the role of LLMs and the urgency to develop methodologies that can help use their capabilities in a safe and efficient code fashion.*

Keywords: large language models, *AI, code generators*

1. INTRODUCTION

With the increasing application of artificial intelligence in software development, especially with the arrival of large language models (LLMs), the whole landscape of software development has undergone a large transformation. In earlier days, code generators [1] were a key aid in the rapid production of software. They did this by generating source code automatically out of high-level specifications, thus cutting down many repetitive tasks, allowing for less human error, and raising productivity. Code generation methods [1] drew primarily on template or rule-based systems, so they were not as adaptable and flexible as one might wish.

Advanced LLMs such as OpenAI's GPT models have introduced new possibilities in automated programming [2]. They were trained on large amounts of natural language and programming code [3]. As a result, they can understand contextually important and generate syntactically relevant code snippets [3]. This advance in capabilities has expanded the range of code generation and also raised the standard and complexity of its results.

This article investigates the connection between traditional code generators and today's modern language models. Ways in which LLMs are rewriting existing practices by examining the strengths and limitations of conventional approaches in contrast to LLM-based systems are discussed. Aim is to review the revolutionary impact of these technologies have on software development methods. Also, ways in which integrating LLMs with code generators can produce smarter, more adaptable, and more efficient tools.

First the article explores the differences between rule and LLM-driven code generation from different perspectives. LLMs work on probabilistic models trained from various codebases, intent, and the creation of entirely new solutions themselves [4]. There are still scenarios for which traditional generators are desirable, such as those structured in nature within enterprises with heavy structure, and situations where LLMs afford greater flexibility. Cases include requirements that are rapidly and often ambiguously expressed.

There are still many practical challenges when integrating an LLM with existing development tools [5]. Some of the key issues being considered include latency incurred in inferring model results, correctness, and security of the code generated, which all need attention. In addition, prompt engineering practices must be developed further [6]. Techniques for this include validating and sanitizing AI-generated code by static analysis, unit testing, and human review. Strategies for mitigating hallucinations and drift also need exploration. By examining actual deployments, researchers can draw together best practices for orchestrating deterministic templates and probabilistic language models in a way that is easy for the developer to use.

Finally, the paper the vision of future automatic programming: an intelligent development assistant formed by LLMs, traditional code generators, and domain-specific tools. Also delving into the larger implications in terms of team dynamics, developer skills, and software quality assurance. And arguing that the next generation of code generation will not replace human expertise, but enhance it: hence empowering developers to face an ever more complex world with greater confidence and imagination.

2. CODE GENERATORS

Code generators are computer programs that are built for automatic creation of source code. These tools create code from descriptions or specifications provided by users and turn them into executable code, cutting down the programming time [7]. They can vary from a simple script that does some repetitive tasks ahead of time to complex systems which generate whole applications based on detailed specifications [8].

All language code generation operations (including the tests) become simple API calls, and any client language code specification is generated in an instant. These templates work well on clearly defined programming tasks. However, they are not the best solutions for new and very complex tasks. Rule-based code generators are other solutions [9]. They use user-defined rules to produce source code. Compared to template-based, rule-based generators offer improved adaptability. However, because they must be repaired and constantly updated with extensive continuous testing, they can be impractical [10]. Code generators have made major contributions in terms of improving developer productivity and maintaining consistency in coding standards. Since they are widely implemented in areas such as web development, database schema creation, integration, and interface design, they have also reduced errors and shortened the cycle for software delivery.

Due to increasing complexity in software systems, the limitations of traditional code generation methods have become more vivid in recent years [11]. The rigidity and lack of adaptability inherent in template-based systems, like traditional rule-based systems, have prompted people to seek a new model that is more flexible and capable of reacting flexibly to changing requirements [12]. At this crossroads, AI-driven solutions are being adopted with the support of the Large Language Models.

3. LARGE LANGUAGE MODELS

Large Language Models (LLMs) [13] are sophisticated machine learning algorithms trained on lots of text data. These guarantees [14] they can understand the contextually accurate text and generate language for users. LLMs such as GPT-3.5, GPT-4, and Google's Gemini use deep neural network architectures based primarily on transformers to achieve impressive results in natural language processing tasks, including text classification, sentiment analysis, translation, and code generation.

The LLMs' fundamental strength is learning subtle language nuances and complex grammar rules from massive quantities of raw data rather than depending on human reference [15]. This contrasts sharply with traditional rule-based techniques; LLMs do not require explicitly programmed rules or templates at all. Instead, they learn a statistical model of associations during training and are able to tune dynamically for different tasks and contexts when that model changes. When LLMs are used to generate code [15], they exhibit great performance. They comprehend [16] all of the constructs and semantics in programming languages and translate natural language descriptions into correct source code that is syntactically and semantically correct. This capacity far surpasses traditional code generators, particularly for handling complex cases and producing original solutions with innovation built in [17]. Since LLMs are still a new technology, many potential challenges lie ahead. For example, they sometimes produce code that must be carefully validated or polished because of inaccuracies produced in low-probability situations.

From these perspectives, therefore, integrating LLMs into software engineering workflows is a big upgrade [18]. It brings more than a boost in productivity for developers; it also heralds major innovations in software development practices overall and improvements to code quality across the board.

These upgrades are possible for any job that consists of document automation with the use of LLMs. The main advantage of an LLM are explanations that can be used to explain the existing code and are logical by construction. It makes onboarding new teams much easier. By making the onboarding process for new team members faster, this not only offers them greater ease of learning but also enhances codebases that are constantly evolving, and yet, without piling an excessive burden upon developers [19]. Safety-critical fields cross-validate the auto-generated documentation against a formal specification. It is easier to check the correctness of generated contents than to write text in which that correctness is logically considered. Some of the areas in which LLMs hold great promise are in intelligent refactoring and tackling technical debt [20]. Traditional refactoring tools are based on specific syntax patterns and static analysis, but an LLM can detect higher-level design and code smells [21].

Any machine learning model may add abstract strategies and detailed changes to the code. These models can now proactively take care of a company's code repository by presenting transformational ideas and examples. The role of humans in the software architecture will change over

time. However, the integration of LLMs into DevOps pipelines raises many governance questions [22]. Models trained on public code repositories can inadvertently capture dangerous coding patterns or snippets licensed under the GPL [23]. With this coming into proprietary software, license compliance and security risks arise. To address this, businesses are rolling out policies that combine LLM output with real-time license-scanning tools and vulnerability databases. Suggestions flagged as problematic can be automatically quarantined or referred for expert judgment to ensure that AI-assisted boost in productivity never goes into illegal or insecure territory. LLMs raise ethical questions about liability and who owns the created code [15]. If, for example, an implemented solution is not apparent but nonetheless arises from data in an empirical corpus from some years ago submitted by someone else should the originator ever receive any credit? Some organizations are trying to tag code with metadata origins [16]. Provenance tags are then embedded into the generated artifacts to show which training set in the corpora influenced a specific suggestion. Such transparency mechanisms attempt to reconcile the benefits of sharing knowledge in open-source communities with giving fair credit to original authors, for here the aspiration is to promote an ecology where we draw on others' contributions but also respect them [15]. LLM decision-making processes remain an unresolved topic for research in terms of their interpretability. While rule-based systems use a series of instructions to carry out their logical function in an exhaustive, precise manner [10], transformer-based architectures consist of distributed representations, so it is tough to explain them coherently [17]. To foster trust among programmers, many are beginning to provide means for probing the 'attention' force--finding out, through examples, which instances occur throughout their training corpus most often in each prompt that a model suggests. Bringing these reflections into alignment with feedback from human recognition software presents a way of iterating on both the model and its implementation points. So that is how a more amenable AI can be constructed. Looking forward, as LLMs become more thoroughly embedded within the day-to-day software life cycle, agents will need new measures to evaluate their impact [19]. Among these indicators are not just the number of lines of code output or hours saved, but changes in developer satisfaction, post-release defects, and reduced time of feature development [20]. Long-term studies are necessary to determine how much AI-aided practices alter team productivity, patterns of cooperation, and decisions about design [18]. The industry has to approach those results carefully so that LLMs can really improve software craftsmanship rather than automate routine work.

4. CODE GENERATION WITH LLMs

The emergence of large language models as tools for code generation is a new development in automated programming [19]. By drawing on their training with mixed datasets that include natural language patterns along with programming languages themselves, LLMs help users go fast from ideas to executable programs [20]. Users describe what they want to do in their natural language, and an LLM reads this description to generate the appropriate source code. Another significant advantage of using LLMs for code generation is their ability to handle a wide variety of languages and programming paradigms unburdened by language-specific templates or rules [21]. This flexibility makes it easy for developers from different regions to create source code directly applicable in diverse locales, reducing greatly the communication overhead and increasing efficiency accordingly. And if we have in mind that LLM-based systems can evolve continuously as they work through the new data and they analyze the code. The source code they produce can remain up-to-date constantly [18].

LLMs simplify exploratory programming by automatically generating alternative solutions and prototypes quickly [19], enabling developers to evaluate various points of view in the shortest possible time. This not only results in quicker development cycles, but also encourages new thinking and experimentation on how software projects are designed.

Despite these benefits, the use of LLMs in code generation has potential security issues [15]. Generated code requires rigorous validation in order to ensure that it is reliable and maintainable. An effort is needed in integrating LLM output with established practices of traditional software engineering.

The introduction of large language models into traditional code generation systems revolutionized their capabilities and methods [22]. The addition of LLMs transforms traditional code generation from a static approach to dynamic, context-aware networks. This integration makes it possible for traditional systems to overcome their limitations.

LLMs improve code generators by enabling them to understand developer intent expressed in natural language better than would be possible otherwise. This reduces the reliance on pre-defined templates and regulations, enabling the generation of more complicated, personalized, and flexible solutions [17].

This also has the advantage that LLM-enhanced code generators are able to go from rapid prototyping to iterative development extremely quickly, saving considerable time in the software lifecycle. Their support for innovation enables researchers to conduct experiments easily, without needing extensive operating guidelines or numerous forms of implementation [5].

Adoption of LLMs presents its challenges. It requires us to ensure the accuracy of the code that is generated. Precautions against potential errors will have to be taken. Errors that may have been learnt from training data. Also, it is advised to answer the interpretability and transparency issues that arise when AI-driven processes result in a result that are created by non-human means [19]. The key to harnessing LLM potential benefits lies in carefully selecting right integration strategies.

Large language models as tools for code generation represent a new development in automated programming methods [3]. By drawing on their substantial training with mixed datasets that include natural language examples along with programming languages themselves, LLMs help close the gap between human intention and executable programs [4].

Further, an interesting direction is to integrate LLMs with continual learning systems that adjust for the evolution of codebases in an organization. By shadowing developer edits and PR feedback, models learn from the code they help produce: this feedback loop helps keep suggestions increasingly accurate and relevant [21]. Such an adaptive learning pipeline could also expose emergent coding patterns specific to a team's domain, giving the LLM a predictive capability to preemptively offer boilerplate, configuration, before it is even asked for [20].

Additionally, with the arrival of AI-powered code generators into the mainstream, the focus of developer education will change to encompass "prompt engineering" best practices and increase AI literacy among developers [18]. Training programs will have to do more than just teach language-agnostic best practices; they will need to teach how to write effective prompts, interpret model explanations, and evaluate generated outputs. Universities and learning programs might offer specific courses on the collaboration between humans and AIs in developing software, focusing on how one can reconcile generative creativity with engineering discipline.

All in all, the legal and regulatory context of AI-generated code seems likely to change fast. Standardizing institutions will have to resolve outstanding questions of intellectual property, liability for flaws in software generated by AI, and ethical data usage in model training [18]. Programming with using LLMs can therefore exert influence on issues across technical, educational, and legal fields. Potential for use of these technologies seams to be unlimited and will have huge impact on the affected industries.

5. CONCLUSION

The introduction of LLMs into code generators is a breakthrough in the discipline of software development. It provides many new opportunities for productivity, innovation, and code quality. Even if those benefits will not be realized immediately upon integration, they still offer major advantages. While traditional code generators could automate some tedious work, combining them with LLMs has resolved the limitations that previously constrained such software tools.

It provides greater flexibility, adaptability, and context-awareness. Still, applying large language models in code generation successfully calls for ongoing research, rigorous validation processes, and an attentive concern for the ethical and practical implications. Security issues are numerous, Intellectual property rights are completely unclear and completely new set of laws will have to be created to assess these issues.

If two developers generate very similar source code who will be the author that has intellectual property rights? What if AI generates code that is similar to code that is already protected as intellectual property? Is the author liable for the damages or is it LLMs fault? What is the value of the newly generated code if everyone using the same tool can get the same code? Is it going to be even possible to protect software as intellectual property and who will decide in the case that it is an international problem? All these and many other questions will have to be addressed in the very near future.

With classic code generators all these answers are clear, however for LLM generated code this questions still remain unanswered. Future studies need to concentrate on many of these and problems that will affect an understanding of models like these and determine their reliability and efficiency. By taking the time to think about integration strategies, we may find new ways to work with the transformative potential of these models in software engineering. One thing remains clear LLM generated code is here to stay and its influence is only going to become more influential in the future.

REFERENCES

[1] A. Dhruv and A. Dubey, “Leveraging Large Language Models for Code Translation and Software Development in Scientific Computing,” arXiv, vol. abs/2410.24119, 2024.

[2] J. Morales-García, A. Llanes, F. Arcas-Túnez, and F. Terroso-Sáenz, “Developing Time Series Forecasting Models with Generative Large Language Models,” ACM Trans. Intell. Syst. Technol., 2024.

[3] R. Ramírez-Rueda, E. Benítez-Guerrero, C. Mezura-Godoy, and E. Bárcenas, “Transforming Software Development: A Study on the Integration of Multi-Agent Systems and Large Language Models for Automatic Code Generation,” in Proc. 12th Int. Conf. Softw. Eng. Res. Innov. (CONISOFT), 2024, pp. 11–20.

[4] M. Liu, J. Wang, T. Lin, Q. Ma, Z. Fang, and Y. Wu, “An Empirical Study of the Code Generation of Safety-Critical Software Using LLMs,” Appl. Sci., 2024.

[5] S. D. Bappon, S. Mondal, and B. Roy, “AUTOGENICS: Automated Generation of Context-Aware Inline Comments for Code Snippets on Programming Q&A Sites Using LLM,” in 2024 IEEE Int. Conf. Source Code Anal. Manipulation (SCAM), 2024, pp. 24–35.

[6] K. Greshake, S. Abdelnabi, S. Mishra, C. Endres, T. Holz, and M. Fritz, "Not What You've Signed Up For: Compromising Real-World LLM-Integrated Applications with Indirect Prompt Injection," Proc. 16th ACM Workshop on Artificial Intelligence and Security, 2023.

[7] V. Narayan et al., “To Implement a Web Page using Thread in Java,” unpublished, 2017.

[8] H. J. Mohammed and K. H. Faraj, “A Python-WSGI and PHP-Apache Web Server Performance Analysis by Search Page Generator (SPG),” UKH J. Sci. Eng., 2021.

[9] Y. Lin, Z. Zhang, and S. Han, “LEGO: Spatial Accelerator Generation and Optimization for Tensor Applications,” in 2025 IEEE Int. Symp. High Perform. Comput. Archit. (HPCA), 2025, pp. 1335–1347.

[10] W. Xu, T. Ding, and D. Xu, "Rule-Based Test Input Generation from Bytecode," in 2014 Eighth International Conference on Software Security and Reliability, 2014, pp. 108–117.

[11] E. Y. Nassar, S. A. Mazen, S. Craß, and I. M. A. Helal, “Modelling Blockchain-Based Systems Using Model-Driven Engineering,” in Proc. 5th Int. Conf. Blockchain Comput. Appl. (BCCA), 2023, pp. 329–334.

[12] O. Hamed, M. Amer, and T. Bejaoui, “Survey on Advancements in Machine Learning for Natural Language Processing,” in 2024 Int. Symp. Networks, Computers and Communications (ISNCC), 2024, pp. 1–6.

[13] K. I. Roumeliotis, N. D. Tselikas, and D. K. Nasiopoulos, “Fake News Detection and Classification: A Comparative Study of Convolutional Neural Networks, Large Language Models, and Natural Language Processing Models,” Future Internet, vol. 17, no. 28, 2025.

[14] Z. Zhou and Y. Sun, “A Machine Learning Model to Predict the Success of Broadway Shows using Neural Networks and Natural Language Processing,” Networks, Blockchain and Internet of Things, 2024.

[15] S. Fakhoury, A. Naik, G. Sakkas, S. Chakraborty, and S. K. Lahiri, "LLM-Based Test-Driven Interactive Code Generation: User Study and Empirical Evaluation," IEEE Transactions on Software Engineering, vol. 50, pp. 2254–2268, 2024.

[16] N. Nascimento, E. Guimaraes, S. S. Chintakunta, and S. A. Boominathan, “LLM4DS: Evaluating Large Language Models for Data Science Code Generation,” arXiv, vol. abs/2411.11908, 2024.

[17] B. Nadimi and H. Zheng, “A Multi-Expert Large Language Model Architecture for Verilog Code Generation,” in 2024 IEEE LLM Aided Design Workshop (LAD), 2024, pp. 1–5.

[18] J. Jiang, F. Wang, J. Shen, S. Kim, and S. Kim, “A Survey on Large Language Models for Code Generation,” arXiv, vol. abs/2406.00515, 2024.

[19] R. Konda, “AI-Powered Code Generation: Evaluating the Effectiveness of Large Language Models (LLMs) in Automated Software Development,” J. Artif. Intell. Cloud Comput., 2023.

[20] L. L. Custode, C. C. Rambaldi, M. M. Roveri, and G. Iacca, “Comparing Large Language Models and Grammatical Evolution for Code Generation,” in Proc. Genetic Evol. Comput. Conf. Companion, 2024.

[21] H. Zhang, W. Cheng, Y. Wu, and W. Hu, “A Pair Programming Framework for Code Generation via Multi-Plan Exploration and Feedback-Driven Refinement,” in 2024 39th IEEE/ACM Int. Conf. Automated Softw. Eng. (ASE), 2024, pp. 1319–1331.

[22] S. Joel, J. J. Wu, and F. H. Fard, “A Survey on LLM-based Code Generation for Low-Resource and Domain-Specific Programming Languages,” vol. arXiv:2410.03981v2, 2024.

[23] T. Ridnik, D. Kredo, and I. Friedman, “Code Generation with AlphaCodium: From Prompt Engineering to Flow Engineering,” arXiv, vol. abs/2401.08500, 2024.

AI'S INFLUENCE ON ORGANIZATIONAL CULTURE IN SOFTWARE SMES IN SOUTHEAST EUROPE: CHALLENGES AND METRICS

Aleksandar Milinčić, AGOGA Consulting Agency, aleksandar.milincic@itserbia.info

Abstract: *Artificial intelligence (AI) has emerged as a transformative force with the capacity to reshape entire industries and redefine organization's way of working. From its early conceptualization to current general prevalent adoption, AI has evolved into a critical element of digital transformation strategies across business domains. Its impact transcends mere operational effectiveness to include the very core of organizational dynamics, like culture, climate, leadership, and employee experience. The research question, "To what extent does artificial intelligence affect organizational culture?" was the result of the author's interest in the topics of organizational culture and AI and the apparent dearth of research in the field. AI has been studied for over half a century, and it is already reshaping organizations from within and through external services. Despite progress, unresolved challenges remain, highlighting the urgency of exploring its cultural implications. The findings presented herein are based on the literature review developed as part of the author's ongoing doctoral research, which explores how artificial intelligence shapes organizational culture in software SMEs across Southeastern Europe.*

Keywords: *Organizational Culture, Organizational Climate, AI, Artificial Intelligence, SME*

1. INTRODUCTION

While AI has the potential to enhance organizational efficiency, its impact on organizational culture remains ambiguous. Does it strengthen cohesion, or fragment workplace identity and trust?

Artificial intelligence has demonstrated its disruptive nature in the case of small and medium-sized companies, where AI is the driver of business transformation [1]. The recent global pandemic only accelerated the digital transformation, and created fertile ground for the post-pandemic development of organizational culture, and especially for the integration of AI into the core of every company's business. That integration brings improvements, but also new, up till now unknown problems in the development of the company's organizational culture [1]. This paper aims to synthesize current research in the field of the impact of artificial intelligence on the transformation of organizational culture in SME companies engaged in software development in the region of Southeast Europe.

The technology underlying artificial intelligence, such as machine learning and natural language processing (NLP), has seen great progress, and thus, naturally, in many areas of software development, it has shown enormous potential to cause revolutionary changes in all areas of the life cycle from specification writing to code writing, testing and reflection [2]. At the same time, in small and medium-sized enterprises, the very implementation of artificial intelligence shows the potential of a significant impact on the workforce, through the need for necessary training and retraining, all with the aim of adequate adaption of the workforce to the changing development environment [3]. What's more, the introduction of artificial intelligence into the software development process itself, as well as into other processes in software companies, imposes the necessary consideration of ethics and other risks, as a permanent obligation of organizations [2].

Changes in business and organizations are faster, more complex and with increasingly unpredictable outcomes [4]. This acceleration of changes and the growth of their complexity was, among other things, due to the emergence of digital transformation [5]. This new environment is often abbreviated with the acronym VUCA, (volatility, uncertainty, complexity and ambiguity [6]. The term "volatility" refers to changeability and impermanence in the pace of changes that occur, while "uncertainty" means the absence of predictability, understanding of changes, as well as complete and correct information. The "complexity" of the environment is reflected in the fact that there is no obvious causality. In the end, "ambiguity" highlights a feature of this complex and dynamic environment that confirms the ambiguity of truth [7]. From a simple acronym, VUCA has become a fundamental basis, synonymous with all internal and external conditions and factors that depress the company [4].

Recently, due to radical changes in business, decentralization, internet technologies, artificial

intelligence and machine learning, business models and industries are experiencing radical and irreversible changes [7]. A world determined by volatility, uncertainty, complexity and ambiguity imposes a challenge on companies when making strategic decisions. That challenge brings the need for quick and timely decisions, because due to the high speed of changes, long-term decisions can easily become ineffective [8]. For modern leaders in the VUCA environment, tools such as experience and knowledge are no longer the only factors that lead to decisions being correct, made at the right time and effective for business. Already today, AI is showing the ability to match the speed of change in the environment, with its ability to quickly offer solutions and support in decision-making leaders. In addition, by increasing visibility and predictability, artificial intelligence brings the potential of reducing costs, reducing opportunities for human bias to confuse the choice of clear decisions, as well as increasing the efficiency of top management [7].

As illustrated by [9] prepared by World Economic Forum, employees can expect that 39% of their existing skill sets will be transformed or become outdated in next five years. However, this measure of "skill instability" has slowed compared to previous editions of the report, from 44% in 2023 and a high point of 57% in 2020 in the pandemic times. Off course, artificial intelligence is first on the list of transformative skills. Relevancy of this data is supported by perspective gathered from 1,000 leading global employers, collectively representing more than 14 million workers across 22 industry clusters and 55 economies from around the world.

The remainder of this paper is organized as follows:
Section 2 defines the research problem and outlines the contextual and theoretical gaps related to the cultural implications of AI integration in software SMEs. Section 3 presents the proposed conceptual framework and methodological approach aimed at assessing cultural transformation through AI. Section 4 outlines the expected results and anticipated outcomes based on the literature review and proposed metrics. Finally, Section 5 concludes the paper by summarizing key insights and offering directions for future empirical research.

2. PROBLEM STATEMENT

Although AI implementation in organizations has taken off in the last couple of years, there is already extensive research on the impact of artificial intelligence on productivity and organizational structures. It is notable that most studies focus on global markets and developed economic regions [10]. The lack of empirical studies on AI-driven transformation in software SMEs in Southeast Europe represents a significant research gap. Given the unique economic and cultural factors shaping this region, it is imperative to explore how AI affects organizational culture and workplace dynamics in a localized context.

Cameron highlights a key limitation of qualitative research on organizational culture: the difficulty of studying multiple organizations due to resource constraints [11]. This poses a challenge for AI-related cultural research in SMEs, where a comparative approach across companies may be essential for understanding industry-wide patterns.

Furthermore, while AI is already embedded in many organizational processes, including software development, marketing, and internal communication, its effect on shared values, identity, leadership, and employee empowerment is still insufficiently addressed. Most frameworks for measuring organizational culture have not yet been adapted to reflect the disruptive influence of AI tools on workplace behavior and social norms.

The challenges in business transformation, driven by rapid technological changes, are particularly intensified in SMEs operating in a VUCA environment, where volatility, uncertainty, complexity, and ambiguity are the norm. As such, traditional leadership models, organizational design, and cultural metrics are no longer sufficient to capture the nuances of AI-induced change in culture.

There is also a scarcity of regionally contextualized research that incorporates the specific sociocultural and economic characteristics of Southeast European countries. Understanding how local cultural codes, hierarchical tendencies, and education systems interact with AI adoption in SMEs is crucial for designing relevant interventions and measurement frameworks.

3. SOLUTION

This paper proposes a multi-dimensional approach to assessing the influence of artificial intelligence on organizational culture in software SMEs, with an emphasis on leadership, communication, employee empowerment, and professional development.

The first part of the proposed solution is a conceptual framework that integrates both classical cultural theory (e.g., Schein, Hofstede, Cameron) and newer AI-relevant dimensions, including digital maturity, AI literacy, and psychological safety. By bridging these dimensions, the study aims to identify how AI tools disrupt, reinforce, or transform existing cultural values and behaviors.

To operationalize this framework, the study builds upon validated models such as the Organizational Culture Assessment Instrument (OCAI) and the Grid-Group Cultural Theory (GGCT), but adapts them to reflect AI-related factors.

For example, in addition to traditional dimensions like clan, hierarchy, adhocracy, and market cultures, the framework includes metrics for:

- AI-driven decision autonomy and trust in AI systems
- Changes in team interaction patterns (especially in remote/hybrid settings)
- Perceived fairness and transparency of algorithmic interventions
- The level of AI-supported skill development and task ownership

The framework also considers regional specificities such as the presence of hierarchical leadership models in Southeast Europe, low tolerance for ambiguity, and the dominant influence of founders in SME environments.

The methodology relies on a mixed-methods approach combining:

- Qualitative interviews with SMEs employees and managers (to explore subjective experiences with AI in the workplace)
- Quantitative surveys adapted from OCAI and GGCT (to generate comparable cultural profiles)
- A mapping of AI adoption stages across participating firms, allowing clustering by maturity level

This integrated approach enables both the measurement of organizational culture and the identification of patterns associated with AI integration. It aims to empower business leaders in the region to make data-informed decisions when designing cultural interventions in AI-enabled environments.

3.1. AI and the Evolution of Workplace Norms

Cameron argues that organizational effectiveness depends more on the type of culture rather than the degree of cultural strength or alignment [11]. This suggests that for AI transformation in SMEs, the key factor is not whether a company has a strong culture, but whether its culture supports flexibility and innovation.

The emergence of artificial intelligence, as an actor in business processes, has led to significant changes in organizational norms and work practices. AI enables process optimization, better insights into customer behavior, innovation in products and services, but also reduction of business risks through demand prediction. However, this transformation of the organization is not without its attendant challenges. Organizations face trust issues, ethical issues, technical barriers, infrastructural limitations, as well as lack of motivation and employee readiness to tackle AI-driven changes. Lu and others showed that the successful integration of AI is possible, only if there is a balance between technological innovation and the preservation of an organizational culture based on human values and professional development [1].

3.2. Human-Centric Design Principles in AI Integration

AI tools like ChatGPT can enhance psychological safety by reducing cognitive load and fostering collaboration. Automation of repetitive tasks, covered by AI tools, allows employees to work more efficiently, minimizing burnout and fear of failure. Additionally, implementation of AI tools in everyday work routine, complements human skills by aiding brainstorming and drafting, enabling employees to focus on creative and strategic thinking. Moreover, ChatGPT supports workplace inclusivity by helping those with weaker communication skills articulate ideas effectively. This reduces anxiety, expands career opportunities, and promotes a psychologically safe environment where employees feel more confident expressing themselves [12]. Prior studies lack empirical evidence on AI's direct impact on workplace efficiency. This study fills that gap by providing controlled experimental results.

An increase in trust in AI correlates with a decrease in critical thinking, while more confident employees exhibit stronger critical thinking, and qualitatively, Generative AI shifts the employee's focus away from confident critical thinking, changing the nature of critical thinking from thinking to information verification, response validation, and response integration. At the end instead of solving tasks, the job looks more and more like task stewardship [13]. As stated in [14] the side effect of the introduction of automation is the atrophied cognitive musculature of the users of automation. Namely, by introducing the automation of routine tasks, and leaving the human user to handle exceptions only, the user remains deprived of the opportunity to practice reasoning, expand his experience on simple challenges, and therefore becomes unprepared for handling exceptions.

The application of artificial intelligence in companies shows revolutionary effects in many segments, encouraging the transition of production even in

traditionally inert industries. The production processes and methods of companies are undoubtedly being re-examined, and are beginning to be largely automated. Parallel to this process of productivity growth and positive expectations from the implementation of AI in production, there is a growing concern and initiation of debates at different levels about the potential of artificial intelligence to lead to job losses in many professions, as well as to cause wage stagnation for most workers [15]. Toral examination of the impact of AI technology on the productivity and employment of companies becomes an indispensable topic.

4. RESULTS

Although this research is still in its early stages, the expected outcomes are grounded in the conceptual framework developed through a comprehensive literature review as well as research proposal and validated methodology approach. The anticipated results of applying the proposed methodology include the following:

1. Identification of Key Cultural Dimensions Influenced by AI

The study is expected to reveal that leadership style, employee empowerment, communication practices, and professional development are among the most sensitive cultural areas impacted by AI integration. In SMEs, where organizational identity is often closely tied to the founder or a small leadership team, AI adoption is likely to reshape traditional leadership models and influence trust dynamics across teams.

2. Mapping of AI-Culture Interaction Patterns

By combining insights from interviews and surveys, the research aims to uncover how different levels of AI maturity correlate with specific cultural traits. For instance, organizations with higher AI integration may exhibit stronger orientation toward autonomy, digital collaboration, and task ownership, but potentially face challenges with cohesion and identity in remote or hybrid settings.

3. Emerging Metrics for AI-Aligned Culture Assessment

The development of adjusted measurement instruments based on OCAI and Grid-Group Cultural Theory is expected to provide a tailored set of indicators for evaluating organizational culture in AI-enabled environments. These may include metrics related to algorithmic transparency, AI literacy, perception of fairness in automated decisions, and employee adaptability to continuous technological change.

4. Regional Cultural Factors as Moderators

In the Southeast European context, it is anticipated that certain cultural constants, such as high power distance, centralized decision-making, and reactive change behavior, will moderate the effects of AI on organizational culture. This interaction between AI-driven change and regional cultural tendencies is likely to produce unique adaptation trajectories for software SMEs in the region.

5. Recommendations for Culturally Sensitive AI Adoption

Based on the findings, the research will offer guidelines for business leaders and policymakers aiming to implement AI tools in a way that aligns with, rather than disrupts, the core values and social fabric of their organizations. Emphasis will be placed on designing human-centered AI strategies that support professional growth, inclusivity, and psychological safety.

Ultimately, the expected results should contribute to both theoretical understanding and practical implementation by providing a nuanced map of how artificial intelligence reshapes culture in software SMEs, and how that transformation can be measured, guided, and optimized.

4. CONCLUSION

Artificial intelligence is no longer a peripheral or experimental component of modern organizations—it is becoming a central force that redefines how people work, interact, learn, and make decisions. While the benefits of AI for productivity and automation are widely recognized, its deeper cultural implications remain underexplored, particularly within the context of small and medium-sized enterprises in Southeast Europe.

This paper has highlighted the need for regionally grounded, culturally sensitive approaches to understanding how AI transforms organizational culture. Existing models of cultural assessment, while valuable, must be adapted to reflect the dynamics introduced by algorithmic systems, remote collaboration, and AI-driven workflows.

The proposed conceptual framework and methodological design aim to fill a gap in current research by offering both a theoretical lens and practical tools for evaluating AI's impact on shared values, leadership styles, communication patterns, and employee empowerment. Moreover, the focus on Southeast Europe introduces a much-needed regional perspective that acknowledges local cultural norms, economic conditions, and leadership structures.

For business leaders and policymakers, this work emphasizes the importance of aligning technological innovation with human-centered cultural strategies. Instead of seeing AI as a driver of disruption, it should be positioned as a catalyst for cultural evolution, one that enhances trust, autonomy, and adaptability across the organization.

Future empirical research based on this foundation will be critical in validating and refining the proposed models. In a time of unprecedented transformation, understanding and guiding the cultural shifts induced by AI is not just an academic challenge, it is a strategic imperative.

REFERENCES

[1] X. Lu, K. Wijayaratna, Y. Huang, and A. Qiu, 'AI-Enabled Opportunities and Transformation Challenges for SMEs in the Post-pandemic Era: A Review and Research Agenda', *Front. Public Health*, vol. 10, Apr. 2022, doi: 10.3389/fpubh.2022.885067.

[2] K. Garg, 'Impact of Artificial Intelligence on software development: Challenges and Opportunities', *Int. J. Softw. Hardw. Res. Eng.*, vol. 11, no. 8, Aug. 2023, doi: 10.26821/IJSHRE.11.8.2023.110801.

[3] S. Morandini, F. Fraboni, M. D. Angelis, G. Puzzo, D. Giusino, and L. Pietrantoni, 'The Impact of Artificial Intelligence on Workers' Skills: Upskilling and Reskilling in Organisations', *Informing Sci. Int. J. Emerg. Transdiscipl.*, vol. 26, pp. 039–068, Feb. 2023.

[4] B. Taskan, A. Junça-Silva, and A. Caetano, 'Clarifying the conceptual map of VUCA: a systematic review', *Int. J. Organ. Anal.*, vol. 30, no. 7, pp. 196–217, Jul. 2022, doi: 10.1108/IJOA-02-2022-3136.

[5] J. Ahmed, B. Mrugalska, and B. Akkaya, 'Agile Management and VUCA 2.0 (VUCA-RR) During Industry 4.0', in *Agile Management and VUCA-RR: Opportunities and Threats in Industry 4.0 towards Society 5.0*, B. Akkaya, M. W. Guah, K. Jermsittiparsert, H. Bulinska-Stangrecka, and Y. Kaya, Eds., Emerald Publishing Limited, 2022, pp. 13–26. doi: 10.1108/978-1-80262-325-320220002.

[6] J. R. L. Kaivo-oja and I. T. Lauraeus, 'The VUCA approach as a solution concept to corporate foresight challenges and global technological disruption', *foresight*, vol. 20, no. 1, pp. 27–49, Mar. 2018, doi: 10.1108/FS-06-2017-0022.

[7] G. Buchashvili, K. Djakeli, and A. Kazaishvili, 'Leadership Challenges and the Role of Education in Forming Leaders in VUCA World', in *Agile Management and VUCA-RR: Opportunities and Threats in Industry 4.0 towards Society 5.0*, B. Akkaya, M. W. Guah, K. Jermsittiparsert, H. Bulinska-Stangrecka, and Y. Kaya, Eds., Emerald Publishing Limited, 2022, pp. 161–168. doi: 10.1108/978-1-80262-325-320220011.

[8] H. Y. Turan and H. Cinnioğlu, 'Agile Leadership and Employee Performance in VUCA World *', in *Agile Management and VUCA-RR: Opportunities and Threats in Industry 4.0 towards Society 5.0*, B. Akkaya, M. W. Guah, K. Jermsittiparsert, H. Bulinska-Stangrecka, and Y. Kaya, Eds., Emerald Publishing Limited, 2022, pp. 27–38. doi: 10.1108/978-1-80262-325-320220003.

[9] 'Future of Jobs Report 2025', World Economic Forum, Jan. 2025. [Online]. Available: https://reports.weforum.org/docs/WEF_Future_of_Jobs_Report_2025.pdf

[10] S. Peng, E. Kalliamvakou, P. Cihon, and M. Demirer, 'The Impact of AI on Developer Productivity: Evidence from GitHub Copilot', Feb. 13, 2023, *arXiv*: arXiv:2302.06590. doi: 10.48550/arXiv.2302.06590.

[11] K. S. Cameron, 'The Conceptual foundation of organizational culture', Working Paper, 1988. Accessed: Feb. 28, 2025. [Online]. Available: http://deepblue.lib.umich.edu/handle/2027.42/35462

[12] S. Noy and W. Zhang, 'Experimental evidence on the productivity effects of generative artificial intelligence', *Science*, vol. 381, no. 6654, pp. 187–192, Jul. 2023, doi: 10.1126/science.adh2586.

[13] L. Hank, Sarkar, Advait, Tankelevitch, Lev, Drosos, Ian, and Rintel, Sean, 'The Impact of Generative AI on Critical Thinking: Self-Reported Reductions in Cognitive Effort and Confidence Effects From a Survey of Knowledge Workers', 2025.

[14] L. Bainbridge, 'IRONIES OF AUTOMATION', in *Analysis, Design and Evaluation of Man–Machine Systems*, G. Johannsen and J. E. Rijnsdorp, Eds., Pergamon, 1983, pp. 129–135. doi: 10.1016/B978-0-08-029348-6.50026-9.

[15] E. Brynjolfsson and A. McAfee, 'Will Humans Go the Way of Horses', *Foreign Aff.*, vol. 94, p. 8, 2015.

DRIVING INNOVATION THROUGH INTELLIGENT AUTOMATION

Dragan Metikoš, Simplify, dragan@simplify.rs

Abstract: *Intelligent automation (IA) represents a significant evolution in the field ov automation, using artificial intelligence (AI), machine learning (ML), and robotic process automation (RPA) to drive operational efficiency, drive innovation and reshape business models. This paper explores the impact of AI on business processes, highlighting its role in business transformation. AI provides organizations with the opportunity to reduce costs, increase productivity and improve accuracy, as well as create time and resources that can be redirected to more strategically important activities and innovation. IA also brings certain challenges and ethical considerations. This paper provides insight into how IA enables organizations to optimize repetitive, manual, and high-volume business processes, drive innovation in product and service development, and reach strategic goals. In addition, this paper highlights that IA is not just a too for process automation but also a catalyst for innovation in business models and organizational structures. It also highlights that the integration of IA into business is essential for maintaining competitive advantage*.

Keywords: *Intelligent automation, Artificial intelligence, Machine learning, Business processes, Innovation*

1. INTRODUCTION

1.1 What is Intelligent Automation?

IA, often referred to as hyperautomation, is a concept that employs a new generation of software automation. It combines methods and technologies to automate business processes instead of relying on human employees. This form of automation mimics human capabilities in performing those activities (e.g., language, vision, reasoning, learning, processing). The goal of using IA is to achieve desired outcomes through redesigned, automatically executed processes with minimal or no human intervention. As a result, IA increases process speed, reduces costs, improves compliance and quality, enhances process resilience, and optimizes decision-making outcomes. All of this ultimately leads to higher customer and employee satisfaction and increased organizational revenue. IA focuses on automating processes that require a level of reasoning and analysis, which are more commonly found in service industries compared to manufacturing [1].

This paper presents the concept of intelligent automation (IA) and its impact on business processes and innovation. It highlights the significant benefits IA provides, such as increased efficiency, cost reduction, and quality improvement, while also addressing the challenges and ethical aspects that accompany its implementation.

The remainder of this paper is organized as follows: Chapter 2 illustrates the role of IA in driving innovation, emphasizing how IA frees up resources and time, enabling employees to focus on creative and innovative activities. Chapter 3 presents examples of IA applications across various industries, such as healthcare and workplace safety, where IA plays a crucial role in improving processes and reducing risks. Chapter 4 discusses the importance of regulation in the context of IA implementation, including frameworks like the EU AI Act, ISO 42001, and ISO 27001, and emphasizes the need for compliance. Finally, the last chapter provides conclusions and explores the future of IA in the context of responsible application and technological development.

2. THE ROLE OF IA IN DRIVING INNOVATION

Two main examples can be highlighted to show how IA can impact innovation. The first is through freeing up time and organizational resources that can be redirected toward innovation. For a large percentage of employees, most tasks performed involve some form of routine. Routine tasks such as entering data into business systems or analyzing and reviewing information are often carried out in the same way. By automating such processes, space is created for certain employees to be reassigned to tasks that involve greater creativity and innovation. Data analysis powered by machine learning gives employees more time to turn insights into innovative products and services. For example, Google encourages its engineers to spend 20% of their workweek on creative projects.

Another advantage in this context is that IA helps organizations face market uncertainties and business cycles. These uncertainties can hinder company progress due to the need for hiring new talent during growth periods or downsizing during downturns. IA provides a virtual workforce that can be scaled with a lower level of investment and minimal disruption to operations [2].
The second example is that IA supports the enhancement of employee competencies and enables the analysis of large datasets, thus facilitating a more efficient research and

innovation process. Compared to traditional training techniques, where employees learn a fixed set of topics and lessons—some of which may never be applied or remembered long term—IA can offer customized lessons on demand. Employees can receive information in the form that best suits their learning style, with relevant data and examples, leading to a more efficient learning model and quicker access to the necessary information for their work.

The concept of incorporating IA into employee development combines the benefits of instructor-led group training and networking with the advantages of self-directed learning and personalized experiences, all within a psychologically safe yet competitive environment that encourages employees to step out of their comfort zones and strive for new skills. In addition, scalability plays a key role in creating larger teams that can be redirected toward innovation. IA enables training to be available simultaneously across various locations and time zones, with materials provided in different languages, and lessons tailored to business areas, departments, competencies, and team experience levels [2].

3. EXAMPLES OF IA APPLICATION

3.1 Occupational Illnesses and Workplace Accidents

The International Labour Organization (ILO) estimates that the global economic cost of work-related accidents, illnesses, and injuries due to stress alone amounts to a staggering $3 trillion annually. IA can play a significant role in monitoring stress levels, reducing workload, taking over more strenuous and high-risk tasks, and leaving the most engaging and creative activities to employees. Overall, analysis in this area suggests that IA has the potential to achieve total savings of approximately $10 trillion per year. This amount is roughly equivalent to the combined annual global spending on healthcare and education. Of course, such benefits cannot be achieved within just 5–10 years. A more realistic estimate is that it will take 10–20 years. If we assume that 50% of these savings can be realized over the next 10 years and redirected through regulation, taxation, and other mechanisms, the $5 trillion in savings enabled by IA could allow for:

1. Doubling the global education budget.
2. Increasing global healthcare budgets by over 70%.
3. Increasing environmental protection investments nearly 20-fold.
4. Ending global hunger and malnutrition.

3.2 Preventing Deaths from Non-Communicable Diseases Through Enhanced Research

Chronic, non-communicable diseases account for more than 70% of global deaths. The leading cause in this category, responsible for a third of all deaths, is cardiovascular disease, followed by cancer, diabetes, and several respiratory illnesses. A common denominator in all these causes is the essential role of research in discovering cures. Machine learning's ability to support documentation and research validation can be critical in clinical trials. Another feature of non-communicable diseases is the higher recovery rate when detected early. Diagnosis is a domain where machine learning can offer substantial benefits.

For example, machine learning has demonstrated the ability to analyze thousands of lung or breast scans and identify cancer with over 80% accuracy—surpassing the accuracy of many physicians. ML also brings the advantage of speed: whereas a diagnosis might take doctors hours to perform, ML systems can process scans in minutes or even seconds. For instance, acute kidney injury (AKI) is estimated to cause 2 million deaths annually worldwide. AKI is difficult to diagnose for several reasons and is typically detected only in its late stages. The current method for detecting AKI involves daily evaluation of lab test results over several weeks. Using IA, AKI can be detected two days earlier compared to traditional approaches.

3.3 Employee Demotivation

After the COVID-19 crisis, remote work became a major challenge for many organizations—due to isolation, lack of support, constant distractions, limited ability to disconnect, and anxiety caused by the global crisis. This significantly impacted employee motivation, efficiency, work-life balance, and contributed to stress and mental and physical health issues. Leading companies have used IA to ensure employee safety, connectedness, and access to essential remote work tools. They also leveraged analytics to support process transparency and remote work tracking.

Additionally, they used downtime to provide reskilling and training on key topics, including future IA-related competencies. This made employees more resilient to future crises and more open to continuous learning and development [1].

4. THE IMPORTANCE OF REGULATION IN IA

As organizations increasingly adopt intelligent automation, it is essential that implementation aligns with applicable regulations and security standards. Regulations such as the EU AI Act issued by the European Union, ISO 42001, ISO 27001, and various ethical guidelines shape how IA is developed, applied, and governed. These frameworks ensure that automation technologies are used in ways that are transparent, secure, and ethically responsible. Therefore, organizations must become familiar with and understand these regulations in order to implement IA safely [3].

4.1 EU AI Act

The EU AI Act, proposed in April 2021, aims to regulate artificial intelligence systems within the European Union. Its goal is to encourage the development of AI technologies while ensuring their ethical and safe use. The regulation categorizes AI systems based on the risk they pose to fundamental rights and safety, introducing tailored requirements for each category. The categories include high-risk, limited-risk, and minimal-risk AI systems.

For organizations implementing AI, the EU AI Act provides a clear framework for ensuring that their systems adhere to core principles such as transparency, accountability, non-discrimination, and safety. It is important to note that beyond the risk of compromising internal safety or the safety of users of products and services, organizations also face financial penalties for non-compliance. For instance, failure to meet requirements for high-risk AI systems can result in fines of up to €30 million or 6% of the company's total global annual turnover—whichever is greater [4].

4.2 ISO 42001

The ISO/IEC 42001:2023 standard provides guidelines for managing AI risks and establishing a framework for AI governance within organizations. It helps businesses develop policies, procedures, and mechanisms for managing AI projects, ensuring that AI systems are developed and deployed in a controlled and secure environment. The standard covers aspects such as design, testing, implementation, and maintenance of AI systems, making it particularly relevant for organizations seeking to scale intelligent automation.

By following the ISO 42001 guidelines, businesses can mitigate the risks associated with deploying AI in critical business functions, such as automated decision-making or handling sensitive data [5].

4.3 ISO 27001

ISO/IEC 27001:2022 focuses on information security management systems (ISMS) and plays a key role in securing AI implementation. IA heavily depends on data, making cybersecurity a top priority. ISO 27001 provides a framework for managing information security risks, protecting data privacy, and ensuring compliance with regulatory requirements such as the General Data Protection Regulation (GDPR) in Europe [6].

5. CONCLUSION

Intelligent Automation (IA) is a major driver in modernizing business processes, enabling organizations to achieve higher levels of efficiency, cost savings, and innovation. By leveraging technologies such as artificial intelligence, machine learning, and robotic process automation, IA not only automates routine tasks but also facilitates the creation of new, innovative business models. This technological advancement also presents an opportunity to free up time and resources that can be redirected to more strategically important activities, such as the development of new products and services.

However, for IA to be successful and sustainable, it is essential that organizations implement these systems in accordance with regulatory standards that ensure security, ethical practices, and transparency. Regulations such as the EU AI Act, ISO 42001, and ISO 27001 play a crucial role in this process. They provide a clear framework for managing the risks that may arise during IA implementation, as well as for protecting data and privacy. By adhering to these standards, organizations can ensure that their IA systems are developed and deployed responsibly, avoiding negative consequences such as bias or decision-making failures.

Given that the use of IA will only continue to expand in the future, the importance of regulation and ethical principles will likewise grow. In this context, this paper demonstrates that a responsible approach to IA integration—one that aligns with legal and ethical standards—is key to ensuring sustainable development and maintaining a competitive edge in the digital age.

REFERENCES

[1] Pascal B., Barkin I., Wirtz J., "INTELLIGENT AUTOMATION: Learn how to harness Artificial Intelligence to boost business & make our world more human", 2020.

[2] Myers M., Brace C., Carden L., "INTELLIGENT AUTOMATION: Bridging the Gap between Business and Academia", CRC Press, 2024.

[3] Nyholm S., "HUMANS AND ROBOTS: Ethics, Agency, and Anthropomorphism", London, United Kingdom, 2020.

[4] Official Journal of the European Union, "REGULATION (EU) 2024/1689 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL", 2024.

[5] ISO/IEC 42001:2023, "Information technology – Artificial intelligence – Management system", 2023.

[6] ISO/IEC 27001:2022/Amd 1:2024, "Information security, cybersecurity and privacy protection – Information security management systems – Requirements", 2024.

TACKLING DATA SCARCITY IN AI: A COMPARATIVE ANALYSIS OF DATA AUGMENTATION AND SYNTHETIC DATA GENERATION

Nikola Vojtek, Smart Consulting Agency | Daon, nikola@smartconsulting-agency.com
Bojan Smudja, Agile Frogg, bojan.smudja@gmail.com

Abstract: *With the rising trend of artificial intelligence (AI) usage in almost every industry, Data Scarcity is becoming one of the challenges organizations face more and more often. Data Scarcity represents scenarios where the available dataset is too limited to train models reliably. This can cause overfitting and poor generalization because the model will not have enough variation during the training phase. One of the solutions is Data augmentation, which involves applying transformations or modifications (e.g., rotations, noise injection in images, or paraphrasing in text) to the existing data, thus creating more examples. The other solution that is becoming more popular recently is synthetic data generation. It leverages the power of generative models (like GANs, Variational Autoencoders, or even advanced language models) to create entirely new data points. This paper compares traditional data augmentation methods with modern synthetic data generation techniques. It highlights the potential biases introduced when generating synthetic data and provides a comparison of a research study with genuine data points versus one that incorporates synthetic data.*

Keywords: *artificial intelligence, project management, data scarcity, machine learning, synthetic data.*

1. INTRODUCTION

With the rising trend of artificial intelligence (AI) usage in almost every industry, Data Scarcity is becoming one of the challenges organizations face more and more often. AI has revolutionized many industries, automated many complex processes, and enabled data-driven decision making to be more accessible and smoother. To enable these advancements, diverse datasets are crucial for training robust AI models [1]. However, data scarcity remains a critical barrier. Data scarcity represents a situation in which available genuine dataset is insufficient either in size or diversity for training the models [2], which could lead to challenges such as overfitting or reduced generalization. It could cause a model to memorize training samples, rather than learning underlying patterns, which will at the end result in poor performance.

In project management, more specifically in resource allocation and utilization, accurate forecasting and decision making are essential [3], and it could be reinforced with the proper use of A tools. The situation "in the field" is that data are either limited, or it is very hard and challenging to extract usable data. Thus, it could be said that data scarcity represents a significant challenge when it comes to project management and training the proper AI models that could aid in project forecasting, execution and decision making.

Decision makers need to overcome data scarcity and collect reliable data for training the AI models. One of the solutions represents a Data augmentation, which involves applying transformations or modifications (e.g., rotations, noise injection in images, or paraphrasing in text) to the existing data, thus creating more examples [4]. The other solution that is becoming more popular recently is synthetic data generation. It leverages the power of generative models (like GANs, Variational Autoencoders, or even advanced language models) to create entirely new data points [5].

Despite the growing interest in data augmentation and synthetic data generation, there is limited research on their application, especially if applied in the project management field. This paper aims to compare traditional data augmentation methods with modern synthetic data generation techniques. It highlights the potential biases introduced when generating synthetic data and provides a comparison of a research study with genuine data points versus one that incorporates synthetic data.

The remainder of this paper is organized as follows: Section 2 provides the comparison of data augmentation and synthetic data generation approaches. Section 3 contains the explanation of the experiment conducted using the data from the survey conducted in the first quarter of 2025. Results of the experiment are summarized in Section 4. Finally, the last section concludes with implications and future research directions.

2. PROBLEM STATEMENT

This section provides the comparison of data augmentation and synthetic data generation approaches, and highlights the potential biases introduced when generating synthetic data. When it comes to the project management, decision makers are facing different challenges of limited data including historical task logs, performance metrics, risk

records, time-tracking and logging, etc [6]. To generate actionable insights in these situations, data augmentation and synthetic data generation could be used.

2.1 Data Augmentation in Project Management

In project management, data augmentation could be used to "stretch" existing project management datasets. This is accomplished by applying transformations to real project records using some of the available techniques and approaches such as time series (scaling durations), adjustments of categorical fields (oversampling rare issue types), paraphrasing risk descriptions or even meeting minutes.

As stated in [7], some of the pros using the data augmentation approach is that it is not complex and it could be faithful to original distributions. On this other side, it could be very limited when it comes to the introduction of truly novel scenarios.

2.2 Synthetic Data generation in Project Management

When it comes to the generative models, their advantage could be observed through their ability to fabricate entirely new project-management records. Generative models are focused on learning the joint distribution and context of project features to create samples of new instances [8]. Different models are available to be used for generating new data and supporting the decision making process, such as Generative Adversarial Networks (GANs), Variational Autoencoders (VAEs), or Transformer-based language models (LMs).

GAN works by confronting two neural networks against each other in a minimax game, thereby learning an implicit model of the data-generating process and the context of the challenge. GANs could be adapted to both sequential (time-series) and tabular project-management data to produce realistic synthetic records when historical logs are scarce. Examples could be seen in [1].

VAEs could be explained as a smart "data compressor and generator". Applied in the project management context, it will first learn the most important patterns hidden in the existing data such as budget, duration of activities, risks, etc [9]. Then, it will use those learned patterns to create new realistic data points, such as project timelines or cost estimates. This means that project managers could apply VAE for taking a small set of historical metrics, let it learn what really drives the project outcomes, and then expand the dataset with machine-generated examples with the aim of improving forecasting, risk analysis or resource planning and allocation. VAEs could surface unseen combinations and different patterns of risks, tasks durations and/or resource allocations. On the other hand, training costs could be significant, and there could be potential over- or under-representation of edge cases [9].

2.3 Comparison

Since we initially introduced both data augmentation and main synthetic data generation algorithms, comparison is briefly provided in this section. Synthetic data generation techniques unlock a wider range of scenarios—making them especially valuable in project management—whereas data augmentation often wins on lower computational and implementation overhead [10].

Data augmentation and synthetic generation could be both beneficial in different project-management contexts. Data augmentation could provide best results when there are moderate-sized logs of task durations, resource hours, or issue types and need quick, low-overhead improvements. Synthetic data generation algorithms are ideal when historical records miss critical edge cases, such as rare risk events or atypical resource allocations, or when "what-if" scenarios need to be explored.

2.4 Potential biases with synthetic data generation

Some of the potential biases with synthetic data generation could be:

- Mode Collapse: produce repeatedly very similar project scenarios, limiting the variety of outcomes that could be analyzed. More about this could be found in [11]
- Bias Amplification: If historical data already favors certain project types or teams, synthetic data can reinforce that skew and distort future insights. More about this could be found in [12]
- Distribution Mismatch: Generated metrics might not match real business data patterns, leading to forecasts that miss the mark [13].
- Temporal & Structural Artifacts: Generated timelines may violate real-world task sequences or dependencies, resulting in implausible schedules. More about this bias could be found in [14].

Since people have distanced themselves from the process of decision-making, they need to know for sure that the decisions these systems make are in no way biased or discriminatory. To tackle the bias, AI has to be supervised.

3. SOLUTION

With the aim of showcasing the difference in using the genuine data and synthetically generated data, experiment is conducted and results are shown in this section. Data from the survey conducted in the first quarter of 2025 was used. The survey was part of the wider research that is covering artificial intelligence and its applications in project management. Like in any decision making process, data will be used for making decisions regarding the usage of AI tools for reporting, metrics, time automation and optimization. For this experiment, only the 3 main questions and results from the survey were used, and the impact of how synthetic data can alter the overall results was measured.

The 3 questions that were asked to participants of the survey, that were multiple choice questions were:

1. Which project management tool do you reach for every day?
2. A stakeholder requests an update on project progress. How often do you find yourself preparing a report?
3. Your report is ready—how do you usually present your findings?

3.1 Results obtained using only genuine data points

All answers were given by the Project Manager and population in the related roles, and their responses showed logical consistency with the standard job role description. No answer had an illogical tooling set, conspicuous intervals of reporting, or an unorthodox way of presentation.

Considering tools that project managers use every day, Jira (Atlassian) and MS Project are both leading with 56.1% and 54.5% responses respectively. We also have Trello with 13% of responses.
When it comes to the project reporting intervals, there are mostly three periods that are part of the standard reporting pattern - weekly (35%), bi-weekly (18.7%) and monthly (24.4%).

Finally, when it comes to presenting the findings/status, the first choice is the slide deck (MS Power point, Google slides, etc.) with 35% of respondents. Additional approaches are Spreadsheets (10.6%), Structured document (9.8%) and email summary (9.8%).

3.2 Results including synthetically generated data without bias

In this scenario, synthetic data generation is performed, but without providing the existing genuine data points to the algorithms. Different versions of the algorithms were used and data was aggregated.

Responses on Project Management Tools with synthetically generated data are now significantly reduced when it comes to the two top choices: Jira (56.1% -> 48.43%), MS Project (54.5% -> 47.53%), and slightly decreased in the case of Trello (13% -> 12.33%).

Responses on reporting intervals are not changed significantly: weekly (35% -> 33.18%), bi-weekly (18.7% -> 18.18%) and monthly (24.4% -> 24.09). This could be considered as a small decrease.

Responses on Status/Findings Presentations are significantly decreased regarding slide decks usage (35% -> 30.72%), but not that much for the rest where there are small decreases Spreadsheets (10.6% -> 10.31%), Structured document (9.8% -> 9.42%) and email summary (9.8% -> 9.64%).

3.3 Results including synthetically generated data based on genuine data (bias)

In this scenario, synthetic data generation is performed, and existing genuine data points were provided to the algorithms. Different versions of the algorithms were used and data was aggregated.

Responses on Project Management Tools with synthetically generated data are not significantly changed: Jira (56.1% -> 54.48%), MS Project (54.5% -> 52.02%), and slightly increased in the case of Trello (13% -> 13.45%).

Responses on reporting intervals are decreased more compared to using the non biased data points: weekly (35% -> 33.03%), bi-weekly (18.7% -> 18.65%) and monthly (24.4% -> 22.92). This could be considered as a small decrease.

Similar as with the previous scenario, responses on Status/Findings Presentations are significantly decreased regarding slide decks usage (35% -> 31.91%), and with only a small decrease for Structured document (9.8% -> 9.66%) and email summary (9.8% -> 9.44%). When it comes to the Spreadsheets, we have a small increase in usage from 10.6% to 11.01%.

3.4 Overall comparison

Considering all three questions, overall comparisons are provided in the next tables respectively.

Table 1. Comparison of the results for question 1

	Genuine	Nonbiased	Biased	Delta Non-biased from Genuine	Delta biased from Genuine
Jira	56.10%	48.43%	54.48%	-7.67%	-1.62%
MS Project	54.50%	47.53%	52.02%	-6.97%	-2.48%
Trello	13.00%	12.33%	13.45%	-0.67%	0.45%

Table 2. Comparison of the results for question 2

	Genuine	Nonbiased	Biased	Delta Non-biased from Genuine	Delta biased from Genuine
Weekly	35.00%	33.18%	33.03%	-1.82%	-1.97%
Monthly	24.40%	24.09%	22.92%	-0.31%	-1.48%
bi-Weekly	18.70%	18.18%	18.65%	-0.52%	-0.05%

Table 3. Comparison of the results for question 3

	Genuine	Nonbiased	Biased	Delta Non-biased from Genuine	Delta biased from Genuine
Slide deck	35.00%	30.72%	31.91%	-4.28%	-3.09%
Spreadsheet	10.60%	10.31%	11.01%	-0.29%	0.41%
Structured document	9.80%	9.42%	9.66%	-0.38%	-0.14%
email summary	9.80%	9.64%	9.44%	-0.16%	-0.36%

Based on the results and comparison provided, it can be concluded that utilizing AI to generate synthetic data in project management could be a valuable and effective solution when sufficient data is lacking for decision-making. The decision to use an approach based on synthetic (and potentially biased) data or non-biased data will ultimately depend on the specific context.

4. CONCLUSION

This paper addresses the issue of data scarcity, where the available genuine dataset is either too small or lacks diversity to effectively train models for use in decision-making processes. To tackle this problem, two approaches were analyzed and compared: data augmentation, which involves applying transformations or modifications (such as rotations, noise injection in images, or paraphrasing in text) to enhance the existing data, and synthetic data generation, which utilizes generative models like Generative Adversarial Networks (GANs), Variational Autoencoders (VAEs), or advanced language models.

When dealing with synthetic data generation, one crucial consideration is bias, as decisions derived from biased data can lead to unfair or discriminatory outcomes. To mitigate this bias, AI systems must be closely monitored, especially when synthetic data generation is applied in project management contexts. This was demonstrated through an experiment where three survey questions were used, and the results were compared with genuine responses.

For the purpose of comparison, three scenarios were analyzed. In Scenario 1, only genuine data points were used; in Scenario 2, synthetic data was generated without any genuine data provided to the algorithms; and in Scenario 3, synthetic data generation was based on genuine data, introducing a potential bias.

When using genuine data to generate additional responses, the answers align more closely with real-world project management practices. Some tools mentioned may be new and previously unknown, but the majority are standard and widely used. The intervals fall within the expected range for organizations, and the presentation style closely mirrors the genuine responses from the survey.

In contrast, when generating data without any genuine responses, the results tend to be more one-dimensional and simplistic. Certain tools, such as Monday and ClickUp, which were rarely mentioned in genuine surveys, appear significantly more often. For the second question, the generated answers show a stronger emphasis on sprint endings, reflecting a bias toward IT and Scrum methodologies. Meanwhile, the third question is answered in a much more simplified manner compared to the actual responses, revealing the greatest differences.

In conclusion, using genuine data to generate more synthetical data (responses), produces results that are more aligned with real-world project management practices, while synthetic data generation without genuine data points tends to simplify responses and introduce more variations. This highlights the importance of monitoring the process of synthetic data generation to ensure it accurately reflects the context and avoids introducing distortions.

Further steps should include refining the AI models to incorporate more diverse and representative datasets, along with implementing stronger supervision mechanisms during synthetic data generation. Additionally, it is crucial to evaluate the impact of synthetic data on decision-making processes in different industries, ensuring the generated insights are reliable and valid for practical use.

REFERENCES

[1] Goodfellow, I., Pouget-Abadie, J., Mirza, M., Xu, B., Warde-Farley, D., Ozair, S., Courville, A., & Bengio, Y. (2014). Generative Adversarial Nets. Advances in Neural Information Processing Systems, 27.
[2] Ms. Aayushi Bansal, Dr. Rewa Sharma, and Dr. Mamta Kathuria. 2022. A Systematic Review on Data Scarcity Problem in Deep Learning: Solution and Applications. ACM Comput. Surv. 54, 10s, Article 208 (January 2022), 29 pages. https://doi.org/10.1145/3502287
[3] Vojtek, N., Smuđa, B., & Milošević, P. (2023). A Novel Approach to the Team Estimations in the Agile Software Development. In M. Mihić, S. Jednak, & G. Savić (Eds.), Sustainable Business Management and Digital Transformation: Challenges and Opportunities in the Post-COVID Era (Lecture Notes in Networks and Systems, Vol. 562). Springer, Cham. https://doi.org/10.1007/978-3-031-18645-5_18
[4] Shorten, C., & Khoshgoftaar, T. M. (2019). A survey on image data augmentation for deep learning. Journal of Big Data, 6, 60. https://doi.org/10.1186/s40537-019-0197-0
[5] Alzubaidi, L., Bai, J., Al-Sabaawi, A. et al. A survey on deep learning tools dealing with data scarcity: definitions, challenges, solutions, tips, and applications. J Big Data 10, 46 (2023). https://doi.org/10.1186/s40537-023-00727-2
[6] Idri, I., Abnane, I., & Abran, A. (2016). Missing data techniques in analogy-based software development effort estimation. Journal of Systems and Software, 117, 595–611. https://doi.org/10.1016/j.jss.2016.04.058
[7] Käppel, M., & Jablonski, S. (2023). Model-agnostic event log augmentation for predictive process monitoring. In D. Fahland, C. Ghidini, J. Becker, & M. Dumas (Eds.), Business Process Management: International Conference, BPM 2023 (Lecture Notes in Computer Science, Vol. 11675, pp. 381–397). Springer. https://doi.org/10.1007/978-3-031-34560-9_23
[8] T. Bakici, A. Nemeh and Ö. Hazir, "Big Data Adoption in Project Management: Insights From French Organizations," in IEEE Transactions on Engineering Management, vol. 70, no. 10, pp. 3358-3372, Oct. 2023, doi: 10.1109/TEM.2021.3091661
[9] Kingma, D. P., & Welling, M. (2013). Auto-Encoding Variational Bayes (arXiv:1312.6114). https://doi.org/10.48550/arXiv.1312.6114
[10] Antoniou, A., Storkey, A. J., & Edwards, H. (2017). Data Augmentation Generative Adversarial Networks (arXiv:1711.04340). https://doi.org/10.48550/arXiv.1711.04340
[11] Creswell, A., White, T., Dumoulin, V., Arulkumaran, K., Sengupta, B., & Bharath, A. A. (2018). Generative adversarial networks: An overview. IEEE Signal Processing Magazine, 35(1), 53–65. https://doi.org/10.1109/MSP.2017.2765202
[12] Mehrabi, N., Morstatter, F., Saxena, N., Lerman, K., & Galstyan, A. (2019). A survey on bias and fairness in machine learning. ACM Computing Surveys. https://doi.org/10.1145/3457607
[13] Xu, L., Skoularidou, M., Cuesta-Infante, A., & Veeramachaneni, K. (2019). Modeling tabular data using conditional GAN. Advances in Neural Information Processing Systems, 32. https://doi.org/10.48550/arXiv.1907.00503
[14] Yoon, J., Jarrett, D., & van der Schaar, M. (2019). TimeGAN: Generative adversarial networks for time-series data. Advances in Neural Information Processing Systems, 32. https://doi.org/10.48550/arXiv.1907.03101

USING ARTIFICIAL INTELLIGENCE IN INFORMATION TECHNOLOGY AUDITS

Dragan Jovičić, PHOENIX Pharma SE, Mannheim, Germany, dragan.r.jovicic@gmail.com
Kristijan Lazić, Argo IT, Belgrade, kristijan.lazic@gmail.com
Vladan Pantović, Faculty of Project and Innovation Management, Belgrade, vladan@pantovic.rs
Marina Jovanović-Milenković, Faculty of Project and Innovation Management, marinajovanovicmilenkovic@gmail.com
Ivan Vulić, Faculty of Project and Innovation Management, Belgrade, vulic.ivan@gmail.com

Abstract: *This paper explores challenges and opportunities that usage of artificial intelligence in the process of information technology audits could have. Emerging technologies are shaping new industrial revolution, and there is not a single organization or department that are not being impact by it. Regulatory, ethnical and resource challenges that organizations are facing need to be addressed in order to have benefits from using AI in information technology audits. Governance frameworks provide good starting point in developing and implementing AI in the IT audit process.*

Keywords: *Artificial Intelligence, Information Technology Audit, Governance frameworks, Ethics, EU AI Act*

1. INTRODUCTION

Emerging technologies are promising faster, cheaper, and more accurate analysis of massive data, resulting in an unprecedented surge in the use of these technologies in almost every aspect of the business. Rapid digitalization and increased usage of technology led to naming this phase Industry 4.0 – the Fourth Industrial Revolution.

Industry 4.0 brings these inventions beyond the previous industrial operations to a higher level, with the usage of four foundational types of new technologies that can be applied all along the processes:

1. Implementation of emerging technologies, moving to cloud technology, introduction of blockchain, usage of sensors and Internet of Things (IoT) in manufacturing,
2. data analytics and artificial intelligence processes supported by advanced analytics and machine learning,
3. interaction between humans and machines, using virtual reality and augmented reality, including robotics and automation,
4. introduction of advanced engineering, such as, 3-D printing, introduction of renewable energy [1].

This industrial revolution is changing business world and every organization and every function or department within organization is going to be impacted, including IT audit departments [2]. With this rapid advancement of technology, every business area is undergoing various challenges, and the IT audit field is no exception [1]. Traditional information technology (IT) auditing is no longer enough to cover risks that organizations are facing. IT audit plays a critical role in identifying potential threats that are coming from usage of technologies in the organizations and ensuring compliance with regulatory requirements. In this paper we will focus on Artificial Intelligence (AI), challenges, benefits and risks of using this technology in the performance of IT audits. This means that the IT audit profession must overcome challenges with implementation of AI in its operations, continually develop and adapt to a future where technology and risk are always changing [3].

2. IMPACT OF AI ON ORGANIZATIONS IT AUDIT

ISACA (Information Systems Audit and Control Association) defined IT audit main task as a performance of specific audit procedures to provide reasonable assurance about the subject matter (audited area) regarding IT, security and operational technologies. IT auditors are working on audit assignments designed to provide assurance on a different level, using methods and techniques such as interviews, testing or examination. Each IT audit must be performed in line with professional standards that only qualified individuals should perform audit assignments, how the audit is performed, what audit procedures are performed and how at the end of audit findings are going to be reported depending on various characteristics of the audit performed, nature of the results obtained and intended audience [4].

European Commission's Communication on AI defined Artificial Intelligence as systems that analyse environments and take actions by displaying intelligent behaviour to achieve goals, and these systems are in some degree have their autonomy. AI-based systems can be divided in two main groups software-based or embedded in hardware devices. Software-based refer to different

voice assistant's systems, AI powered software for image analysis, speech and face recognition systems. Hardware devices refer to advanced robotics, autonomous driving cars, Internet of Things systems used in various industries [5].

Market development shows significant increase in investments in AI in US, from 134 billion in 2023, to over 184 billion U.S. dollars in 2024. Looking at the year 2030, expected growth is going to be even faster, and the market will past 826 billion U.S. dollars [6]. Adoption of AI will impact productivity and cause labour changes worldwide. This impact is not expected to be only negative. Adoption of AI, based on some predictions, should move workers to other value-added industries from simple manual labour-intensive ones. These industry shifts should lead to a more productive economy.

Expectations from the various stakeholders in the organization put pressure on IT audit, to shift labour-intensive and repetitive audit tasks, which are performed manually, to be performed with use of AI. It is expected that auditors will understand what AI offers, what are the potential use case scenarios, possibilities to perform faster audit tasks, to minimize human errors and bias by overcoming limitations that are coming from sampling, to use AI to examine entire population of transactions, and at the end to have lower audit costs. Significant changes in professional practices, and adoption of AI in auditing process can be seen as significant change, create unique challenges for both audit professionals and governing bodies. These challenges are directly connected with whether auditors are ready for technological advancements, whether they want to adapt their approach to new audit tasks, and how the ethical considerations of utilizing AI in their work are performed [7].

3. CHALLENGES RELATED TO THE USE OF AI IN IT AUDITS

There are challenges in using AI in IT audits, and adoption of AI needs to overcome a lot of challenges before the organizations could implement and use AI. These challenges vary from regulatory, organizational and resource point of view.

3.1 Regulatory challenges – EU Artificial Intelligence act

The European Union was first to adopt regulation of AI (in the world) as it became aware of emerging risks associated with the implementation and usage of AI. The European Union, on June 13, 2024, adopted first global digital Regulation (EU) 2024/1689, commonly referred to as the Artificial Intelligence Act (AI Act) [8].

The AI Act was adopted under the dual legal bases, which concerned data protection and the internal market. At its core, the AI Act is intended to facilitate the development and implementation AI in the internal market while safeguarding the core EU. The regulation responds to several pressing concerns: fragmented national AI regulations, lack of legal certainty for operators, potential misuse of AI technologies, and the need to preserve fundamental rights.

One of the Act's most significant parts is its risk-based classification framework, which stratifies AI systems into four categories. It introduces a risk-based classification of AI systems:

1. Unacceptable Risk – Banned AI systems, such as those using manipulative techniques, biometric surveillance in public, emotion recognition at work, or social scoring.
2. High-Risk – Strictly regulated systems used in sectors like healthcare, education, law enforcement, and transport. They require risk assessments, transparency, human oversight, and conformity assessments.
3. Limited Risk – Require transparency; users must be informed when interacting with AI (e.g., chatbots, deepfakes).
4. Minimal Risk – Consumer AI applications, that are unregulated but encouraged to follow best practices (e.g. spam filters) [8].

The Act introduces a robust governance structure:

- A new European Artificial Intelligence Board (EAIB) will coordinate the consistent application of the law across Member States.
- National supervisory authorities will be designated to oversee compliance.
- Notified bodies will conduct third-party assessments for high-risk systems.

Additionally, a database will be maintained for transparency, listing all high-risk AI systems deployed in the EU. Providers must register their systems in this central repository before deployment.

Non-compliance with the AI Act can result in significant fines, including:

- Up to 35 million euros or 7% of annual global turnover for breaches involving banned AI practices.
- Up to 15 million euros or 3% for violations of high-risk system obligations.
- Up to 7.5 million euros or 1% for failures in transparency or data provision.

These penalties are designed to ensure strict adherence and accountability, especially for large tech companies and high-impact applications.

3.2 Organizational challenges

Challenges remain in integrating AI across organizations, due to the rapid adoption of AI. These organizational challenges can be divided in three main categories: technological, ethical, and resource availability.

3.2.1 Technological challenges

Technological challenges involve ensuring how to integrate new AI systems with current audit methodologies and audit processes, tools and current level of AI adoption within the organization. Ethical concerns are about AI algorithms used for auditing, what is their setup and how questions of bias, transparency, and accountability are being handled. Resource availability refers to having skilled employees in the team. It is critical to address these gaps in order to ensure that the responsible and effective implementation of AI is done, specifically in the times where regulatory frameworks are still being developed.

Technological challenges can be mitigated by understanding the technical aspects of the AI solutions that are going to be implemented, what are the model types, data sources from which AI is going to gather data, what are the biases and capabilities. To select proper solution organization needs to consider what are the needs for AI, legal obligations depending on the industry in which organization operates and based on performed risk assessment to make a decision between public or private AI platforms [9]. It is important to know in which direction organization is heading with the implementation of AI, and to be onboarded to that process. To have successful implementation, understanding how organization intends to use AI, what is the purpose, what kind of data analysis will be done, and other functions are key. Due to the new regulations, it is important to clearly articulate the AI's boundaries and its intent, to ensure its ethical use and to meet legal standards.

3.2.2 Ethical challenges

Ethical guardrails should be embedded in the process of design of the system. It is essential that auditors remain vigilant in ensuring that predictive models do not perpetuate historical biases and make fair, accountable, and transparent decisions [9]. Ethical guidelines for AI use must be documented, explained to the users via training and awareness campaigns. These guidelines may need to be frequently modified due to changes in AI use which are evolving. Organization can build competency which considers both technology and ethics through impact assessments of AI systems and formalizing processes and tools. Many organizations have formed AI Ethics Committees to deal with the ethical issues presented by AI, including unintended bias, privacy violations, harm to people and property, reputational injuries, and violations of laws and regulations [10]. Organizations should develop a comprehensive code of ethics specifically for AI use. This document would guide the organizations design, development and deployment of AI applications. It should incorporate fairness, transparency, privacy and accountability principles [11].

3.2.3 Resource challenges

Like with any new technology, it is hard to find on the market resources that would help organization to implement and use AI tools and models. Organizations need to invest in their auditor's knowledge regarding AI, to get best possible value from usage of AI on one side and to minimize potential loss due to the usage of AI. It is important that auditors gain knowledge and understanding required to use AI systems. Basic understanding of AI is needed with technical skills to use the AI with increased ethical and legal awareness of impact that AI can have when it is used. AI can change auditing practices, since it offers potential improvements across audit process. However, to realize potential efficiencies and improvement, auditors must first build knowledge and effective training to proper use AI [11]. This requires continuing education that will provide auditors with needed techniques and skills required to perform audits. These new technologies introduce new risk factors that can challenge IT auditors [3]. Like in any other implementation and usage of new technologies, there is a learning process which will help to the have an effective use AI in IT audits. To create quality AI requests, auditor needs to have a combination of domain knowledge and technical understanding of AI capabilities and limitations [11].

4. OPPORTUNITIES OF USING AI IN IT AUDITS

Currently there is not an organization in the world that does not use AI, and that is the reason why it is needed to manage and operate AI in consistent manner. AI, machine learning or deep learning and other new technologies help organizations to improve their processes. No matter which process is being automated, new opportunities arise from using AI to have better efficiency and effectiveness of organization processes [12].

4.1 Opportunities of using AI in Audit

The use of AI technologies provides auditors with the opportunity to make the audit work more proactive than reactive. AI is helping auditors to remain timely and useful for investors, creditors, and other stakeholders that base

their decision-making processes on entities' financial statements. Generative AI has transformed IT audit engagements, improving efficiency and effectiveness significantly.

- Efficiency and Effectiveness – the emergence of generative AI has brought changes to IT audit engagements, primarily in terms of efficiency and effectiveness.
- Compliance – Technologies such as AI, edge computing, and others are reshaping many industries. Consequently, the development of related standards, regulations, and certifications is crucial for effectively governing and regulating these disruptive technologies and ensuring their responsible implementation by qualified professionals.
- Better resource utilization – by removing manual activities auditors can focus on the higher-value activities. This allows an organization to invest time and resources to keep up with new technological risks and business challenges [13].
- Increased business value – using AI with data analysis techniques provides auditors better view of samples that are analysed, which provides increased assurance to the organization.
- Reliability of Information Provided by Entity – that is, any forms or documentation produced or provided by the entity under audit – serves as audit evidence [14].

4.2 Training and further education of IT auditors and AI professionals

Although "traditional" trainings in the domain of IT Audit are still valuable [15, 16], IT audit and AI together require more skilled employees, that understand technology risks and know how to provide assurance. That is where ISACA, a global professional association and learning organization can provide support. There are currently more than 185,000 members who work in various fields from IT audit, security to IT risks. Knowledge, whitepapers and training for information security, governance, assurance, risk, privacy and quality are provided to ISACA members. With a global presence, ISACA is recognized for its guidance, credentials, education, training and community. ISACA's recent AI Pulse Poll shows that its members believe that they will need AI training in next two years, in order to keep up with the future requirements of their positions or to have a possibility to advance in their careers [17]. ISACA provides important certification in fields of IT audit and AI.

ISACA is best known for its Certified Information Systems Auditor (CISA) certificate. It was first introduced in 1978, and up to now more than 200.000 professionals have obtained it. It covers areas of auditing, monitoring, and assessing IT and business systems. In recent years in has also included the importance of emerging technologies. To obtain CISA certification person has to show expertise and ability to apply a risk-based approach to audit engagements. To maintain CISA certificate, continuing professional education is required and keeping and monitoring of emerging technologies like AI and blockchain, certificate holders stay up to date with new technology trends and advancements [18].

In 2025 ISACA introduced new certificate the Advanced in AI Audit (AAIA). This is the first certification designed for experienced auditors for auditing AI. This should help CISA qualified to build on the skills and knowledge on AI. The AAIA certification should help auditors to gain knowledge that would help them and their organization to understand risks and benefits of AI and future of AI [19].

5. FRAMEWORKS FOR USING AI IN THE IT AUDIT

Governance frameworks are used to implement the best practices and industry guidance in any area of organization. This is the case also with AI governance frameworks, which should address the operational questions surrounding AI. Organizations must ensure that AI systems designed ensure the privacy and security of data [20].

Every governance framework is designed to address questions like ownership, responsibility and auditing. This is achieved by providing a structured approach to decision-making. Governance framework ensures consistency and accountability in managing processes. A governance framework should:

- Provide clarity on roles and responsibilities.
- Ensures accountability by assigning ownership for the processes.
- Promotes transparency by keeping stakeholders informed.
- Maintains consistency of the processes, that all processes are done on the same way.
- Facilitates risk management by helping in identification of risks and their mitigation.
- Builds stakeholder trust in systems management.
- Aids in regulatory compliance to align with evolving regulations.
- Offers flexibility, processes can adapt to new challenges or opportunities [19].

We are going to discuss couple of governance frameworks that are developed by professional associations such as ISACA and Institute of Internal Auditors (IIA) and also one framework developed in collaboration between academic and business community

5.1 ISACA – COBIT framework

ISACA has created COBIT (Control Objectives for IT) in 1996 to help organizations organize and control IT processes. Latest version 2019 helps organization to have governance and management over processes. Since it is not technology or process specific, latest version provide resources to have framework over use of AI systems. This approach has proven value in other important areas of IT processes and controls like GDPR regulation, cloud, emerging technologies. Using this framework help better planning of resources, understanding underlying risks and improvement of processes and controls.

The five COBIT domains that are in the 2019 version are as follow:

- Evaluate, Direct and Monitor (EDM) – This is governance domain, that looks on the alignment of business and IT goals, strategies and objectives. Main goal to provide alignment in organization.
- Align, Plan and Organize (APO) – This is management domain, focusing on technologies, solutions by providing specific solution, like strategy, risk management, procedures and guidelines.
- Build, Acquire and Implement (BAI) – This is management domain that helps organization in the process of developing in house systems or deploying vendor acquired systems. Also provides guideline how to integrate business requirements with IT processes.
- Deliver, Service and Support (DSS) – This management domain is mainly focused on operations and security of IT processes. It helps organization to deliver services as required and agreed with business. Also, one of the key areas is to provide business with continuity of operations in case of disaster.
- Monitor, Evaluate and Assess (MEA) – This management domain provides monitoring of key performance indicators and service level agreements, to have improvement of services provided by IT. It is also evaluating how much IT has met organizational goals. [12].

5.2 IIA framework

The Institute of Internal Auditors (IIA) created AI Auditing Framework to help internal auditors to understand the risks, to identify best practices and to implement internal controls for AI. Purpose of the framework was to help internal auditors to develop knowledge around AI. Framework has four integral parts:

1. First part is the overview and history of AI.
2. In the second part it is explained how an organization can use AI.
3. Third part provides Auditing Framework, details three domains and their activities: Governance, Management, and Internal Audit.
4. Fourth part gives glossary of terms and guide to auditors.

The IIA's AI Auditing Framework contains of three levels:

1. Governance level – the framework's first domain – based on what is organization's approach to strategic planning of implementing and using AI and how oversight and monitoring are provided over AI. It is also explained how AI is planned, managed, and executed by management.
2. Management level – domain outlines what approach should organization take when it is planning and executing AI within. Provides details how "First line" is established surrounding AI.
3. Internal audit – domain explains usage of audit "Third Line" including aspects of advisory activities to management and in providing assurance services in an audit capacity. It provides help to internal audit to set up roles when tasked with participating in AI assignments [21].

5.3. Generative artificial intelligence (GenAI) framework

This framework was built in collaboration between academic and business community with aim to help organizations use the power of generative artificial intelligence (GenAI). This was joint effort of more than 1,000 practitioners and academics, which have contributed to the development of the framework. This Governance Framework can be split in five essential domains.

1. Strategic Alignment and Control Environment which provides alignment on goals and develops policies.
2. Data and Compliance Management which establishes processes and compliance with regulations.
3. Operational and Technology Management integrates AI into processes.
4. Human, Ethical, and Social Considerations ensures ethical usage and provides training.
5. Transparency, Accountability, and Continuous Improvement sets traceability in decision-making and updates practices.

Each of these domains in the framework identifies risks and provides controls to be considered. By combining risks and control considerations, this framework provides support to organizations, to better understand how GenAI can impact organizational objectives and to governance approaches and organizations response that mitigate those risks. This framework provides the set of risks and control considerations for organizations to use [22].

6. CONCLUSION

Fourth industrial revolution has changed the way how we are using technology in the IT audit. EU AI Act establishes an important legal framework for the classification and governance of AI systems, particularly in defining risk tiers and promoting transparency, it also has limitations, including specifications in technical definitions, limited guidance for sector-specific applications like auditing, and evolving enforcement mechanisms. In this context, implementing AI in IT audits requires alignment not only with regulatory expectations but also with established professional frameworks such as ISACA and the Institute of Internal Auditors (IIA). These frameworks emphasize risk-based auditing, governance, control assurance, and ethical integrity. Although AI can significantly improve audit efficiency, objectivity, and coverage, its deployment also presents challenges related to data quality, explainability, model governance, and accountability. By adhering to ISACA's COBIT, ITAF, and Risk IT Frameworks, and IIA's International Standards for the Professional Practice of Internal Auditing, organizations that are using best practice governance frameworks can ensure that AI-based audit solutions are effective, secure, ethical, and ultimately accepted by regulators, audit committees, and society.

REFERENCES

[1] McKinsey, "*What are Industry 4.0, the Fourth Industrial Revolution, and 4IR?*", URL: https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-are-industry-4-0-the-fourth-industrial-revolution-and-4ir#/

[2] Kress, R. "*Transforming the IT Audit Function – Taking the Digital Journey*", URL: https://www.isaca.org/resources/isaca-journal/issues/2016/volume-1/transforming-the-it-audit-functiontaking-the-digital-journey, ISACA Journal 2016, volume 1

[3] Curtis, B "*The Impact of Poor IT Audit Planning and Mitigating Audit Risk*", URL: 2020 Volume 3 The Impact of Poor IT Audit Planning and Mitigating Audit Risk, ISACA Journal 2020, volume 3

[4] ISACA, "*IT Audit Framework (ITAF) – Professional Practices Framework for IT Audit, 4th Edition*", 2020

[5] European Commission (2018): "*A Definition of AI: Main capabilities and disciplines*", URL: https://ec.europa.eu/futurium/en/system/files/ged/ai_hleg_definition_of_ai_18_december_1.pdf

[6] Statista, "*Artificial intelligence (AI) market size worldwide from 2020 to 2030*" https://www.statista.com/forecasts/1474143/global-ai-market-size

[7] ISACA "*Keeping Pace With AI: YOUR GUIDE TO POLICIES, ETHICS AND RISK*", ISACA, 2024

[8] Regulation (EU) 2024/1689 of the European Parliament and of the Council https://eur-lex.europa.eu/eli/reg/2024/1689/oj/eng

[9] Carmichel, M. "*Key Considerations for Developing Organizational Generative AI Policies*", AtIsaca, Volume 44, 2023

[10] Ross, S. "*Information Security Matters: Artificial Intelligence – Ethics and Security*" ISACA Journal 2025, volume 3, 2025

[11] Chong, C. and Chan, MF. "*Harnessing GenAI to Improve Audit Work Efficiency Through Proper Planning*", URL: https://www.isaca.org/resources/news-and-trends/industry-news/2025/harnessing-genai-to-improve-audit-work-efficiency-through-proper-planning, ISACA, 2025

[12] ISACA "*Leveraging COBIT for Effective AI System Governance*" White Paper, URL: White Papers 2025 Leveraging COBIT for Effective AI System Governance, ISACA, January 2025

[13] Shinde, B. "*Artificial Intelligence Adoption in Internal Audit Processes*" URL: https://www.isaca.org/resources/news-and-trends/newsletters/atisaca/2021/volume-40/artificial-intelligence-adoption-in-internal-audit-processes, ISACA Journal 2024 volume 6

[14] Isaac Lee, RF. "*Exploring Opportunities and Challenges: An IS Audit Perspective on Generative AI Adoption*" URL: https://www.isaca.org/resources/isaca-journal/issues/2024/volume-6/exploring-opportunities-and-challenges, ISACA Journal 2024 volume 6.

[15] Wurzburger S, Zlatanović I, Simonović A, Popović V, Lazić K, Pantović V, "*Kontinuirana obuka internih revizora u oblasti informacionih tehnologija*", XXIX Skup Trendovi Razvoja: 2023.

[16] Wurzburger S, Zlatanović I, Simonović A, Popović V, Lazić K, Pantović V, "*Obuka internih revizora u oblasti upravljanja rizicima*", XXX Skup Trendovi Razvoja, 2024.

[17] ISACA, "*We are ISACA*", URL: https://www.isaca.org/about-us/who-we-are

[18] ISACA, "*What is the CISA*", URL: https://www.isaca.org/credentialing/cisa

[19] ISACA, "*Advanced in AI Audit*", URL: https://www.isaca.org/credentialing/aaia

[20] Adnan Ahmed, SH "*Developing an Artificial Intelligence Governance Framework*", URL: https://www.isaca.org/resources/news-and-trends/newsletters/atisaca/2022/volume-38/developing-an-artificial-intelligence-governance-framework

[21] Institute of Internal Auditors, "*THE IIA'S Artificial Intelligence Auditing Framework*", IIA 2025

[22] Eulerich, M, Emett SA, "*Generative AI Governance Framework*" URL: https://www.genai.global/home

———

Note: All on-line references were accessed on 24.05.2025.

ORGANIZATIONAL RESILIENCE AND COMPETITIVENESS WITH ISO/IEC 42001: A FRAMEWORK FOR AI DATA SUPERVISION

Nikola Vojtek, Smart Consulting Agency | Daon, nikola@smartconsulting-agency.com
Vladan Pantović, Faculty of Project and Innovation Management, vladan@pantovic.rs

Abstract: *As artificial intelligence (AI) systems increasingly influence business operations, companies face new risks related to the training of AI models and the use of AI-driven decision-making. Data quality issues, bias, lack of transparency, and regulatory non-compliance can expose organizations to significant legal, financial, and reputational harm. ISO 42001, the new international standard for AI Management Systems, offers a structured framework to mitigate these risks. This paper analyzes ISO 42001 through the lens of organizational protection, focusing on how it provides essential guidelines for supervising data used in model training and monitoring AI decision processes. It explores the requirements for data governance, auditability, human oversight, and continuous improvement, demonstrating how ISO 42001 helps companies build safer, more accountable, and more trustworthy AI systems. By embedding ISO 42001 practices into their operations, companies could not only comply with emerging regulations but also strengthen their resilience and competitiveness in an AI-driven market.*

Keywords: *ISO/IECC 42001, Artificial intelligence, Management System, Model Training, AI supervision*

1. INTRODUCTION

Artificial Intelligence is transforming industries by enabling faster, more accurate and more reliable decision-making, personalized services, and operational efficiency. With the rise of the machine learning application, and large-scale learning models usage, the need for more data has grown exponentially as well following the general AI trend [1]. These models require vast amounts of data to be properly calibrated, enabling them to generate reliable conclusions and actionable insights. However, this also introduces significant risks when the data powering these systems is flawed, biased, or improperly governed [2].

Data quality issues, bias, lack of transparency, and regulatory non-compliance can expose organizations to significant legal, financial, and reputational harm. This represents a great concern for the training of AI models and for establishing AI-driven decision-making systems. Without robust supervision, AI systems can make decisions based on inaccurate, biased, or outdated data—leading to unfair outcomes, regulatory violations, or reputational damage.

As organizations rush to deploy AI, many are discovering that technical performance alone is insufficient. Without structured oversight, AI systems risk producing unreliable or even harmful outcomes. Harvard Business Review reports that a lack of governance is a leading factor in AI project failures [3]. This reality is also recognized by regulators, with the European Union's AI Act mandating strict governance obligations for high-risk AI systems [4]. ISO/IEC 42001 directly addresses these concerns, offering a formal, standards-based approach to building trustworthy and auditable AI practices [5].

ISO 42001, the new international standard for AI Management Systems, offers a structured framework to mitigate these risks. This paper analyzes ISO 42001 through the lens of organizational protection, focusing on how it provides essential guidelines for supervising data used in model training and monitoring AI decision processes. It explores the requirements for data governance, auditability, human oversight, and continuous improvement, demonstrating how ISO 42001 helps companies build safer, more accountable, and more trustworthy AI systems.

This paper is organized as follows. In section 2, a brief overview of the new ISO 42001 AI Standard was introduced. Section 3 highlights the risk landscape, and deals with the question why companies need protection. ISO 42001 AI Guidelines regarding Data governance in AI model training and supervised AI-driven Decision making process are described in section 4. Concluding remarks and directions for continuation of the research are provided in section 5.

2. PROBLEM STATEMENT

This section provides a brief overview of the ISO/IEC 42001, including scope, references to technical AI standards, reason why standard is developed, key elements, and relationship to other standards.

2.1 Scope

ISO/IEC 42001:2023 is the world's first international standard specifically designed for Artificial Intelligence Management Systems (AIMS). It is developed jointly by ISO and IEC, and it provides organizations with a

framework to govern AI systems responsibly, ethically, and in compliance with legal and stakeholder expectations, which is different from the technical AI standards.

When it comes to the technical AI standards, some of the notable are:

- ISO/IEC 22989:2022 - Artificial Intelligence — Concepts and terminology
- ISO/IEC 23053:2022 - Framework for AI systems using machine learning
- ISO/IEC 24028:2020 - Trustworthiness in AI
- ISO/IEC TR 24027:2021 - Bias in AI systems and AI-aided decision making
- ISO/IEC DIS 5259-x (upcoming series) - Data quality for analytics and machine learning

Unlike technical AI standards that focus on algorithms or performance benchmarks, or data, ISO 42001 targets the organizational processes and management controls required to safely and effectively deploy AI technologies. It is applicable to any organization — public or private, large or small — that develops, deploys, or uses AI.

2.2 Why ISO 42001 was developed

Application of AI is increasingly impacting almost all industries, and the absence of clear management practices and guidelines has led to rising concerns about:

- Data bias, poor data quality and data scarcity
- Unintended consequences of AI-driven decisions
- Regulatory non-compliance
- Lack of accountability and transparency

ISO/IEC 42001 was developed to provide these management practices and guidelines around processes in organizations. It is intended to be used as a proactive tool for organizations and companies to build trust in AI.

2.3 Key aspects of the standard

Five key aspects of the ISO/IEC 42001 standard are provided below.

1. Risk-Based Approach: Helps companies to assess and mitigate AI-related risks at every stage of the AI lifecycle.
2. Data Governance Requirements: Ensures high-quality, auditable, and traceable data, especially in training and inference phases, provides support in the data scarcity challenges.
3. Human Oversight: Defines when and how humans should be included in AI-driven decision-making processes.
4. Continuous Improvement: Promotes ongoing monitoring, evaluation, and updates to AI systems and governance frameworks, including policies and roles.
5. Documentation and Auditability: Requires detailed logs, policies, controls, identification of scope and key stakeholders, supports internal reviews and external audits.

2.4 Relation to other ISO Standards

ISO/IEC 42001 is designed, aligned and suitable to integrate with existing management system standards, such as:

- ISO 9001 (Quality Management)
- ISO/IEC 27001 (Information Security)
- ISO/IEC 23894 (AI Risk Management)

This alignment enables organizations to leverage their existing governance frameworks instead of creating entirely new systems. When used alongside related standards, ISO/IEC 42001 can help companies fully realize the benefits of structured and responsible AI management.

3. RISK LANDSCAPE: WHY COMPANIES NEED PROTECTION

In scenarios where AI decision-making systems take on greater responsibility — from approving loans to screening job applicants — the consequences of errors, bias, or misuse can escalate rapidly [6]. There are several risk areas that could be considered, as provided below.

Risk Area: Data Quality & Dataset Bias

- **Explanation:** Poor-quality or unrepresentative training data leads to faulty decisions [7].
- **Example:** An AI used in hiring trained only on past male applicant data results in gender-biased recommendations.

Risk Area: Lack of Transparency (Black Box AI)

- **Explanation:** AI systems often operate in ways that are hard to interpret [8], making it difficult for companies to justify decisions to regulators or clients.
- **Example:** A rejected mortgage application where the applicant receives no clear reason, violating fairness or legal disclosure rules.

Risk Area: Regulatory and Legal Risks

- **Explanation:** Laws like GDPR, the EU AI Act, and other consumer protection regulations impose

strict requirements on automated decisions and explainability [4].

- **Example:** Under GDPR Article 22, companies are limited in making fully automated decisions without human review — violations can lead to fines or legal action.

Risk Area: Financial and Operational Risks

- **Explanation:** AI systems acting on faulty assumptions can lead to poor business decisions, financial losses, or process disruptions.
- **Example:** Predictive maintenance, fraud detection, or demand forecasting systems all rely on accurate models — errors in these systems can cause major operational failures.

Risk Area: Reputational Damage and Loss of Trust

- **Explanation:** Mistakes made by AI systems can quickly turn into public controversies, damaging the company's image and customer relationships.
- **Example:** If an AI system is seen as biased or irresponsible, customers and partners may lose confidence and walk away.

These analyzed risks are not hypothetical — they're happening already, and are surprisingly or not, very often. They illustrate why companies must move beyond ad hoc controls and adopt structured, standards-driven approaches like ISO/IEC 42001 to ensure trust, accountability, long-term resilience, and continuous improvements.

4. SOLUTION

To mitigate the systemic risks outlined in the previous section, ISO/IEC 42001 provides a structured framework that emphasizes data governance and oversight throughout the AI lifecycle — especially during model training and decision execution. These safeguards help in ensuring fair, reliable, and explainable AI outcomes.

4.1 ISO/IEC 42001 and Data Governance in AI Model Training

To ensure the reliability and fairness of AI systems, ISO/IEC 42001 places strong emphasis on data governance during the model training phase. There are several sections in the standard that are providing requirements regarding Data governance processes in model training, as shown in table 1.

These measures ensure that models are not only technically robust, but also ethically and socially responsible. By establishing clear data governance procedures throughout the AI training lifecycle, ISO 42001 helps companies reduce operational risks and enhance trust in their AI outputs.

Table 1. ISO/IEC 42001 and Data Governance in AI Model Training

Section	Interpretation	Example of How It Can Be Fulfilled
A.6.2 — Data and Input Management	Requires organizations to verify that all data used in AI systems is appropriate, accurate, complete, and up-to-date; emphasizes validation before using data for training or operation.	Implement a mandatory data quality review checklist before allowing datasets to be used for model training, including accuracy validation and completeness checks.
A.6.4 — Dataset and Input Traceability	Mandates tracking and documenting the origin, modification history, and transformations of datasets to ensure transparency and accountability in data handling.	Maintain a dataset version control system (e.g., using DVC or Git-based systems) where each dataset change is logged with metadata on source, editor, and reason for change.
A.6.5 — Dataset and Input Lifecycle Management	Requires managing datasets throughout their lifecycle, including regular reviews, updates, and deprecation of outdated or irrelevant data to maintain data relevance and quality.	Establish a policy that datasets must be reviewed and revalidated every 12 months, and create a deprecation process for outdated datasets.
A.6.6 — Representation and Bias Management	Demands evaluation of dataset representativeness and proactive management of biases to ensure fair, reliable, and non-discriminatory AI outputs.	Run periodic bias analysis reports to assess demographic representation in datasets and retrain models with balanced or augmented data where gaps are found.

4.2 ISO/IEC 42001 and and Supervising AI-Driven Decision-Making

Beyond model training, ISO/IEC 42001 introduces critical safeguards for organizations that rely on AI in the decision-making process. There are three key sections with the requirements in the standard that are important.

Clause A.5.3 -> The standard calls for the assignment of roles and responsibilities ensuring that individuals or teams are clearly designated to oversee AI decisions, monitor outcomes, and respond to unexpected behavior.

Clause A.6.7 -> The standard emphasizes the need for human oversight of the AI, particularly in high-impact scenarios. This includes clearly defining the boundaries of autonomous AI decisions and ensuring that humans retain the ability to override or validate AI outputs when necessary.

Clause A.6.4 -> Additionally, ISO 42001 requires organizations to implement comprehensive logging and audit mechanisms that record key information about each AI-driven decision — including the input data used, the version of the model applied, and the rationale or explanation (if available) behind the outcome. These audit trails are essential for compliance, accountability, and post-decision review.

Together, these governance measures help companies to manage the complexity and opacity of AI systems while maintaining control, transparency, and trust in their decision-making processes.

5. CONCLUSION

As AI becomes more common in everyday business activities, the risks tied to poor data quality, data scarcity, model training errors, and unchecked automated decisions are becoming harder to ignore. This paper briefly shows some of the key requirements in ISO/IEC 42001 that could be used as a practical framework to help companies manage AI in a responsible way, from the data used to train models all the way through to how AI decisions are made and reviewed. In general, ISO/IEC 42001 isn't just about compliance — it's strategic protection.

ISO/IEC 42001 gives clear guidance on things like checking data quality, keeping track of where data comes from, reducing bias, making sure people stay involved in decisions, and keeping records of how AI works. These steps help companies deal with some of the biggest challenges when using AI — like unclear decision-making, unfair results, data scarcity, legal risks, or damage to reputation. The standard supports businesses in building AI systems that are not only technically strong but also responsible and in line with what society and the law expect.

Companies that invest in AI supervision will be safer, more resilient, and more competitive. As outlined in ISO/IEC 42001 Clauses A.6.4, A.6.7, A.5.3, and A.9.1, organizations are required to implement traceability mechanisms for input and output data, assign accountability for AI system oversight, and maintain documentation and monitoring processes to ensure transparency, auditability, and compliance throughout the AI lifecycle.

Rather than requiring companies to start from scratch, ISO/IEC 42001 aligns with existing governance models and complements related standards such as ISO/IEC 27001 (information security) and ISO/IEC 23894 (AI risk management). When adopted thoughtfully, it provides a foundation for building trustworthy, transparent, and accountable AI ecosystems — helping companies unlock the benefits of AI while minimizing operational, legal, and ethical risks.

In a fast-changing market where AI is becoming a key part of business, companies that adopt ISO/IEC 42001 will be better positioned to manage risks, attract investment, and stay ahead of the competition.

REFERENCES

[1] McKinsey & Company. (2023). The state of AI in 2023: Generative AI's breakout year. https://www.mckinsey.com/capabilities/quantumblack/our-insights/the-state-of-ai-in-2023

[2] PwC. (2022). AI predictions 2022: Embracing AI's full potential. https://www.pwc.com/gx/en/issues/technology/ai-analysis/pwc-ai-predictions-2022.pdf

[3] Ransbotham, S., Khodabandeh, S., Kiron, D., & LaFountain, B. (2022). Why AI projects fail. Harvard Business Review. https://hbr.org/2022/07/why-so-many-ai-projects-fail

[4] European Commission. (2024). Proposal for a regulation laying down harmonised rules on artificial intelligence (Artificial Intelligence Act). https://artificialintelligenceact.eu/

[5] International Organization for Standardization. (2023). ISO/IEC 42001: Artificial Intelligence Management System — Requirements. https://www.iso.org/standard/81230.html

[6] Brundage, M., et al. (2018). The malicious use of artificial intelligence: Forecasting, prevention, and mitigation. https://arxiv.org/abs/1802.07228

[7] Obermeyer, Z., Powers, B., Vogeli, C., & Mullainathan, S. (2019). Dissecting racial bias in an algorithm used to manage the health of populations. Science, 366(6464), 447–453. Doi: https://doi.org/10.1126/science.aax2342

[8] Rudin, C. (2019). Stop explaining black box machine learning models for high-stakes decisions and use interpretable models instead. Nature Machine Intelligence, 1(5), 206–215. Doi: https://doi.org/10.1038/s42256-019-0048-x

INTEGRATION OF ARTIFICIAL INTELLIGENCE TOOLS IN PEER-REVIEW: TRANSPARENCY, EFFICIENCY AND RELIABILITY OF HYBRID MODEL

Dragorad Milovanović, RAF, Belgrade, dragoam@gmail.com
Zoran Jovičić, AI United College, Belgrade-London, zoran jovicic.zoran24@gmail.com
Siniša Ristić, Faculty of Medicine, University of East Sarajevo, ristic.m.sinisa@gmail.com

Abstract: *In contemporary scientific publishing, the requirements for transparency and quality in the peer-review process is becoming increasingly. Application of artificial intelligence (AI) as a support tool in peer-review is under consideration academic, regulatory, and research institutions. The traditional peer-review system faces numerous challenges including subjectivity, inconsistent review quality, delays, and reviewer fatigue. AI tools enable efficient and systematic analysis of manuscripts, including the identification of logical flaws, stylistic and technical shortcomings, and ethically questionable content. In academic settings and regulatory bodies, hybrid models are especially promising, combining algorithmic processing with expert human judgment, supported by multi-layered systems for assessing the quality and relevance of content. Integrating these tools also raises a range of theoretical, conceptual, ethical, and legal questions. This paper explores the potential and limitations of AI-supported peer-review.*

Keywords: *scientific publishing, hybrid model, ethics.*

1. INTRODUCTION

The review process is one of the basic components of scientific publishing for the quality, relevance and integrity of scientific publications. In the field of biomedical sciences, the reliability of information directly affects health and the development of therapeutic approaches, the importance of objective and thorough evaluation of scientific works is additionally emphasized. However, the modern peer-review system faces a number of structural challenges, including limited capacity, lack of standardization in grading, subjectivity of evaluation, and increasing pressure on speed of publication. In numerous regional and global contexts there is a problem of uneven quality of peer-review reports, which rely on individual affinities, inadequate expertise or conflict of interest [1].

The application of artificial intelligence (AI) tools to support or supplement the traditional review model is attracting increasing interest. AI tools support efficient and structured processing of manuscripts, including language analysis, logical consistency check, text similarity assessment, and preliminary assessment of scientific contribution. The application of AI in scientific publishing is in an experimental phase, especially in the biomedical domain, numerous projects and research indicate the potential to contribute to the transparency, efficiency and reliability of the evaluation [2, 3].

However, the integration of artificial intelligence AI into evaluation processes also opens set of significant questions. The dilemma arises to what extent algorithmic tools can replace or complement expert judgment in complex aspects of scientific argumentation, innovation and methodological validity. Also, there are ethical and legal challenges to ensure transparency, auditability and respect for academic norms [4, 5].

This paper aims to explore the theoretical and practical aspects of the application of artificial intelligence AI tools in the review process. Through the presentation of technological capabilities, ethical and conceptual limitations, as well as the application of hybrid models, the paper seeks to contribute to the formation of informed guidelines for the responsible and effective integration of AI in modern scientific publishing.

2. REVIEW MODELS

The application of artificial intelligence in the review process requires an understanding not only of technological aspects, but also of theoretical foundations that shape the way we evaluate scientific information. Reviewing, as a cognitive and epistemological activity, implies a complex interpretation of evidence, conceptual analysis and evaluation of the logical and methodological coherence of the manuscript. In this sense, the use of AI tools is not only a technical innovation, but also an epistemological change in the way we define valid argumentation.

In the traditional peer-review model, the evaluation of scientific work relies on expert assessment of credibility, originality, and methodological consistency. The criteria often depend on the implicit knowledge, experience and cognitive patterns of the reviewers. The introduction of algorithmic tools raises the question of codifying the

criteria into a form accessible to computers, and to what extent it is possible to ensure that AI systems replicate (or improve) human judgment. They function within the paradigm of reducing complex scientific insights to formal, quantitatively tractable patterns.

Experts use heuristics (mental shortcuts) in the evaluation process, which can lead to bias, but also enable intuitive recognition of innovations. Algorithms, on the other hand, operate based on explicitly defined rules and models trained on large data sets. Here there is a gap: experts can perceive conceptual depth and novelty of ideas, while algorithms are limited in understanding meaning and context, especially in innovative or interdisciplinary works. In hybrid models, AI initially analyzes, and experts perform qualitative validation.

In the context of scientific review, a hybrid model (HI+AI+ExpertReview+BiasInspection) can be applied, which combines several layers of evaluation:

- AI systematically analyzes structure, language, bibliography, text similarity assessment and basic statistical checks
- expert reviewer interprets the findings of the AI system and supplements it with his own professional analysis
- independent evaluator (or AI module) checks for potential biases and conflicts of interest
- feedback layer ensures that all findings are documented and transparent, as well as possibility of revision.

The hybrid model allows for consistency, reduced bias, and increased accountability in the evaluation chain, especially in settings that do not have developed reviewer training systems or clear procedural protocols.

Regardless of their technical sophistication, AI tools lack the ability to understand the context, rhetorical fine distinction, and philosophical depth of arguments. The questions are crucial for building ethical and professional standards for the use of AI in knowledge evaluation.

3. TECHNOLOGICAL POTENTIAL OF AI TOOLS

Advances in the field of artificial intelligence AI have enabled the development of tools that not only automate the technical aspects of manuscript evaluation, but increasingly enter the domain of interpretive content analysis. In the review process, AI tools can have multiple functions, from checking basic compliance with formal publisher requirements, to sophisticated semantic analysis and detection of potential ethical problems. AI tools open up the possibility of significantly improving the efficiency, objectivity and standardization of the review process.

In modern practice, several types of AI tools that are under development for review purposes can be distinguished:

- Linguistic tools and stylometers analyze writing style, clarity of expression, grammatical correctness and terminological precision. The tools are useful for evaluating the technical and linguistic quality of manuscripts.
- AI-assisted text similarity detectors include in-depth semantic analyzes that allow the identification of paraphrased but non-original parts of the text.
- Semantic analytical tools are used to detect logical inconsistencies, misalignment of goals, methods and results, as well as identify data manipulation.
- AI tools for bibliometric evaluation recognize incorrect or irrelevant references, analyze citation networks and ranking of sources, which contributes to checking the relevance of the literature.

LLM large language models (GPT, BERT), trained on huge datasets of scientific and general texts, enable the generation of comments, summaries and the formulation of suggestions for improving manuscripts. The ability to analyze context and identify semantic patterns makes them useful in the pre-review phase (AI pre-screening). Use requires strict control and validation, since they can generate falsely convincing but inaccurate ratings (*hallucinations*) [6, 7, 8].

One of the most practical contributions of the AI tool is the automation of the process of checking the compliance of the manuscript with the formal requirements of the journal (structure of the abstract, format of references, number of words, presence of graphic elements). Such support relieves the reviewers from routine tasks and allows them to focus on the scientific essence.

Of particular importance are tools for analyzing research protocols, evaluating transparency in reporting results, and detecting possible conflicts of interest in biomedical research. AI tools based on the principles of logical and statistical coherence can serve as an early filter in the prevention of unethical actions or weak methodological foundations.

Despite the mentioned advantages, there are significant limitations:

- AI systems may contain bias if they are trained on unbalanced data sets.
- AI systems cannot adequately evaluate interdisciplinary works or innovative methodological approaches.
- It is necessary to clearly mark the limits of the use of AI tools in the review process in order to avoid excessive automation and marginalization of human evaluation.

4. HYBRID REVIEW MODELS

Despite the progress in the development of artificial intelligence AI, the consensus of researchers and editors is that algorithmic tools cannot completely replace an expert in the evaluation of scientific work. As the most acceptable and efficient approach, the hybrid review model, which combines automated content processing with qualified expert assessment, is increasingly being highlighted. The model not only preserves the cognitive and epistemological depth of expert evaluation, it strengthens it through the support of the analytical capacities of AI tools.

4.1 Structure and advantages of the hybrid model

Hybrid models are based on multi-level evaluation, different stages of the review process are performed either by experts or algorithmic systems, depending on the nature of the task.

Models typically include the following steps:

- an automated pre-screening tool identifies formal errors, non-compliance with journal guidelines, suspicious statistical patterns and possible text similarity
- thorough AI analysis uses tools for semantic analysis, logical consistency and stylistic processing, to generate suggestions and risks for the expert reviewer
- evaluation by an expert who interprets the findings of the AI system, in-depth scientific aspects of the manuscript, innovation, methodological originality and social relevance are checked
- meta-peer validation is optionally performed by the editorial team or an additional evaluator and checks the consistency of AI recommendations and expert evaluation, especially in sensitive cases.

The advantages of the hybrid approach are numerous:

- increased efficiency and automation of routine steps significantly shortens the time from receipt of work to the decision to publish
- standardization of evaluation and reduced variability in the initial assessment of formal and technical quality of work
- rational management of human resources enables reviewers to focus on complex aspects instead of simple technical corrections
- transparency and audit based on detailed reports of AI tools that enable subsequent verification of the evaluation process.

4.2 Risks and conditions for responsible development and application

Hybrid models require careful design and regulation to avoid the following problems:

- an over-reliance on algorithms because there is a risk that expert reviewers mechanically validate AI findings without critical consideration, which can lead to incorrect decisions
- limited revision of AI modules if proprietary models are used whose operation is not transparent, thus making error tracking and accountability difficult
- potential bias of AI algorithms based on systemic bias from training data (linguistic, geographical, disciplinary)
- lack of education among reviewers because effective use of AI tools requires technical and ethical training of reviewers and editors.

The recommended principles for developing a hybrid system are:

- transparency requires clear labeling of parts of the process with the use of AI
- reversibility represents the possibility of expert non-acceptance of automated recommendations
- continuous system evaluation requires regular monitoring of the accuracy and impact of AI tools
- ethical responsibility requires compliance with data protection policies, academic ethics and research integrity.

5. ETHICS, TRANSPARENCY AND RESPONSIBILITY

The application of artificial intelligence in the evaluation of scientific manuscripts cannot be seen exclusively as a technical issue. Ethical and epistemological challenges encroach on the essential principles of scientific integrity, autonomy of the academic community and trust in scientific institutions. It is necessary that the introduction of algorithmic systems in the review process is guided by clearly defined norms that ensure responsibility, fairness and transparency [5].

One of the key ethical problems of applying AI in the peer-review process is the limited ability of algorithms to interpret the contextual depth, creativity and innovation of a scientific idea. Scientific originality is not always expressed through formal or quantitatively measurable parameters. Originality can be conceptual, philosophical or interdisciplinary, and as such can be overlooked by algorithmic models that operate according to predefined rules. In this sense, excessive reliance on AI can lead to a conservative effect, where works that reproduce existing patterns of knowledge are privileged, and innovative and disruptive approaches are rejected as inconsonant or inconsistent.

When decisions to accept, revise, or reject a scientific manuscript are partially or fully based on analysis generated by an algorithm, the question of liability for potential error arises. Ethical ambiguity can have serious implications for academic reputations, researchers' careers, and the fate of publications. Therefore, it is necessary to establish a clear chain of responsibility, where the human

actor, editor or reviewer, is the ultimate decision-maker, with full insight into the data produced by the AI system. In this context, it is necessary to treat AI as an advisor and not as a decision maker.

One of the basic ethical principles in the use of AI tools is transparency towards authors and reviewers. It is necessary to inform the authors that their manuscript was subject to algorithmic evaluation and exactly which procedures were used. Similarly, reviewers must be informed when analysis results are generated by the AI system and how they can use (or discard) them. It is necessary that the introduction of a mandatory notification about the use of AI in the review process, as well as a clear description of the functions performed by the algorithm, become an integral component of the ethical policies of journals and publishers.

AI tools are only as unbiased as the data they are trained on. In the context of peer-review, this means that it is possible for models to reproduce existing language, gender, geographic and disciplinary biases. For example, manuscripts from non-English-speaking countries may be penalized for linguistic irregularities, even though the content may be scientifically valid and significant. Therefore, it is recommended to implement strategies to regularly test AI tools on different types of manuscripts; inclusion of representative corpora in training datasets; as well as the establishment of independent ethical committees for evaluating the impact of AI tools.

6. APPLICATION GUIDELINES

The introduction of artificial intelligence AI into peer-review processes takes on specific features when there are institutional, cultural and technical challenges that further complicate the integration of new technologies into academic structures. Although there is strong academic interest in digital tools and improving the peer-review process, practice and infrastructure lag behind global trends.

Academic and scientific institutions are characterized by significant differences in the degree of digitalization of the review process, procedures for the selection of reviewers, as well as the existence of formal evaluation quality policies. In this context, the use of AI can represent a worthy opportunity for standardization and improvement, but also a challenge from additional reliance on tools in the region and not knowing their scope and limitations. Institutions have limited human and technical capacities for introducing complex AI solutions. Therefore, the development of customized, modular and open AI solutions that do not require complex infrastructure and can be used in smaller newsrooms or faculties is crucial.

7. CONCLUDING REMARKS

In the previous sections, the potentials, challenges and limitations of the application of artificial intelligence (AI) in the process of scientific review were presented. One of the key conclusions is that the applied AI proves to be a useful tool for improving the technical, linguistic and formal quality of manuscripts, as well as for increasing the efficiency of the review process. The greatest potential lies in hybrid models when algorithms and experts collaborate in evaluation, complementing each other.

Globally, leading scientific publishers test and implement AI solutions at various stages of the review process, from checking the format and similarity of the text, to assessing statistical validity. However, the systems operate within clearly defined frameworks, with high standards of ethical responsibility and expert supervision. In contrast, in the region, the integration of AI tools enters the phase of conceptual analysis. The difference indicates the need for locally adapted solutions, which adapt models from developed countries through pilot-projects, modular tools and actor education.

REFERENCES

[1] J.A.Drozdz, M.R.Ladomery, "The Peer Review process: past, present, and future", *British Journal of Biomedical Science*, vol.81, Article 12054, June 2024.

[2] A.Checco, L.Bracciale, P.Loreti, S.Pinfield, G.Bianchi, "AI-assisted Peer Review", *Humanities and Social Sciences Communications*, vol.8, Article 25, 2021.

[3] B.Doskaliuk et al., "Artificial Intelligence in Peer Review: enhancing efficiency while preserving integrity", *Journal of Korean Medical sciences*, vol.40, no.7, 2025.

[4] Y.Güçlütürk et al., "Multimodal first impression analysis with deep residual networks", IEEE *Transactions on Affective computing*, vol.9, no.3, pp.316-329, July-Sept. 2018.

[5] A.Carobene et al., "Rising adoption of artificial intelligence in scientific publishing: evaluating the role, risks, and ethical implications in paper drafting and review process", *Clinical Chemistry and Laboratory Medicine*, vol.62, no.5, pp.835-43, 2024.

[6] T.I.Leung et al., "Best practices for using AI tools as an author, peer reviewer, or editor", *Journal of Medical internet research*, vol.25, 2023.

[7] A.Abd-Alrazaq et al., "Large language models in medical education: opportunities, challenges, and future directions", JMIR *Medical education*, vol.9, 2023.

[8] B.Meskó, E.J.Topol, "The imperative for regulatory oversight of large language models (or generative AI) in healthcare", *NPJ Digital medicine*, 6(1):120, 2023.

LEVERAGING KNIME FOR AI MODEL DESIGN IN IOT AND EDGE COMPUTING SCENARIOS

Petar Prvulović, School of Computing, Union University Belgrade, petar@prvulovic.com
Nemanja Radosavljević, School of Computing, Union University Belgrade, nradosavljevic@raf.rs
Đorđe Babić, School of Computing, Union University Belgrade, dbabic@raf.rs
Dušan Vujošević, School of Computing, Union University Belgrade, dvujosevic@raf.rs

Abstract: *This paper explores the potential of using the KNIME platform for developing artificial intelligence (AI) models intended for execution on edge nodes in Internet of Things (IoT) systems. Special attention is given to the analysis of the capabilities and limitations of popular IoT platforms such as Arduino and Raspberry Pi. The paper provides a classification of devices, an analysis of their hardware characteristics, and an evaluation of their ability to execute models trained within the KNIME environment. Various model storage formats (PMML, TFLite, ONNX, HDF5) are discussed, with consideration of their compatibility with available libraries and runtime environments. The conclusion assesses the practical applicability of KNIME for creating AI models suitable for resource-constrained devices.*

Keywords: *KNIME, IoT, edge computing, artificial intelligence, AI/ML model.*

1. INTRODUCTION

Internet of Things (IoT) is experiencing rapid growth and is being applied across a wide range of domains, including precision agriculture, water resource management, smart cities, transportation, healthcare, and fitness industry. IoT systems rely on wirelessly connected devices—nodes—equipped with sensors that collect environmental data. These data are subsequently stored and processed to support decision-making processes.

Data processing can be performed locally, on the node where the data are collected, following the edge computing paradigm. This approach reduces latency and network load, but it also requires additional computing resources on the nodes themselves. Alternatively, data can be transmitted over the network to a centralized infrastructure for processing, reducing the computational burden on the nodes at the cost of increased network resource consumption. In practice, a hybrid model is frequently employed, where initial processing is performed locally, and the results are forwarded for further analysis.

The integration of artificial intelligence (AI) and machine learning (ML) into IoT data processing enables more advanced functionalities and pattern-based decision-making. However, ML models require certain computational resources for execution, which presents a challenge for devices with limited capabilities.

This paper investigates the applicability of the KNIME platform [1] for the development and deployment of AI models on edge nodes within IoT systems. The analysis includes the potential of Arduino [2] and Raspberry Pi [3], platforms, supported model formats (PMML [4], TFLite [5], ONNX [6], HDF5 [7]), and their compatibility with relevant software environments on these devices. The paper also considers KNIME's support for commonly used algorithms such as SVM, logistic regression, and decision trees, and explores the possibility of exporting these models into formats suitable for deployment on IoT nodes.

The structure of the paper is as follows: Section 2 provides a classification of IoT devices and an analysis of their hardware characteristics; Section 3 presents an overview of model storage formats and their runtime support; Section 4 describes relevant KNIME functionalities; and Section 5 discusses the practical applicability of the platform in the context of edge computing in IoT systems.

2. IOT DEVICES CLASSIFICATION

IoT devices can be broadly categorized into two main groups: *Single Board Microcontrollers* (SBM), such as the Arduino Uno and Raspberry Pi Pico, and *Single Board Computers* (SBC), such as Raspberry Pi 4 and 5 [8].

SBM devices are characterized by limited memory and processing capabilities. They are implemented as microcontrollers on a board, with exposed input/output pins for direct sensor connection. Depending on the model, communication modules (typically Bluetooth and Wi-Fi) may be integrated or connected as external modules. These devices are compact and energy-efficient, making them suitable for mobile, battery-powered IoT nodes. They are typically deployed at the edge of IoT systems, where they

monitor the environment via sensors, perform basic data processing, and communicate data across the network for further aggregation and analysis. Microcontrollers include non-volatile memory for program storage. If present, operating systems on such devices are typically in the category of Real-Time Operating Systems (RTOS), optimized for efficient resource management under time constraints [9].

SBC devices, by contrast, are fully functional computers on a single board. They feature a processor, RAM, storage unit (typically MMC or MicroSD), and standard I/O ports (USB, HDMI, Ethernet, etc.). SBCs usually support full operating systems, most commonly based on the Linux kernel, such as Raspbian/Raspberry Pi OS [10]. Due to their larger size and higher energy consumption, they are typically powered by solar panels, generators, or connected to the electric grid. Within IoT systems, SBC devices are suitable for use as aggregation nodes, supporting intensive communication and data processing, or as sensor nodes which require greater computational capabilities, such as image processing from a camera.

Table 1 presents a comparative overview of representative IoT devices, including processor clock speed, RAM size, physical dimensions, and their classification according to the aforementioned criteria [2], [3], [11], [12], [13], [14], [15].

Table 1. Overview of Representative Platforms for IoT Device Development

Model	CPU Clock Speed	RAM	Dimensions (mm)	Type
RPi 3 Model B+	1.4GHz	1GB	56x85	SBC
RPi 4 Model B	1.5GHz	1-8GB	56x85	SBC
RPi 5	2.4GHz	2-16GB	56x85	SBC
RPi Pico W 2	150MHz	520KB	21x51	SBM
Arduino Nano	16MHz	2KB	18x45	SBM
Arduino Uno Rev3	16MHz	2KB	54x69	SBM
Arduino Due	84MHz	96KB	53x101	SBM
Arduino MKR GSM	48MHz	32KB	25x68	SBM

3. AI/ML MODEL FORMATS

There are several standardized formats for storing and transferring trained models. PMML is an XML-based format that describes models such as regression, decision trees, and Naive Bayes algorithms. TFLite is a compact binary format for TensorFlow models, optimized for mobile and IoT devices, with support for both C and Python. ONNX is an open format that enables model transfer between different machine learning frameworks and is widely supported in C++ and Python environments. HDF5 is mainly used within the Keras/TensorFlow ecosystem for storing neural network weights and is accessed through Python APIs. It is important to consider which types of models each format supports, along with the hardware and software requirements for execution, in order to make a feasible choice based on available hardware [16].

3.1 PMML

PMML (Predictive Model Markup Language) [4] is an XML-based standard designed for exchanging predictive models between various data mining tools and model execution systems. It was developed to enable interoperability between tools such as KNIME, IBM SPSS, SAS, RapidMiner, R, and Python libraries. Thanks to its readability and simple structure, PMML has seen significant adoption in business systems where transparency and simple model execution are important.

PMML does not require an operating system, but it does require an XML parser and model interpreter. There are implementations available in Java (JPMML) and Python (PyPMML). Due to its textual nature and the complexity of interpretation, executing PMML models on microcontrollers is feasible only for very simple models and requires manual implementation.

PMML supports a wide range of algorithms, including linear and logistic regression, Naive Bayes classification, decision trees, SVM, and simple neural networks. It is not suitable for complex models such as deep neural networks (DNN) or convolutional neural networks (CNN). The main advantages are interoperability and standardization, while limitations relate to execution complexity and lack of support for modern models.

3.2 TFLite

TFLite (TensorFlow Lite) is an optimized binary format for running TensorFlow models on resource-constrained devices such as mobile phones, IoT devices, and embedded systems [5]. It was developed as part of the TensorFlow project to allow easy and fast execution of trained models on devices that cannot run the full TensorFlow runtime. TFLite uses the FlatBuffer format, which enables fast loading and minimizes memory usage. As of 2024, this format is known as LiteRT [17].

TFLite runtimes are available for Python (on Linux/Android platforms), C/C++ (suitable for embedded systems), Java (Android), and for microcontrollers through TensorFlow Lite for Microcontrollers (TFLM). TFLM enables execution of TFLite models on devices without an operating system, including platforms such as the RPi Pico. Model quantization (e.g., 8-bit instead of 32-bit weight representation) is often necessary to fit models into microcontroller memory.

TFLite supports a large number of models, including CNNs, DNNs, RNNs, and classical classification and regression models. On microcontrollers, practical use is generally limited to simple models, such as small CNNs for pattern detection or basic neural networks for classification. KNN and SVM are not explicitly supported due to their different execution architecture. In practice, TFLite is the most practical choice for executing machine learning models in IoT systems.

3.3 ONNX

ONNX (Open Neural Network eXchange) [6] is an open format developed to enable the exchange of neural networks between different deep learning tools. ONNX represents models as operator graphs, independent of language and platform, and can be used with libraries such as PyTorch, TensorFlow, Keras, Caffe2, MXNet, and others. ONNX models are stored in binary protobuf format.

Model deployment is supported through ONNX Runtime libraries for Python, C, C++, Java, and .NET, which require an operating system (Linux, Windows, Android) to run. There is currently no ONNX runtime for microcontrollers, but models can be partially reconstructed for manual implementation on such platforms.

ONNX supports a wide range of algorithms, including classical ones (linear regression, logistic regression, Naive Bayes, SVM) and neural networks (DNN, CNN, RNN, LSTM). In practice, ONNX is used for implementation on SBC devices such as Raspberry Pi 4/5, Nvidia Jetson, and other ARM/Linux platforms, while TFLite is preferred for lower-end microcontrollers. The key advantages of ONNX are interoperability and efficient execution on modern devices.

3.4 HDF5

HDF5 (Hierarchical Data Format 5) [7] is a binary format developed for efficient storage and management of large structured data sets. In machine learning, it is most often used for saving TensorFlow/Keras models, including architecture, weights, and optimizer configuration.

HDF5 is supported in Python via h5py and keras.models.save_model(), as well as in C, C++, and Fortran. Running models stored in HDF5 format requires interpretation within a Keras/TensorFlow environment, and there is no standalone runtime for HDF5 models. Therefore, this format is not suitable for direct execution on devices without an operating system. It is also not suitable for model export in deployment environments and is primarily used during model training and development.

HDF5 is used for all types of neural networks. Executing these models requires a TensorFlow runtime, making them suitable only for devices with an operating system and sufficient memory, which SBC platforms can provide. HDF5 is typically used as an intermediate format during training and development, while deployment formats are TFLite or ONNX.

Table 2 provides a comparative overview of the characteristics of the mentioned formats, with a focus on their use on IoT devices.

4. KNIME

KNIME is a visual tool for data processing and machine learning model development, enabling easy training and evaluation of models through a graphical interface [1]. It is based on the concept of visual programming, where the data processing flow is built by connecting nodes, each performing a specific operation. The output of one node is passed as input to the next, forming a data processing pipeline.

KNIME includes a large number of nodes for various operations, ranging from basic data manipulation to nodes implementing machine learning algorithms, model training, and execution. Its key advantage is that it does not require programming knowledge, making it accessible to professionals from various fields [18].

Table 2. Overview of Model Storage Formats

Feature \ Format	PMML	TFLite	ONNX	HDF5 (Keras/TensorFlow)
Format Type	XML (text-based)	FlatBuffer (binary)	Protobuf (binary)	Hierarchical binary format
Typical Usage Context	BI systems, predictive analytics	IoT, embedded, mobile apps	Cloud/Edge AI, cross-platform deployment	Training and development of deep models
Primary Use	Business rules, classical models	Optimized deployment on mobile/IoT devices	Model transfer between tools/platforms	Storing and loading models
Usable on SBM	Theoretically possible, impractical	Yes (with quantization and TFLM)	No (requires OS)	No (requires Keras runtime)
Usable on SBC (with Linux OS)	Yes	Yes	Yes	Yes (with TensorFlow/Keras runtime)
Supported Algorithms	Regression, SVM, Naive Bayes, DT, NN	CNN, DNN, MLP, RNN	CNN, DNN, SVM, Regression, LSTM	Any Keras/TensorFlow model
Complex Models	Limited	Yes (optimized for quantization)	Yes (high flexibility)	Yes (not optimized for deployment)
Suitable for Deployment	Yes (business logic, server)	Yes (mobile, embedded)	Yes (SBC, servers, GPU)	No (used before deployment phase)
Model Size	Moderate	Very small (with quantization)	Medium (can be optimized)	Large (no optimization)
Performance	Poor (not optimized)	Excellent (quantization, F32/F16/INT8)	Good (requires more resources)	Poor (large models, not optimized)
Inference Speed	Low	High (especially INT8 models)	Moderate to high	Low
Recommendation for Edge AI	No	Best choice for edge	Only for higher-end devices (e.g., RPi)	Only for development, not deployment

Among the supported algorithms are Decision Tree, Random Forest, Logistic Regression, SVM, Naive Bayes, and Neural Networks. Models can be exported in PMML format using the *PMML Writer node* [19]. Additional extensions enable working with TensorFlow. The *TensorFlow 2 Network Writer* node [20] exports models to the HDF5 format, while the *TensorFlow Network Writer node* [21] exports to the TensorFlow SavedModel format. From there, conversion to the TFLite format can be performed using the Python tensorflow library.

5. APPLICABILITY OF KNIME FOR TRAINING THE AI MODELS USABLE ON EDGE IOT NODES

Considering the classification of devices and supported formats, the applicability of models that can be developed in KNIME varies depending on the class of device. On the low-end SBM devices, it is only feasible to manually implement simple models like decision trees. In such cases, KNIME can be used for model training, but the rules need to be implemented directly in code, based on the PMML representation. Microcontrollers with more processing resources, such as RPi Pico, can run TFLite models using available C libraries. With the use of a short script, a model trained in KNIME can be exported to TFLite and run on a microcontroller.

SBC devices like RPi 4 and RPi 5 have an OS based on the Linux kernel, allowing execution of models stored in ONNX, TFLite, and PMML formats using the necessary libraries and runtime environments. These devices generally have sufficient resources to run all model types.

KNIME is available on Linux. A KNIME model can be executed in *headless* mode, within the KNIME environment [18]. This approach requires significant time and computing resources, which are typically available on SBC-class devices. While feasible, this method requires careful consideration of resource usage and system response time limitations.

Real-time response requirements impose strict constraints. Video and image processing are memory- and CPU-intensive. The RPi 5 features a GPU coprocessor that significantly enhances performance, and cameras can be connected to these devices. The number of cameras and image resolution are factors that must be considered to ensure AI models execute within required timeframes.

KNIME can be a valuable tool in the initial stages of model development and testing, with the resulting models then adapted and deployed to target IoT platforms.

6. CONCLUSION

This paper examined the storage formats for ML and AI models and their suitability for execution on devices commonly used in IoT systems, as well as the usability of the KNIME tool for developing ML and AI models targeted at edge IoT devices.

Devices were classified into single-board microcontrollers (SBM) and single-board computers (SBC), and their processing capabilities were discussed. It was shown that SBC-class devices can support all model types within their hardware capacities, while some formats—primarily TFLite—are feasible on SBM-class devices. On lower-end devices, application requires simplification and manual implementation, whereas more powerful devices allow direct execution using runtime libraries. Proper classification of devices and model format selection are crucial for successful AI integration in IoT systems.

The assessed devices are especially interesting for prototyping and proof-of-concept purposes and are a popular choice among professionals in non-programming fields. KNIME enables intuitive development of data processing and machine learning/AI models, which can be exported in formats suitable for deployment on edge IoT devices. Its intuitive interface and programming-free approach make it especially useful to domain experts outside the field of computer science and can help promote broader adoption of AI and machine learning in IoT systems.

REFERENCES

[1] "KNIME: The Konstanz Information Miner | SpringerLink." Accessed: May 22, 2025. [Online]. Available: https://link.springer.com/chapter/10.1007/978-3-540-78246-9_38

[2] "Arduino Hardware." Accessed: Feb. 10, 2025. [Online]. Available: https://www.arduino.cc/en/hardware

[3] "Raspberry Pi hardware - Raspberry Pi Documentation." Accessed: Oct. 25, 2024. [Online]. Available: https://www.raspberrypi.com/documentation/computers/raspberry-pi.html

[4] A. Guazzelli, M. Zeller, W.-C. Lin, and G. Williams, "PMML: An Open Standard for Sharing Models," R J., vol. 1, no. 1, p. 60, 2009, doi: 10.32614/rj-2009-010.

[5] "LiteRT overview | Google AI Edge," Google AI for Developers. Accessed: May 23, 2025. [Online]. Available: https://ai.google.dev/edge/litert

[6] "ONNX | Home." Accessed: May 24, 2025. [Online]. Available: https://onnx.ai/

[7] "The HDF5® Library & File Format - The HDF Group - ensuring long-term access and usability of HDF data and supporting users of HDF technologies." Accessed: May 24, 2025. [Online]. Available: https://www.hdfgroup.org/solutions/hdf5/

[8] J. L. Álvarez, J. D. Mozo, and E. Durán, "Analysis of Single Board Architectures Integrating Sensors Technologies," Sensors, vol. 21, no. 18, Art. no. 18, Jan. 2021, doi: 10.3390/s21186303.

[9] A. Antony and S. S., "A Review on IoT Operating Systems," Int. J. Comput. Appl., vol. 176, no. 24, pp. 33–40, May 2020, doi: 10.5120/ijca2020920245.

[10] R. P. Ltd, "Raspberry Pi OS," Raspberry Pi. Accessed: Oct. 19, 2024. [Online]. Available: https://www.raspberrypi.com/software/

[11] "Arduino Nano Product Reference Manual." Dec. 02, 2025. Accessed: Feb. 16, 2025. [Online]. Available: https://docs.arduino.cc/resources/datasheets/A000005-datasheet.pdf

[12] "Arduino UNO R3 Product Reference Manual." Dec. 02, 2025. Accessed: Feb. 16, 2025. [Online]. Available: https://docs.arduino.cc/resources/datasheets/A000066-datasheet.pdf

[13] "Raspberry Pi Pico 2 series." Nov. 2024. Accessed: Feb. 16, 2025. [Online]. Available: https://datasheets.raspberrypi.com/pico/pico-2-product-brief.pdf

[14] "Raspberry Pi Pico 2 W Datasheet: An RP2350-based microcontroller board with wireless.".

[15] "Processors - Raspberry Pi Documentation." Accessed: Feb. 22, 2025. [Online]. Available: https://www.raspberrypi.com/documentation/computers/processors.html

[16] R. Immonen and T. Hämäläinen, "Tiny Machine Learning for Resource-Constrained Microcontrollers," J. Sens., vol. 2022, no. 1, p. 7437023, 2022, doi: 10.1155/2022/7437023.

[17] "TensorFlow Lite is now LiteRT- Google Developers Blog." Accessed: May 23, 2025. [Online]. Available: https://developers.googleblog.com/en/tensorflow-lite-is-now-litert/

[18] P. Prvulovic and D. Vujoševic, "Povećanje upotrebljivosti analitičkog rešenja u vidu eksponiranja Najm modela kao RESTful servisa," E-RAF J. Comput., vol. 9, 2017, Accessed: May 24, 2025. [Online]. Available: https://joc.raf.edu.rs/images/vol9/povecanje-upotrebljivosti-analitickog-resenja-u-vidu-eksponiranja-najm-modela-kao-RESTful-servisa.pdf

[19] "PMML Writer," KNIME Community Hub. Accessed: May 23, 2025. [Online]. Available: https://hub.knime.com/knime/extensions/org.knime.features.base/latest/org.knime.base.node.io.filehandling.pmml.writer.PMMLWriterNodeFactory2

[20] "TensorFlow 2 Network Writer," KNIME Community Hub. Accessed: May 23, 2025. [Online]. Available: https://hub.knime.com/knime/extensions/org.knime.features.dl.tensorflow2/latest/org.knime.dl.tensorflow2.base.nodes.io.filehandling.tfnetwork.writer.TF2WriterNodeFactory

[21] "TensorFlow Network Writer," KNIME Community Hub. Accessed: May 23, 2025. [Online]. Available: https://hub.knime.com/knime/extensions/org.knime.features.dl.tensorflow/latest/org.knime.dl.tensorflow.base.nodes.export.TFExporterNodeFactory

INTERNAL AUDIT IN K–12 EDUCATION IN THE AGE OF ARTIFICIAL INTELLIGENCE: CHALLENGES, POTENTIALS, AND RECOMMENDATIONS

Sonja Djukić Popović, Faculty of Mathematics and Computer Science, Belgrade, Serbia, sonja.popovic@alfa.edu.rs
Stefan Popović, Faculty of Information Technology, Belgrade, Serbia, stefan.popovic@alfa.edu.rs
Dražen Jovanović, Faculty of Pharmacy, Bijeljina, Bosnia and Herzegovina, drazen.jovanovic@alfa.edu.rs

Abstract: *This paper explores the potential of applying artificial intelligence (AI) in the function of internal audit within K–12 education, with the aim of improving governance and the quality of the teaching process. Using a narrative literature review, the study examines the possibilities and challenges of integrating AI into school audit mechanisms. Particular emphasis is placed on technological, organizational, and ethical aspects, as well as on practical recommendations for implementation. The findings highlight the need for a strategic approach, pilot programs, and the development of locally adapted AI solutions tailored to the educational context.*

Keywords: A*rtificial intelligence, internal audit, K–12 education, teaching quality, educational governance*

1. INTRODUCTION

Modern society is increasingly characterized by a commitment to transparency, accountability, and efficiency, especially in the public sector[1][2]. Education, as a cornerstone of social development, particularly requires mechanisms that ensure quality, effective management, and responsible use of resources. In this context, internal audit emerges as a key tool for improving internal control processes, supporting decision-making, and enhancing quality assurance in educational institutions[3][4][5].

Although internal audit is well established in the private sector and higher education institutions, its implementation in K–12 educational institutions in Serbia remains at a low level. The main obstacles include insufficient awareness, institutional resistance, limited capacities, and a lack of understanding of the audit function. Research indicates that school administrations often lack the capacity or initiative for systematic monitoring of internal processes, resulting in the absence of effective internal control mechanisms[6][7].

At the same time, artificial intelligence (AI) is becoming increasingly prominent in governance and decision-making processes. Its ability to process large volumes of data, detect patterns, support predictive analytics, and automate administrative tasks provides new perspectives for the field of internal auditing. In the educational context, AI can enhance audit practices through analysis of teaching implementation, budget monitoring, risk management, and the detection of irregularities. AI enables auditors to access complex datasets in real time and formulate evidence-based conclusions, thereby improving the objectivity and efficiency of internal audit procedures.

The aim of this paper is to provide a comprehensive review of research at the intersection of three domains: internal audit, K–12 education, and artificial intelligence[8][9][10]. It explores the potential of applying AI in internal auditing within primary and secondary schools, highlighting advantages, challenges, and ethical considerations. The paper also offers practical recommendations and directions for future research, particularly in the context of creating conditions for improving teaching quality, school governance, and the responsible management of public resources [11].

2. LITERATURE REVIEW METHODOLOGY

Given the review-based nature of this paper, a narrative approach was employed to analyze the relevant literature, with the aim of assessing the current state of research on the application of artificial intelligence (AI) in internal auditing within K–12 education [12]. The focus was placed on studies that address three interrelated domains: internal audit in education, the use of AI in management and auditing, and the impact of technological innovation on the quality of the teaching process.

The literature search was conducted between March and May 2025 using academic databases such as Google Scholar, Scopus, DOAJ, and CEON/SCIndeks. In addition, relevant national sources were included, such as articles published in the journal Revizor and reports from professional and research organizations like RSM Serbia. The search was guided by keywords including: internal audit in education, artificial intelligence, educational management, AI in auditing, teaching quality, as well as their English equivalents (e.g., internal audit, artificial

intelligence, educational management, school governance, AI in education).

The included literature met the following criteria:

- Published in peer-reviewed journals or official sources;
- Provided a theoretical or empirical contribution to the topic;
- Focused on the application of auditing or technological methods within educational contexts;
- Relevant to pre-university education (i.e., preschool, primary, and secondary education levels).

The analysis was conducted qualitatively, through the identification of key themes, methodological approaches, principal findings, and conclusions [13]. Special emphasis was placed on integrating theoretical insights and practical examples that demonstrate the potential of AI as a tool for enhancing internal auditing and, by extension, improving educational quality.

3. BIBLIOMETRIC ANALYSIS OF RESEARCH (2014–2024)

Bibliometric analysis indicates a strong and sustained growth in interest in artificial intelligence (AI), both in general and within the context of education. Between 2014 and 2024, the number of publications on AI increased by more than 500%, with notable expansion in fields such as education, healthcare, and governance. Data suggest an average annual growth rate of 30–35%.

In contrast, the number of academic publications on internal auditing has remained relatively stable, with minor fluctuations. The peak was recorded in 2016, followed by a slight decline. The total number of publications on internal audit during the period 2000–2024 amounts to 674. Within the field of K–12 education, research has been primarily focused on curriculum reform and digital transformation, especially during the COVID-19 pandemic, which led to a significant spike in publications in 2020–2021.

Studies that simultaneously address all three topics—AI, internal audit, and K–12 education—are extremely rare. A 2024 study based on the Web of Science database identified only 62 publications linking AI and internal auditing. Although the application of AI in K–12 education continues to grow, the integration of all three domains remains underexplored, indicating a significant gap in the existing body of research.

Table 1: Comparative Table: Number of Published Papers (Approximate Values)

Year	Artificial Intelligence	Internal Audit	K–12 Education
2014	2,000+	35	40
2016	4,200+	60 *(peak)*	60
2020	8,000+	45	140 *(peak)*
2022	10,500+	50	110
2024	12,000+ *(estimated)*	52 *(estimated)*	120 *(estimated)*

4. INTERNAL AUDIT IN PRE-UNIVERSITY EDUCATION

Internal audit, as an independent management function in the public sector—including educational institutions—has the potential to significantly improve transparency, efficiency, and accountability. Although the legal framework in Serbia mandates the establishment of internal audit and financial management and control systems (FMCS) in the public sector, pre-university educational institutions have been slow to implement these mechanisms in practice [9][10][11].

As shown in the study by Popović et al. (2022),[9][10][11] nternal audit is not widely recognized as a support mechanism for improving the quality of teaching and institutional management. Schools often face institutional barriers such as limited understanding of the role of internal audit, insufficient financial resources, a shortage of qualified personnel, and resistance among staff toward audit activities. Survey results among educational stakeholders indicate a certain level of hesitation and incomplete awareness regarding the importance and function of internal auditing in the educational context. [14]

Nevertheless, the authors emphasize a general openness among stakeholders toward internal audit as a potential mechanism for institutional improvement—particularly when auditing goes beyond financial oversight to include supervision of teaching quality and management processes. In practice, some schools and professional teams have already begun establishing internal controls through collaborative efforts involving teachers, school staff, and administration, laying a solid foundation for the introduction of formal audit procedures.

These efforts are supported at the national policy level through initiatives such as the RELOF2 project, which aims to implement FMCS in primary and secondary schools, and to develop practical guides for applying internal audit procedures. However, despite this

institutional support, there remains a need for further development of awareness and capacity within the schools themselves.

Finally, as the authors note, there exists a considerable gap between strategic plans and the real-world capabilities of schools—especially in the management of material and technical resources. In this context, when effectively implemented, internal audit can contribute to better organization, more rational resource use, and improvement of the overall educational process.

5. APPLICATION OF ARTIFICIAL INTELLIGENCE IN INTERNAL AUDITING

Artificial intelligence (AI) is rapidly transforming numerous aspects of business operations, including the field of auditing. In the domain of internal audit, AI enables auditors to analyze large volumes of data, detect patterns, predict risks, and make data-driven decisions in real time [15][16][17]. While AI has already been implemented in audit practices within the private sector, its potential in the public sector—and particularly in pre-university education—is only beginning to be explored.

The application of AI in internal auditing involves the use of machine learning algorithms, natural language processing (NLP), and automated analytics to monitor key indicators, detect anomalies, and signal risk-prone areas. Rather than relying on manual analysis of extensive financial and administrative documents, auditors supported by AI tools can significantly speed up their work and focus on deeper interpretation of findings.

In the context of educational institutions, AI can support audit processes through:

- automated monitoring of budget expenditures and deviations from financial plans;
- analysis of teaching efficiency based on indicators such as student attendance, achievement, and curriculum implementation;
- identification of behavioral patterns that may indicate the need for intervention (e.g., high student attrition, underutilization of resources);
- generation of audit reports with greater consistency and reduced time investment.

Although these technological solutions already exist, their practical implementation depends on multiple factors: the level of technological infrastructure in schools, staff capacity to operate new tools, and the existence of a regulatory framework that ensures the safe and ethical use of data. The Serbian education system is only beginning its digital transformation in terms of governance, and AI represents the next step in modernizing internal auditing as a tool of internal oversight.

Introducing AI into school-based internal auditing does not imply replacing the human element, but rather enhancing the auditor's capacity for data collection, processing, and interpretation. Instead of periodic and fragmented reviews, AI enables continuous auditing—providing constant oversight of processes and timely identification of potential issues.

Given the complexity of operations in schools and the growing demand for transparency and accountability, AI presents itself as a tool that can significantly contribute to the professionalization and efficiency of internal auditing within the educational system.

6. ARTIFICIAL INTELLIGENCE IN PRE-UNIVERSITY EDUCATION

The development of artificial intelligence (AI) is increasingly influencing education, including the pre-university level. Schools around the world—including those in Serbia—are progressively exploring the potential of AI tools in school management, teaching, communication, and student support. Although the application of these technologies is still in its early stages, their importance in improving teaching quality and management efficiency is becoming more evident.

The most common applications of AI in K–12 education include:

- Personalized learning, where AI-based systems analyze student progress and recommend learning content tailored to individual needs;
- Learning analytics, which provide teachers and school leadership with insights into academic achievement, dropout risks, and common learning difficulties;
- Automated grading and test processing, which reduce teachers' administrative burden;
- Chatbots and virtual assistants, which interact with students and parents to provide information and support[18][19][20].

From the perspective of internal audit and school governance, these technologies can generate large volumes of structured data about the activities of teachers, students, and administrators. When available in real time, such data can become a key resource for auditors—not only in tracking financial flows but also in supervising pedagogical processes.

For example, a system that records all aspects of teaching (attendance, lesson implementation, test outcomes, parent

communication, etc.) can help the internal audit unit identify trends that signal systemic weaknesses, such as inconsistent teaching practices, poor alignment between planning and implementation, or insufficient student engagement.

However, the use of AI in education also raises several important concerns. Chief among them are:

- Privacy and data security, particularly when dealing with data on children;
- Ethical dilemmas related to the automation of decision-making;
- Equity of access, as some schools have the necessary technological infrastructure and personnel, while others do not.

The introduction of AI into education—and consequently into internal audit—must be accompanied by clear strategies, ethical frameworks, and continuous support for teaching and administrative staff [21][22][23]. Only under these conditions can technology genuinely contribute to enhancing the quality of education and governance in line with the public interest.

Table 2: Comparison of AI and Internal Audit Application in Education

Application Area	Artificial Intelligence (AI)	Internal Audit
Primary Purpose	Personalization of learning, data analysis	Improvement of governance and quality assurance
Current Implementation	In early phase, growing interest	Limited, greater implementation needed
Challenges	Technological infrastructure, ethical concerns	Lack of awareness, perceived as a cost
Improvement Potential	High – enhanced teaching and management	High – better resource management and teaching quality

The integration of artificial intelligence (AI) into internal auditing processes in K–12 education carries substantial potential for improving efficiency, transparency, and objectivity. However, this transformation requires careful consideration from both technical and ethical standpoints.

Benefits

- Automation and process acceleration

AI can significantly reduce the time required to analyze large datasets, enabling auditors to identify issues more quickly and focus on strategic insights.

- Continuous auditing

Unlike traditional periodic audits, AI enables real-time monitoring and ongoing evaluation of processes.

- Objectivity and consistency

When properly configured, algorithms operate without bias, thereby reducing subjectivity in audit assessments.

- Enhanced risk analysis

Machine learning can help predict risky behaviors or areas in need of intervention—for example, inefficient resource use, lapses in teaching implementation, or weaknesses in internal controls.

- Integration with other school systems

AI can be connected with e-government platforms, digital gradebooks, financial systems, and other tools, facilitating comprehensive oversight.

Challenges

- Limited technological infrastructure

Many schools in Serbia still lack adequate ICT equipment and reliable internet access, which is a major barrier to the implementation of AI tools.

Insufficient staff training

Teachers and administrators often lack the necessary skills to use analytical and AI tools effectively, which may lead to resistance and underutilization of technology.

- Institutional resistance

The concept of internal audit already faces resistance in educational institutions, and adding AI is often perceived as an additional burden or threat.

- Implementation costs

Developing, maintaining, and customizing AI solutions for educational needs requires investment, which is often a limiting factor in the public sector.

Ethical Aspects

- Privacy and data protection

The use of AI involves access to sensitive data—about students, staff, and finances. These must be protected in line with national data protection laws and GDPR principles.

- Algorithm transparency

AI-based decisions must be understandable and verifiable. "Black box" models that do not clearly explain how a conclusion was reached are ethically unacceptable in education.

- Bias in data

If the training data for AI systems is incomplete or biased, the outcomes may replicate or even exacerbate existing inequalities (e.g., regarding students from vulnerable groups).

- Human-centered decision-making

AI should support—not replace—human judgment, particularly in complex pedagogical situations. The human element remains essential in educational decision-making.

Recommendations

- Develop a national strategy for AI implementation in education, including auditing components.
- Establish ethical guidelines and supervisory bodies to oversee AI usage.
- Provide continuous training for education professionals, especially in digital competencies and internal controls.
- Launch pilot projects in selected schools to assess effectiveness and enable wider application.

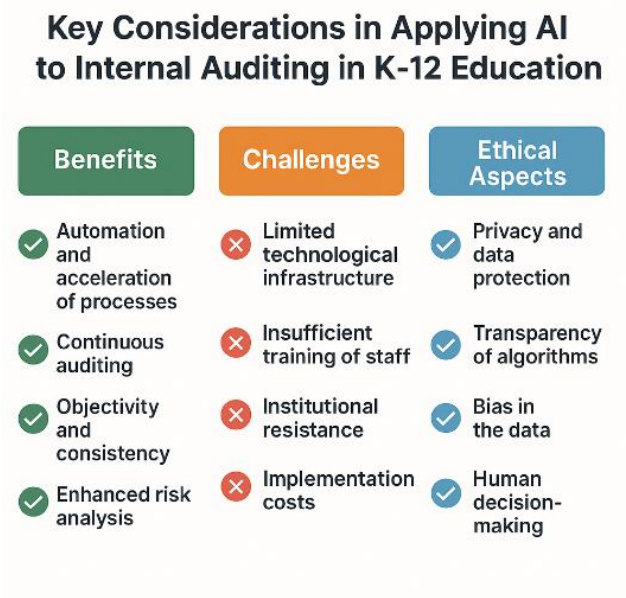


Figure 1. AI in Educational Internal Audit: Benefits, Challenges, and Ethics.

7. CONCLUSION

The application of artificial intelligence in internal auditing within pre-university education represents a significant step toward modernizing management systems, improving operational efficiency, and ensuring higher quality in the educational process. AI technologies enable deeper, faster, and continuous data analysis, providing internal auditors with new tools for oversight, prediction, and influence on decision-making.

At the same time, implementation is not without challenges. Adequate technological infrastructure, staff training, and overcoming institutional resistance are necessary preconditions. Most importantly, ethical concerns related to privacy, algorithm transparency, and the role of the human factor in educational decision-making must be addressed.

Based on the literature reviewed and existing research, the following recommendations are proposed:

Develop a strategic framework for the digitalization of internal auditing in education, with a particular focus on AI integration.

Establish pilot programs in selected schools to test the effects of AI on internal controls and teaching processes.

Ensure continuous education and professional development for teaching and administrative staff in the fields of digital literacy and audit competencies.

Develop ethical guidelines and protocols for the use of AI in educational institutions.

Strengthen collaboration between educational institutions, the scientific community, and the IT sector to develop domestic, contextually appropriate AI tools.

Future research should include empirical studies on the effects of AI on internal audit functions in educational institutions, as well as long-term impacts on education quality, resource management, and transparency in school operations.

REFERENCES

[1] Parker, Lee, and Graeme Gould. "Changing public sector accountability: critiquing new directions." *Accounting forum. Vol. 23. No. 2. Taylor & Francis*, 1999.

[2] Choudhury, Enamul, and Shamima Ahmed. "The shifting meaning of governance: Public accountability of third sector organizations in an emergent global regime." *International Journal of Public Administration* 25.4 (2002): 561-588.

[3] Spira, Laura F., and Michael Page. "Risk management: The reinvention of internal control and the changing role of internal audit." *Accounting, Auditing & Accountability Journal* 16.4 (2003): 640-661.

[4] Moorthy, M. Krishna, et al. "The impact of information technology on internal auditing." *African Journal of Business Management* 5.9 (2011): 3523.

[5] Nogueira, Sónia Paula da Silva, and Susana Margarida Faustino Jorge. "The perceived usefulness of financial information for decision making in Portuguese municipalities: The importance of internal control." *Journal of Applied Accounting Research* 18.1 (2017): 116-136.

[6] Amegble, Innocent. Assessment of Internal Control Systems in the Administration of Senior High Schools in the Volta Region of Ghana. *Diss. Universtiy of Cape Coast*, 2021.

[7] Yao, Peter Lartey, Kong Yusheng, and Fatoumata Binta Maci Bah. "A critical examination of internal control systems in the public sector, a tool for alleviating financial irregularities: evidence from Ghana." *Research journal of finance and accounting* 8.22 (2017): 94-110.

[8] Lu, Hongru, and Zhiang Wu. "Revisiting intelligent audit from a data science perspective." *Neurocomputing (*2025): 129431.

[9] Popović, Sonja Đukić, Jozefina Beke-Trivunac, and Stefan Popović. "Is internal audit the cost?(on the example of high schools)." *REVIZOR* Časopis za upravljanje organizacijama, finansije i reviziju* 25.97-98 (2022): 111-120.

[10] Popović, Stefan, Sonja Đukić Popović, and Nebojša Jeremić. "Participants of the teaching process and internal audit–survey on the awareness of the participants of the teaching process about internal audit." *REVIZOR* Časopis za upravljanje organizacijama, finansije i reviziju* 25.100 (2022): 41-48.

[11] Popović, Stefan, and Sonja Đukić Popović. "Značaj uvođenja interne revizije u ustanove douniverzitetskog obrazovanja." *Revizor*, vol. 24, no. 94, 2021, pp. 37-43. DOI.org (Crossref), https://doi.org/10.5937/rev2194037P.

[12] Guo, Shuchen, Yuanyuan Zheng, and Xiaoming Zhai. "Artificial intelligence in education research during 2013–2023: A review based on bibliometric analysis." *Education and Information Technologies* 29.13 (2024): 16387-16409.

[13] Curry, Leslie A., Ingrid M. Nembhard, and Elizabeth H. Bradley. "Qualitative and mixed methods provide uniq*ue contributions to outcomes research."* Circulation 119.10 (2009): 1442-1452.

[14] Mahzan, Nurmazilah, and Andy Lymer. "Examining the adoption of computer-assisted audit tools and techniques: Cases of generalized audit software use by internal auditors." *Managerial Auditing Journal* 29.4 (2014): 327-349.

[15] Abdullah, Abdulwahid Ahmad Hashed, and Faozi A. Almaqtari. "The impact of artificial intelligence and Industry 4.0 on transforming accounting and auditing practices." *Journal of Open Innovation: Technology, Market, and Complexity* 10.1 (2024): 100218.

[16] AldemİR, Ceray, and Tuğba Uçma Uysal. "AI competencies for internal auditors in the public sector." *Edpacs* 69.1 (2024): 3-21.

[17] Fedyk, Anastassia, et al. "Is artificial intelligence improving the audit process?." *Review of Accounting Studies* 27.3 (2022): 938-985.

[18] Chiu, Thomas KF. "A holistic approach to the design of artificial intelligence (AI) education for K-12 schools." *TechTrends* 65.5 (2021): 796-807.

[19] Yim, Iris Heung Yue, and Jiahong Su. "Artificial intelligence (AI) learning tools in K-12 education: A scoping review." *Journal of Computers in Education* 12.1 (2025): 93-131.

[20] Casal-Otero, Lorena, et al. "AI literacy in K-12: a systematic literature review." I*nternational Journal of STEM Education* 10.1 (2023): 29.

[21] Pedro, Francesc, et al. "Artificial intelligence in education: Challenges and opportunities for sustainable development." (2019).

[22] Mouta, Ana, Eva María Torrecilla-Sánchez, and Ana María Pinto-Llorente. "Comprehensive professional learning for teacher agency in addressing ethical challenges of AIED: Insights from educational design research." *Education and Information Technologies* 30.3 (2025): 3343-3387.

[23] Michel-Villarreal, Rosario, et al. "Challenges and opportunities of generative AI for higher education as explained by ChatGPT." *Education Sciences* 13.9 (2023): 856.

HUMAN AND ARTIFICIAL INTELLIGENCE IN TEAM WORK

Vesna Buha, Faculty of Project and Innovation Management prof. Petar Jovanović, PhD vesnabuha@gmail.com
Rada Lečić, Faculty of Project and Innovation Management prof. Petar Jovanović, PhD ekonomijale@gmail.com
Mirjana Dejanović, Faculty of Project and Innovation Management prof. Petar Jovanović, PhD mrmirjanadejanovic@gmail.com

Abstract: *The main purpose of the article is to observe some aspects of the development of artificial intelligence (AI) that have influenced the emergence of innovative forms of teamwork - Human - Artificial Intelligence - Team (HAIT). The topic of the paper includes the analysis of team complementarity in business, between humans and AI. AI has become a dynamic actor of the team, which engages its capacities for learning, develops models, proposes solutions. In such a constellation, a person deals with management and more creative segments of business ventures. In the paper, in a quantitative sense, the growing trend of the number of AI users was established. Numerous research areas are opening up in the pursuit of creating future AI-based prototypes. A Case Study - an experiment, which concerned the understanding of human-artificial intelligence cooperation, was presented, which provided some of the relevant answers. AI represents a major contribution to the world of work, simultaneously creating its new paradigm in the 21st century. The sublimation of the topics covered suggests that a large number of operational jobs can be effectively outsourced to AI. The tendency towards balance HAIT implies, in addition to efficiency, the preservation of human values.*

Keyword: *Artificial Intelligence (AI), Generative Artificial Intelligence (GAI), Human – Artificial Intelligence - Team (HAIT), Artificial Intelligence Agent*

1. INTRODUCTION

Traditional considerations of teamwork indicate that every group of people does not necessarily mean that it is a team. Team work implies the orientation of people towards a common goal, their logical division of roles that they realize on the way to the goal. The place of an individual in a business team is largely determined by his competencies, achievements and previous work experiences. The result of the team usually exceeds the sum of the individual results. Complex business problems can be properly solved together in a team, interaction and mutual influence of members is achieved and a sense of belonging is created, bearing in mind that activities are shared and collective norms of behavior are generally accepted. In such a context, it is necessary to find its place for the innovative actor - Generative Artificial Intelligence (GenAI). GenAI appears in the literature as a dynamic partner - an agent that independently analyzes, learns and develops proposals. Its previously largely reactive role has been replaced by a dynamic, interactive one. The rapid development of GenAI includes an intuitive interface, contributes to the possible reduction of human cognitive load, but also contributes to working in a reliable system with greater transparency. GenAI is constantly changing, with a tendency to adapt to the user and his needs. As such, it is implemented and controlled. Humans, on the other hand, gain confidence in the usability and reliability of AI work, striving to jointly achieve maximum efficiency during work. From the point of view of business goals, HAIT teams act in the same direction and in cooperation achieve synergistic effects, effects that go beyond the simple sum of individual achievements.

The introduction of HAIT affects communication, decision-making and mutual trust within the team. Although AI contributes to efficiency, the human component remains crucial for cohesion and motivation. The transparency and predictability of AI increases trust, thereby improving team synergy. Therefore, *the subject of this paper* is to investigate the changes in the work of teams that arise from the development of Information Technologies, with a specific focus on artificial intelligence. *The aim of the work is:* To determine the characteristics of innovative HAIT teams consisting of humans and artificial intelligence. It is based on the hypothesis that the implementation of artificial intelligence in the *world of work* will lead to greater automation of business processes and a higher level of efficiency. However, there are known examples that show that AI often goes beyond the initial premises. Therefore, this paper will be focused on proving the initial hypotheses as well as detecting cases that exceed expectations from GenAI, which is also the reason and motivation for writing this paper.

2. DEFINING KEY TERMS

The term *Intelligence* was created in the twenties of the 20th century. It consists of the Latin words "inter" (between) and "legere" (to choose, to collect, to read) with a general meaning - to see interconnections. It represents [1]: the ability to think abstractly, the ability to learn quickly and successfully, or the ability to adapt successfully, which usually means successful problem solving. Differences in definitions stem from different

types of content in which intelligence is engaged, or differences arise as a consequence of the level of generality of the definition. We can also deal with intelligence in Thurston's sense [1], determining primacy such as: verbal comprehension, word fluency, numerical factor, spatial, associative, perceptual speed, reasoning, etc. Such a possible starting point points to the intellectual abilities of man. However, how would we then describe artificial intelligence? To what extent were the ways of creating Artificial Intelligence based on a possible parallel with human intelligence, and how much on technology? Artificial intelligence (AI) is defined by IBM [2] as a technology that enables computers and machines to simulate human learning, understanding, problem solving, decision making, creativity and autonomy. While generative artificial intelligence (GenAI) is defined [3] as a technology that can create original text, images, video and other content. To understand GenAI, whose popularity is growing from 2024, it is necessary to understand the technologies on which GenAI tools like Machine Learning (ML) or Deep Learning (DL) are built. Large Language Models (LLM) is a powerful form of artificial intelligence that has the capacity to generate human-like text, while Small Language Model (SLM) [3] focuses on specialized tasks with less data. Retrieval-Augmented Generation (RAG) improves these models by pulling in external information to produce more accurate results. [3] AI Agents use GenAI to autonomously perform tasks such as writing or research. Together they achieve a high level of automation and creativity.

McKinsey (2024) presents an empirically based analysis [4] of employees' readiness to integrate GenAI into everyday work processes. The analysis indicates a pronounced discrepancy between the perception of the leader and the real behavior patterns of the employees. Employees demonstrate a higher degree of acceptance and operational use of AI tools than senior management estimates. Specifically, three times as many employees are using GenAI to complete their work tasks compared to leader estimates. Employees express a clear need for support in terms of formalized trainings, access to experimental versions of tools and the introduction of stimulating mechanisms for their use. Despite their readiness, there is currently a deficit of organizational infrastructure that would enable the systemic integration of AI into everyday work [4]. According to these researches, it can be concluded that there is a significant potential for HAIT synergistic action, which implies proactive and strategic management action.

3. ARTIFICIAL INTELLIGENCE AGENTS AND THEIR ORCHESTRATION

AI agents, with all the features they bring, point to the need for their implementation. In this sense, orchestration is necessary, which according to Malec, M. [5] represents the process of coordinating different AI tools and artificial intelligence systems for their joint, efficient work. Like an "orchestra" in which each of the instruments creates a common melody and harmony, AI tools and systems should work harmoniously as a single system and lead to a common outcome - efficient communication, data sharing, etc.

The innovations that come with the use of AI and the benefits are manifold. IBM in the research paper: Orchestrating agentic AI for intelligent business operations [6], lists the key topics of autonomous automation:

- Acceptance of the new paradigm of the workplace - technology leads operations, and the analytical, creative part of work and technology is managed by a humane manager. Business transformation shows that employees, suppliers and customers are already heavily interacting with AI as the main point of contact for transactions. Their development indicates the possibility to realize different intelligent flows in business operations. It is also the possibility to leave simple execution to AI agents, and human resources to raise their activities to a higher level. This change marks a transition from traditional hierarchical models to hybrid teams where AI agents become full-fledged "collaborators", especially in tasks that require processing large amounts of data and making quick decisions. AI agents differ from classic automated systems, as they act independently, learn from the environment, adapt their behavior and make decisions in real time.
- The use of AI affects the empowerment of employees and increases their agility. By automating routine tasks, employees can focus on strategic and creative activities, but this transition requires continuous education and development of digital skills to avoid the digital divide among employees.
- Outcome optimization – AI agents are more focused on outcomes and less on business rules. They are looking for more and more efficient ways to achieve results. Like an autonomous car that drives itself to its destination and moves through interpretations of the environment, and makes decisions through sensors and algorithms, so AI agents perceive their environment, set a goal and dynamically change actions, in order to reach the goals. In this context, AI agents function as advanced intelligent systems that recognize patterns and make optimal decisions.

  In the banking sector, for example, AI agents are used to automatically evaluate loan applications. Agents analyze the client's credit history, current market indicators and other risk factors. AI systems are used during the evaluation of the loan request, so that the bank officer will be able to clearly and logically explain the reasons for his decision, which ensures the transparency of the process and the preservation of the client's trust.

- Fast value tracking – indicates possible differences of the AI agents themselves, according to the differences in their expertise and their impact on the orchestration of different data sources and systems. The introduction of AI agents cannot rely solely on the IT sector, but requires an interdisciplinary collaboration of experts from the fields of technology, law, ethics, finance and management. Artificial intelligence [7] has a profound impact on social structure, economy and human relations, becoming a key catalyst for changes shaping our future. This technological progress raises numerous ethical, social and legal issues, requiring continuous adaptation of society and educational institutions in order to respond to new challenges.

The future of intelligent business operations depends not only on technology, but also on how humans and AI will collaborate in new hybrid work environments. Organizations that align technical innovation with human values and competency development will be the ones to profit most in the AI future.

4. ARTIFICIAL INTELLIGENCE AND ITS USERS

Artificial intelligence agents provide the ability to achieve a competitive advantage for organizations. Automation of business processes and further improvement of work efficiency in cooperation with AI is expected. AI agents (IBM) autonomously learn, adapt and optimize in real time. These are intelligent agents that proactively anticipate challenges, personalize experiences and drive innovation. It is a shift from automating [8] tasks to orchestrating processes that constantly adapt to a dynamic environment.

The company Statista Market Insights [9] conducted research and determined that already in 2020. has 115.9 million users of AI tools. How the number of users is growing can be seen in Figure 1.

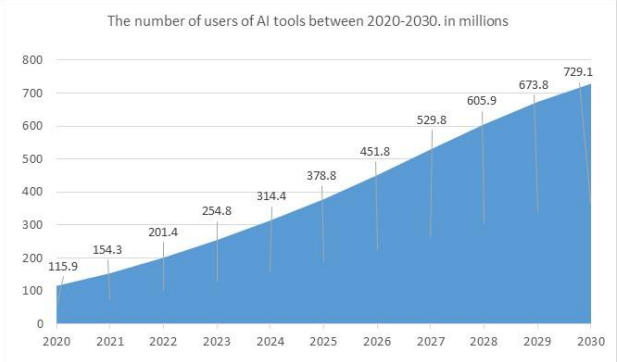


Figure 1 Statista Market Insights - Showing growth in the number of users of AI tools

On the displayed graph, you can see the current data for 2025. which indicates that, in the current year, there are 378.8 million AI users, representing a growth rate of 3.3 times. The following years show the projection of a further upward trend in the use of AI agents. An upward trend is evident, indicating a great interest of users in AI and its use. It should be emphasized that quantitative growth also implies changes in the field of work habits, critical thinking and creative autonomy.

5. CASE STUDY

In addition to well-known research and theoretical knowledge about traditional team cooperation, there is a need for a current examination of the relationship of trust in the team, in situations where the teams consist of humans and artificial intelligence (HAIT). An illustrative example is certainly an experiment with the Honda Research Institute MHCI @ CMU, entitled: Understanding Human-AI Collaboration — Insights from Hands-On Experiments and Research Synthesis (2024). The experiment [10] aimed to investigate team dynamics between human and artificial intelligence. It is called: Wizard of Oz experiment. The pilot research they conducted focused on service users. The intent was to determine how errors and confusing AI instructions affect user trust in AI. The scenario of the experiment was such that one of the participants simulates the work of AI during navigation, in order to create the desired user experience. He guided users through a "confusing" part of the CMU (Carnegie Mellon University) building. After that, the respondents filled out a questionnaire on the subjective assessment of trust in relation to AI. The specified flow is shown by the following model:

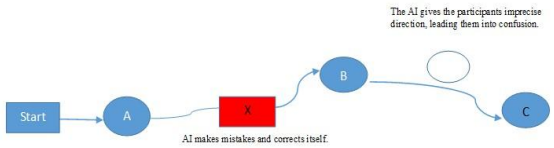


Figure 2. A simple navigation path used in the Pilot Experiment

In the beginning, there was a simple and exact path (from start to point A). After that, the AI makes one mistake, but corrects itself. A deliberate mistake should initiate a reaction from the user and thereby detect their level of trust in the AI. In the sequel, the AI gives the participants imprecise direction and confuses them. Confusion should initiate a user reaction against a lower level of AI response competence. During the experiment, participants could interrupt the AI and ask for further explanations. The obtained data can be seen in Figure 2.

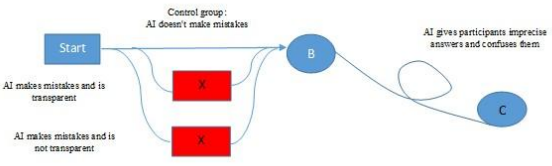


Figure 3. Updated navigation map

It can be seen that when there is transparency, whereby the AI admits its mistake and corrects it - the level of trust increases. Conversely, if the AI makes a mistake and is not transparent, the level of trust decreases. The confusion remains and there are no further answers. A correlation was registered between additional questions and the level of trust. If there is a correction by AI, no additional questions are registered. If there is non-transparency, the number of questions is increased, in order to increase the level of certainty in statements (such as: "Are you sure that this is the right way?").

The presented Pilot research represents an original contribution to future possible scenarios of working with artificial intelligence and determining the reaction of different segments of the population to AI. This type of experiment provides useful insights in terms of prototypes that can be implemented in Chatbot frameworks. It opens up a wide interdisciplinary experimental field as well as the possibilities of practical application of AI. Such experiments raise additional questions: what would the results look like in different cultural contexts? Does the level of trust in AI differ between cultures that value hierarchy in teams more than those that favor egalitarianism? These aspects could become the subject of future comparative research.

6. CONCLUSION

Theoretical considerations and the experimental endeavor described in the Case Study point to the fact that AI is becoming a dynamic partner within the HAIT team that analyzes, learns, develops models, and proposes solutions. The Human - Artificial Intelligence - Team (HAIT) model has a synergistic outcome based on human abilities and AI capabilities. The complementarity in the work of the HAIT team implies that a large number of operational tasks can be effectively left to AI, which confirms the initial hypothesis of this work. Also, experiments like the one shown point to more complex segments of work with AI in which the level of confidence in the competence of AI can be detected, and therefore its usability in the world of work. Future research and experiments in this area may greatly influence the development of AI prototypes, while more AI systems will be in need of orchestration.

The evaluation of HAIT also depends on the established balance between AI and the preservation of human values (creativity, empathy, mutual trust). As AI becomes more sophisticated, we can expect further development and enhancement of the sociological dimension of HAIT. We are continuously working on adapting GenAI to the user and his needs. At the same time, the transparency of GenAI, the intuitive interface, working in a reliable system, is a great contribution of GenAI to the world of work in the digital age.

REFERENCES

[1] Krstić, D., Psihološki rečnik Savremena administracija, Beograd, 1991.

[2] Stryker, C., & Kavlakoglu, E., What is Artificial intelligence? 2024. https://www.ibm.com/think/topics/artificial-intelligence

[3] What is Generative AI? What are LLMs and SLMs? What is a RAG? What are AI Agents? 2025. https://generativeai.net/

[4] McKinsey & Company. Employees are ready for AI; now leaders must step up. McKinsey Global Institute. 2024. https://www.mckinsey.com/

[5] Malec, M., AI Orchestration Unleashed: What, Why, & How for 2025, 2024. https://hatchworks.com/blog/gen-ai/ai-orchestration/

[6] IBM, Institute for Business Value, Orchestrating agentic AI for intellignt busiess operations, 2025. https://www.ibm.com/thought-leadership/institute-business-value/en-us/report/agentic-process-automation

[7] Luknar, I. Social dynamics in the era of artificial intelligence. Serbian Political Thought, 90(2), 145–162. Institute for Political Studies, Belgrade. 2025.

[8] IBM, Institute for Business Value, Orchestrating agentic AI for intelligent business operations, 2025. https://www.ibm.com/downloads/documents/us-en/12fc84a1aed95bbc

[9] Edge AI + Vision Alliance, Global AI Adoption to Surge 20%, Exceeding 378 Milion Users in 2025, 2025. https://www.edge-ai-vision.com/2025/02/global-ai-adoption-to-surge-20-exceeding-378-million-users-in-2025/

[10] Honda Research Institute MHCI @ CMU, Understanding human-ai collaboration insights from hands on experiments and research, 2024. https://medium.com/99p-labs/sprint-4-understanding-human-ai-collaboration-insights-from-hands-on-experiments-and-research-fbde74f1160d

[11] Georganta, E., & Ulfert, A.-S. Would you trust an AI team member? Team trust in human–AI teams. Journal of Occupational and Organizational Psychology, 97(3), 1212–1241. 2024. https://doi.org/10.1111/joop.12504

[12] Lin, C.-P., & Chen, P.-C. Mentoring for effective human-AI collaboration: An integrated theoretical framework. Total Quality Management & Business Excellence. 2025. https://doi.org/10.1080/14783363.2025.250

2.

Information Security

AI'S ROLE IN CYBERSECURITY THREATS AND DEFENSES - EXAMPLES OF CONCRETE SOLUTIONS

Dragan Pleskonjić, Glog.AI, dragan@glog.ai
Luka Tica, Glog.AI, luka.tica@glog.ai
Vladimir Jelić, Glog.AI, vladimir.jelic@glog.ai
Dušan Todorović, Glog.AI, dusan.todorovic@glog.ai
Anthony English, Bot Security Solutions Inc., tony@botsecuritysolutions.com

Abstract: Artificial Intelligence is transforming cybersecurity into a high-speed chess game. While AI can detect, respond, and even prevent cyberattacks faster than ever, it is also being weaponized by threat actors at an alarming rate. This paper will delve into the potential misuse of AI in orchestrating cyberattacks and subsequently explore how AI and ML are being strategically applied within projects like Glog.AI, INPRESEC, Security Predictions, and vSOC to fortify software, information systems, and networks against these evolving threats. It also explores the Security-Analyst-in-the-Loop (SAIL) concept employed by Glog.AI and INPRESEC, illustrating how human-AI synergy helps mitigate the risks posed by over-automated systems. As digital transformation accelerates across industries, the role of AI in cybersecurity becomes not just a technical issue but a strategic imperative for organizations worldwide.

Keywords: Cybersecurity, Software Security, Artificial Intelligence, Risk Assessment, Security Analyst in the Loop

1. Introduction: Weaponizing Intelligence for Cyberattacks

The inherent capabilities of AI – its ability to learn, adapt, automate, and process vast amounts of data – make it a powerful tool that can be turned towards malicious ends in the cybersecurity landscape. Traditional cyberattacks often rely on predictable patterns and known vulnerabilities. However, AI empowers attackers to develop and deploy threats that are far more sophisticated and adaptive, posing a significant challenge to existing security measures.

The democratization of AI tools—such as open-source large language models and automated coding assistants—further complicates the threat landscape. Cybercriminals no longer need deep technical expertise to generate attack scripts, automate reconnaissance, or mimic legitimate communication, increasing the scale and frequency of AI-powered threats. One of the primary areas of concern is the use of AI to enhance social engineering and phishing attacks. By analyzing massive datasets of personal information and communication styles, AI can craft highly personalized and convincing phishing emails, text messages, or even voice calls. Natural language processing (NLP) allows attackers to mimic trusted individuals with remarkable accuracy, increasing the likelihood of successful deception. Deepfake technology further amplifies this threat by enabling the creation of realistic audio and video of individuals, potentially leading to more elaborate and believable scams.

2. Current Uses of AI in Cybercrime

AI can also be leveraged for automated vulnerability exploitation. Instead of relying on manual reconnaissance and exploitation, AI-powered bots can be trained to autonomously scan networks and systems for a wider range of vulnerabilities, including zero-day exploits. These intelligent agents can learn from past successful attacks, adapt their scanning techniques in real-time, and even chain together multiple vulnerabilities to achieve deeper system penetration. This automation significantly accelerates the attack lifecycle and reduces the need for extensive attacker intervention.

Furthermore, AI can be integrated into evasive malware. Polymorphic and metamorphic malware, which change their code to avoid signature-based detection, can be significantly enhanced with AI. Machine learning algorithms can enable malware to learn which code mutations are most effective at evading specific antivirus solutions and intrusion detection systems. Reinforcement learning could even allow malware to adapt its behavior dynamically based on the security environment it encounters.

Figure 1: Current Uses of AI in cybercrime

The orchestration of more sophisticated Distributed Denial-of-Service (DDoS) attacks is another area where AI poses a threat. Instead of simply overwhelming targets with sheer volume, AI-driven botnets can analyze network traffic patterns, identify critical infrastructure components, and launch targeted attacks designed to disrupt specific services. These botnets can also adapt their attack vectors in real-time to evade mitigation efforts, making them significantly more challenging to defend against.

Beyond these examples, AI can also be misused for AI-powered cryptojacking, where malicious AI agents optimize resource utilization and evasion techniques for illicit cryptocurrency mining, and potentially for bypassing biometric authentication systems through the development of sophisticated spoofing techniques. The versatility and adaptability of AI make it a potent weapon in the hands of cybercriminals, demanding a paradigm shift in how we approach cybersecurity defense.

3. Current uses of AI in Cyber Defense

There are multiple examples of use of AI in cyber defense. Here are some examples.[1]

Security analysts use AI to enhance threat detection, automates responses, and improve overall security posture. Even more are depicted in the figure below.

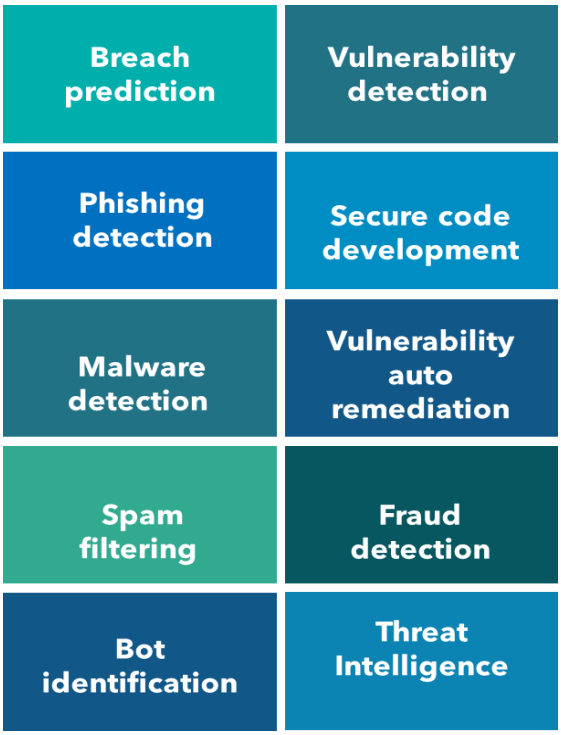


Figure 2: Current Uses of AI in Cyber Defense

AI techniques used in cyber defense include:

- Machine Learning (ML): For pattern recognition and anomaly detection.
- Deep Learning (DL): For advanced threat detection and analysis.
- Natural Language Processing (NLP): For analyzing and understanding text-based threats.
- Knowledge Representation and Reasoning (KRR): For decision-making and automated reasoning.

We present here some of our specific examples developed by Glog.AI.

AI security risks are increased when AI operates in isolation. This underscores the value of SAIL-based defenses, which reintroduce human reasoning into the decision pipeline. Instead of AI replacing human analysts, it augments their capabilities, allowing them to focus on high-value tasks that require critical thinking, contextual understanding, and strategic decision-making.

4. Glog.AI – Securing Software with AI-Powered Vulnerability Remediation

Figure 3: Glog.AI

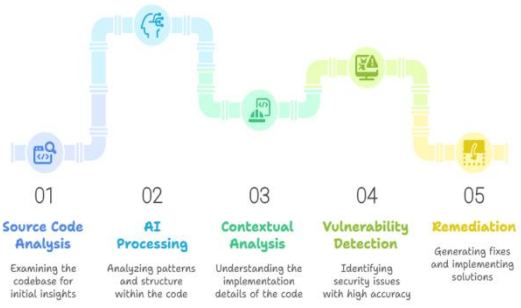
Glog.AI directly addresses the challenge of software security by leveraging AI to seamlessly identify and remediate security vulnerabilities within software code [2]. Recognizing that vulnerabilities in software are a significant entry point for many cyberattacks, Glog.AI empowers development teams to build more secure products from the outset.

At its core, Glog.AI employs AI-powered vulnerability detection. This goes beyond traditional static and dynamic analysis techniques by utilizing machine learning models to understand the context and semantics of the code [3]. This allows Glog.AI to identify genuine vulnerabilities with greater accuracy and significantly reduce the number of false positives that often plague traditional security scanning tools. By focusing on the actual risks, development teams can prioritize their remediation efforts more effectively.

A key differentiator of Glog.AI is its drive towards automated security vulnerability remediation. While currently focused on intelligent identification, the ultimate goal is to autonomously fix identified vulnerabilities. This would represent a significant leap forward in software security, allowing for true agility by embedding security directly into the development pipeline without causing delays. Imagine a system that not only identifies a flaw but also automatically applies the necessary fix, allowing developers to focus on building features rather than spending extensive time on manual remediation.

Glog.AI also provides seamless integration into the software development lifecycle (SDLC). By embedding its analysis capabilities within the development workflow, Glog.AI ensures that security is considered early and often – a principle known as "extend-to-left." This early detection and remediation of vulnerabilities is far more efficient and cost-effective than addressing them in later stages of development or in production.

Furthermore, Glog.AI empowers development teams by providing them with clear and actionable remediation advice. When a vulnerability is identified, the platform offers specific guidance on how to fix the issue, often including code examples and best practices. This not only helps in resolving the immediate vulnerability but also educates developers on secure coding practices, leading to more secure code in the future. By making security



a more integrated and less disruptive part of the development process, Glog.AI aims to foster a culture of security within development teams.

Figure 4: Glog.AI pipeline

5. INPRESEC and Security Predictions – Proactive Network and Threat Intelligence with AI/ML

INPRESEC (Intelligent Predictive Security) and Security Predictions represent a proactive approach to cybersecurity, leveraging AI and ML to anticipate and prevent attacks on networks and endpoints. Sensor component works on the Linux platform.[4]

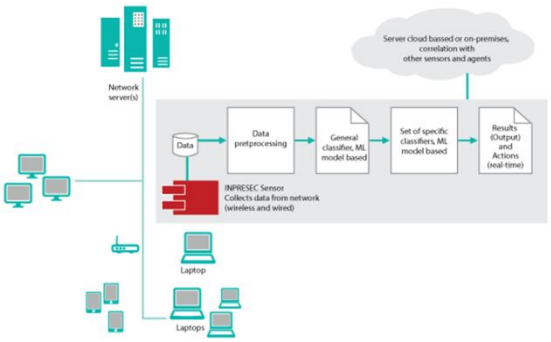


Figure 5: INPRESEC Sensor

INPRESEC focuses on network and endpoint security by employing AI and ML to detect anomalies in behavior, identify security threats, and predict potential attacks. Its novel approach aims to shift from reactive defense to proactive prevention. By analyzing network traffic patterns, user behavior, and system logs, INPRESEC's AI algorithms can establish baselines of normal activity. Deviations from these baselines, which could indicate malicious activity or the early stages of an attack, are flagged for investigation. The "intelligent predictive security" aspect lies in its ability to analyze these anomalies and other indicators to predict the most likely cyberattacks that an organization might face [5]. This predictive capability allows for the planning and implementation of optimal preventive and proactive cybersecurity defensive measures, effectively hardening systems before an attack can fully materialize.

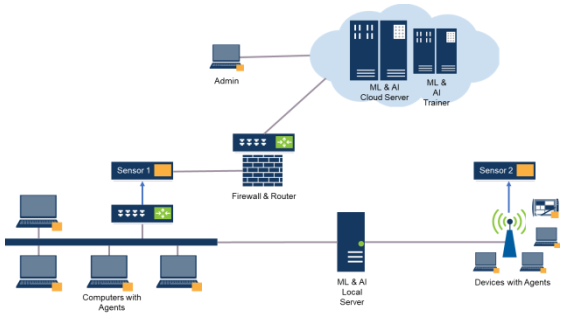


Figure 6: INPRESEC Deployment Model

Security Predictions focuses on threat intelligence, utilizing AI and ML to analyze a wide array of internal and external data sources. This data can include security reports, vulnerability databases, dark web activity, social media trends, and network traffic analysis. By applying proprietary algorithms to this vast dataset, Security Predictions generates probabilities of potential future threats and attacks. This predictive threat intelligence allows organizations to stay ahead of emerging threats, understand attacker tactics, and proactively adjust their security posture to mitigate potential risks. For example, if Security Predictions identifies a surge in discussions about a specific vulnerability being exploited, organizations can prioritize patching those systems.

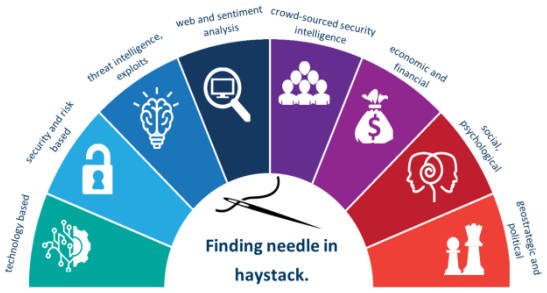


Figure 7: Security Predictions - Example of inputs

The synergy between INPRESEC and Security Predictions is evident. Security Predictions can provide INPRESEC with valuable insights into emerging threats and attack trends, allowing INPRESEC to refine its anomaly detection models and better predict the specific types of attacks that are likely to target the network and endpoints it protects. This collaborative approach, powered by AI and ML, enables a more dynamic and adaptive security posture.

6. vSOC (Virtual Security Operations Center) – Orchestrating AI-Powered Defense

The vSOC (Virtual Security Operations Center) automation by using AI represents a holistic approach to cybersecurity operations by integrating the capabilities of Glog.AI, INPRESEC, and Security Predictions, along with other security tools, into a centralized and AI-driven platform. The goal of a vSOC is to create a more efficient, effective, and proactive security operations capability.

Figure 8: vSOC

By leveraging Glog.AI's vulnerability detection and remediation insights, the vSOC can gain a deeper understanding of the security posture of the organization's software assets. This allows for proactive measures to address potential weaknesses before they can be exploited in a network attack.

INPRESEC's network and endpoint anomaly detection and predictive capabilities form a crucial layer of the vSOC, providing real-time monitoring and alerting on suspicious activities and potential attacks targeting the infrastructure. Its predictive nature allows the vSOC to anticipate and prepare for likely attack scenarios.

Security Predictions' threat intelligence feeds the vSOC with valuable context about the evolving threat landscape. This information allows the vSOC to prioritize alerts, understand attacker motivations and tactics, and proactively hunt for potential threats that might be emerging.

The "virtual" aspect of the vSOC emphasizes the potential for automation and remote operation, leveraging AI to augment and, in some cases, automate tasks that traditionally require significant human intervention. AI within the vSOC can be used for intelligent alert correlation, reducing alert fatigue by grouping related events and providing a more comprehensive picture of an incident. It can also facilitate automated incident response by triggering pre-defined playbooks based on the type and severity of the detected threat. Furthermore, AI can enhance threat hunting activities by identifying subtle patterns and anomalies that human analysts might miss.

In essence, the vSOC acts as an intelligent orchestration layer, bringing together the specialized AI and ML capabilities of Glog.AI, INPRESEC, and Security Predictions to provide a comprehensive and proactive defense across the entire IT ecosystem – from the software development lifecycle to network infrastructure and endpoint security. This integrated, AI-powered approach is essential for effectively countering the increasingly sophisticated and AI-driven cyber threats of today and the future.

Glog.AI’s penetration testing services, enhanced by the power of Artificial Intelligence, offer a more efficient, comprehensive, and insightful approach to identifying security vulnerabilities compared to traditional methods

7. Continuous Learning with Security Analyst in the Loop (SAIL)

In the context of Glog.AI and INPRESEC, SAIL is not just a theoretical model—it is a core operational strategy that enables rapid development of new security capabilities and ongoing refinement of existing ones. Through SAIL, AI becomes an intelligent partner that empowers cybersecurity professionals to work more efficiently, adapt faster, and make better-informed decisions.

When deploying AI/ML systems to detect novel cyber threats or address new attack surfaces, the first hurdle is the availability of high-quality training data. Security analysts play a vital role in

bridging this gap. By labeling and annotating raw data, they create the foundational datasets that enable supervised learning. This human-labeled data allows AI models to learn the distinction between benign and malicious activity, drastically improving their accuracy from the outset.

One of the most challenging scenarios for AI is the so-called cold start problem—where historical data is insufficient to bootstrap a new model. Here, SAIL excels by enabling analysts to provide initial labels and feedback that guide the model in its early learning stages. As a result, AI systems under the SAIL model reach maturity faster and begin delivering value more quickly than those trained in isolation. Before any AI model is widely deployed, it must be validated on live or representative datasets. Analysts test the model's performance, flag incorrect assumptions, and verify whether the model is detecting the right types of threats.

SAIL ensures that human analysts remain actively involved in this evolution. Their feedback is fed directly into the system to reduce false positives and false negatives, which remain one of the biggest sources of inefficiency and alert fatigue in cybersecurity operations.

8. Conclusion

The rise of AI presents a double-edged sword for cybersecurity. As AI technologies evolve, so must our approach to cybersecurity — not as a series of reactive measures, but as a continuously learning and adapting system. While malicious actors can leverage its power to create more sophisticated and evasive attacks, AI and ML also offer unprecedented opportunities to enhance our defensive capabilities. The question is not whether AI will dominate the cybersecurity landscape, but how we ensure it does so on the side of defense. Projects like Glog.AI, with its focus on AI-driven software security, INPRESEC's intelligent network and endpoint protection, Security Predictions' proactive threat intelligence, and the integrated AI-powered operations of a vSOC represent a crucial step forward in building more resilient and adaptive security postures. By strategically applying AI and ML across the security landscape, we can strive to stay ahead of evolving threats and protect our increasingly digital world.

References

[1] Dragan Pleskonjic, "AI in Cybersecurity and Software Security", *European Lotteries and World Lottery Association (EL/WLA) Security & Operational Risks Seminar: New Threats & Opportunities: Evolving AI & Security Risks*, Marseille, France, 2024.

[2]. Website Glog.AI, May 2025.

[3] Dragan Pleskonjic, Vladimir Jelic, "How IGT Protects Clients and Players with Rigorous Application Security Practices", *Think 2019*, San Francisco, California, USA, 2019.

[4] Borislav Đorđević, Dragan Pleskonjić, Nemanja Maček, "Operativni sistemi: UNIX i Linux", *Viša elektrotehnička škola*, Beograd, 2004.

[5] Dragan Pleskonjic, "Wireless intrusion detection systems (WIDS)", *19th Annual Computer Security Applications Conference*, Las Vegas, Nevada, USA, 2003.

SIRIUS E-LEARNING PLATFORM FOR CREATING AND CONDUCTING ACCREDITED ONLINE SEMINARS - IT SECURITY IN SCHOOLS

Vladan Stevanović, Sirius online, vladan@onlinetest.rs

Abstract: *The Sirius e-learning platform supports working with interactive simulations of real environments, enabling maximum efficiency in online training. Accredited online seminars by the Institute for the Improvement of Education and Upbringing represent the most significant form of professional development for educational staff in Serbia. This paper will present a new accredited seminar on the Sirius e-learning platform.*

Keywords: *Online training, e-learning platform, accredited seminar, data protection, cybersecurity, research results.*

1. INTRODUCTION

The Ministry of Education published the Digital Competence Framework "Teacher for the Digital Age 2019," [1] which defines the digital competencies for the teaching profession. The first category of competencies includes security, caution, protection, and safeguarding of data and devices, which is precisely the topic of this seminar.

Over the past ten years, we have conducted numerous online seminars aimed at enhancing IT competencies of teachers in primary and secondary schools, during which we noticed insufficient preparedness among teachers to apply basic security principles in the domain of computer and personal data protection. The online seminar "Protection of Personal Data and IT Security in Schools" familiarizes teachers with current topics in IT security.

2. ABOUT THE SEMINAR "PROTECTION OF PERSONAL DATA AND IT SECURITY IN SCHOOLS"

The seminar relates to the following competencies:

K1: Teacher competencies for a specialized professional field,

K4: Teacher competencies for communication and collaboration,

K22: Director competencies for ensuring the legality of the institution's operations.

Priority area:
P6: Enhancing digital competencies and the use of information and communication technologies in the implementation of the educational process.

2.1 Goals and Outcomes of the Seminar

The general goal of the training is to raise awareness of the security aspects of using computers in teaching, as well as the protection of personal data and student data.

Specific objectives are:

- Understand the importance of personal data protection and identify common principles of data protection and privacy control;
- Recognize threats to personal security due to identity theft and potential threats to data in the cloud;
- Understand password policies and perform file encryption;
- Identify network and Wi-Fi security risks.

Expected outcomes:

- Protect personal data, student data, and teaching materials from unauthorized access, loss, or misuse;
- Ensure the safe conduct of lessons using digital technologies and computer lab resources;
- Educate students about the importance of personal data protection, recognizing threats, and taking preventive measures.

2.2 Seminar programme:

The training programme is in accordance with the Law on Personal Data Protection of RS [3], the Law on Information Security of RS [4], GDPR (General Data Protection Regulation) [2].

Seminar programme:

1) **Security concepts and personal data protection** (data threats, cybercrime, data protection, information security properties, laws, GDPR) [2];

2) **Personal security** (social engineering [5], identity theft, file security, encryption, password policy);
3) **Malicious programmes:** types and methods (viruses, worms, trojans, ransomware, DDoS,...), protection, resolution and removal;
4) **Network security:** types of networks and connections, Firewall, Wireless security;

3. TRAINING CONCEPT ON THE SIRIUS E-LEARNING PLATFORM

The online seminar was created and conducted on the Sirius e-learning platform, featuring interactive simulations of real environments, enabling participants to fully master practical skills and procedures.

3.1 Sirius e-learning platform

Basic functionalities:

- Production of online training courses,
- Textual, video, and interactive content,
- Exercises with interactive simulations of real situations and procedures,
- Self-assessment of acquired knowledge through passing quizzes and a final test,
- Monitoring participants' progress based on outcomes and test results,
- Organization of exam testing by sessions,
- Platform administration with multiple access levels,
- Clear and comprehensive reports.

Image 1. Admin module

The training content is provided in both text and video formats, while complex procedures are presented as interactive exercises.

Image 2. Training concept

The training was personalized, with measurable results, so the certificate is awarded based on outcomes — successfully passing the tests. After each chapter, participants had a quiz for self-assessment of acquired knowledge, and at the end, a final test. The condition for receiving the certificate was passing all quizzes and the final test with a score of 70% or higher. For each successfully passed test, participants received corresponding badges (smile).

Test concept

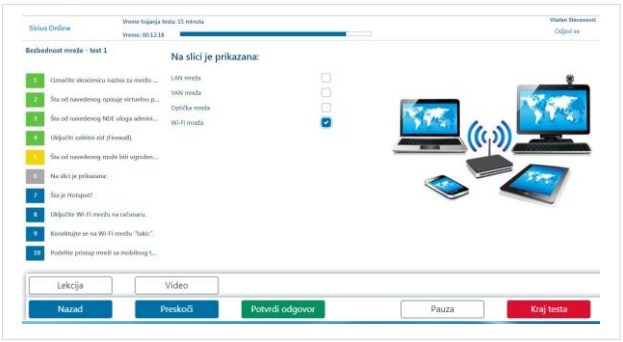


Image 3. Test concept

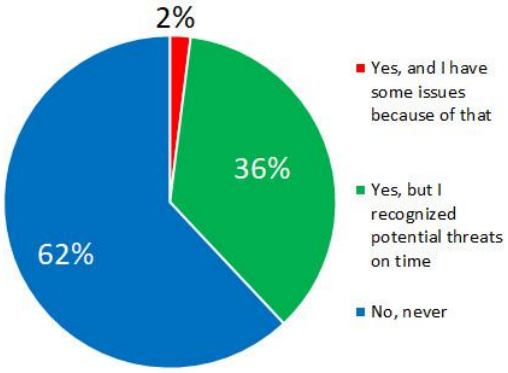
Types of test questions:

- Interactive tasks
- Paperclip (answer linking)
- *Drag & Drop*
- Correct / incorrect
- Choosing one of multiple answers offered
- Click on the image
- A combination of the previous two
- Entering an answer in the field

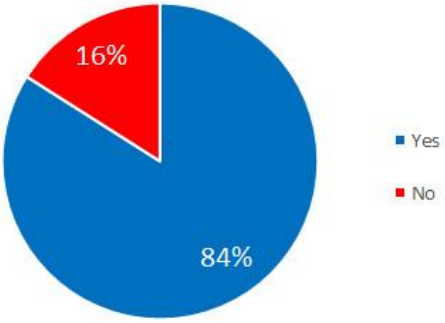
The training was available to participants for four weeks (24/7). After completing the online training, we conducted a survey with 100 seminar participants, the results of which will be presented below.

4. RESEARCH RESULTS

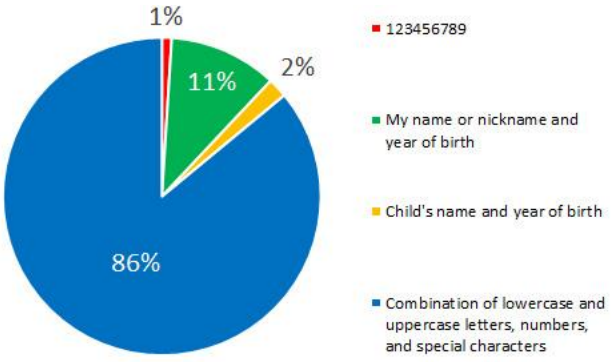
1) Have you been exposed to any type of cyber attack?



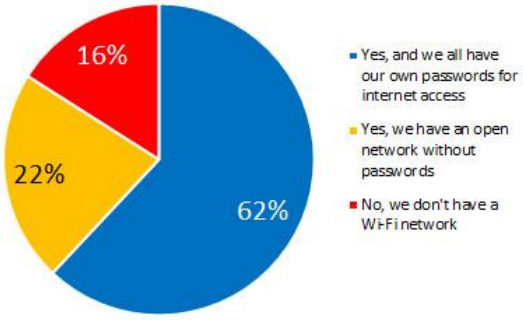
2) Do you have user name and password



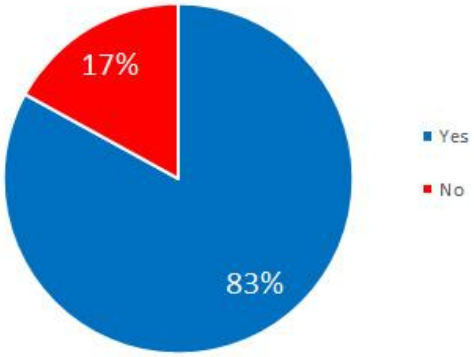
3) What does your password look like?



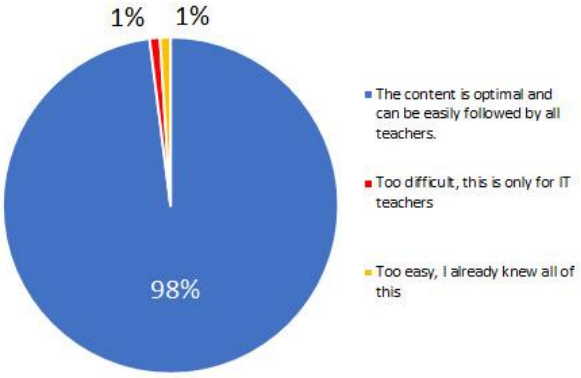
4) Do you have a secured Wi-Fi network at your school?



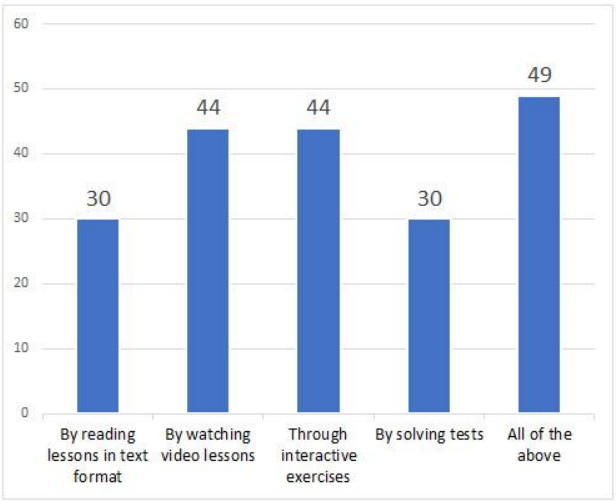
5) Do you use antivirus programmes?



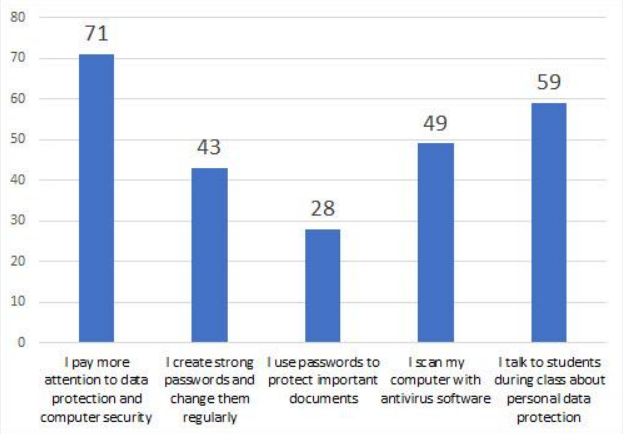
6) How would you rate the content of the online seminar in relation to your needs for safe computer use?



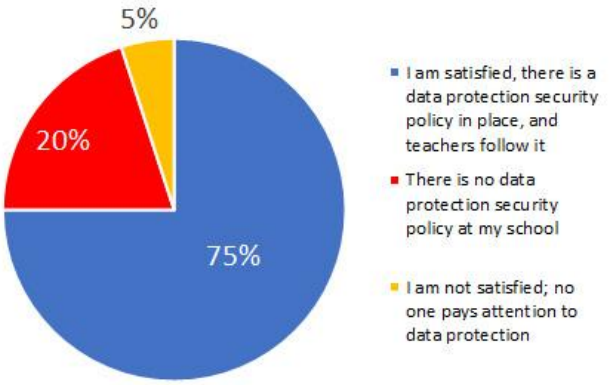
7) In what way did you learn the most during the seminar? (you can select multiple answers)



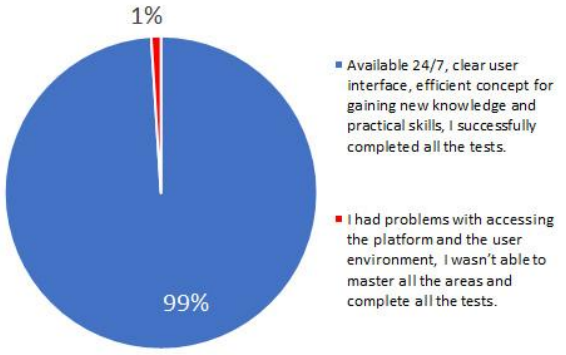
8) How do you apply the newly acquired knowledge? (you can select multiple answers)



9) Are you satisfied with the data protection security policy at your school

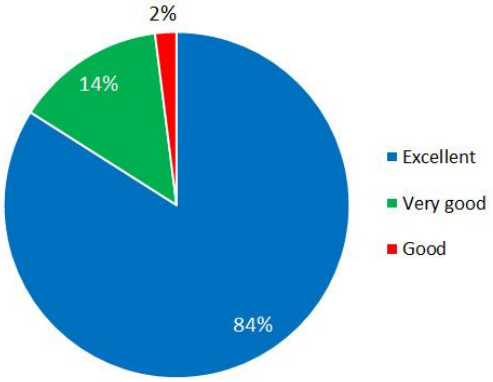


10) What is your user experience with the operation, features, and accessibility of the Sirius e-learning platform used for the seminar?



Available 24/7, clear user interface, efficient concept for acquiring new knowledge and practical skills, I successfully completed all the tests, 99 users responded.

11) Overall rating of the online seminar?



5. CONCLUSION

The implementation of the Sirius e-learning platform for the accredited online seminar "Protection of Personal Data and IT Security in Schools" has proven to be an effective model for the professional development of educators in the field of digital security. Through interactive simulations and practical exercises, teachers successfully acquired the competencies necessary for the safe use of information and communication technologies in the educational process.

The seminar addresses key needs of teaching staff regarding data protection, identity security, and IT infrastructure, thereby directly contributing to the improvement of digital literacy and cybersecurity in schools.

Research results indicate significant progress in participants' ability to apply basic IT security principles in everyday practice.

REFERENCES

[1] Digital Competence Framework "Teacher for a Digital Age 2019",

[2] EU Regulation 2016/679 of the European Parliament and of the Council – General Data Protection Regulation (GDPR),

[3] Personal Data Protection Act of the Republic of Serbia,

[4] Information Security Act of the Republic of Serbia,

[5] Cyber Psychology, Katarina Kacer.

RISK ASSESSMENT OF THE INFORMATION SYSTEM BY APPLYING THE AHP METHOD

Branko Vujatović, Center for Applied Mathematics and Electronics,Beograd, branko.vujatovic@vs.rs
Sanja Klajić, Center for Applied Mathematics and Electronics, Beograd, sanja.klajic@vs.rs
Darko Grubač, Center for Applied Mathematics and Electronics, Beograd, darko.grubac@vs.rs
Marija Vujatovć, Departman of Telecommunications and Informatics (J-6), Beograd, marija.vujatovic@vs.rs
Nenad Stojanović, Center for Applied Mathematics and Electronics, Beograd, nenad.m.stojanovic@vs.rs

Abstract: *In this paper we described a model for multi-criteria decision-making (MCD) in assessing the security vulnerability of an information system (IS). Multi-criteria analysis (MCA) was carried out using the Analytic Hierarchy Process (AHP) method, creating a mathematical model for solving the assessment itself, and it was implemented in the Expert Choice (EC) program. In the researched model for MCD, based on the analysis of the security threat assessment itself, basic criteria are defined according to alternatives, that is, potential threats to the information system. In the initial phase of the development of the decision support system (DSS), the assessment of the threat of the system is carried out according to the basic alternatives of human resources. In the initial phase, criteria were given in two criterion levels with three alternatives. The first criteria level is based on the seven generally required criteria. In the second criteria level – sub-criteria, we have broken down the criterion "unwanted system state" into four additional sub-criteria. The MCD model itself is designed so that it can be applied to assess the security vulnerability of any IS, and at the same time it provides the possibility of the required expansion in real time and in a specific situation. The presented model for MCD represents the initial element of the decision support system with the aim of providing assistance to management, i.e. to decision makers in making a decision. By developing a decision support system for the IS security manager, we analyze the criteria by which the IS security vulnerability will be assessed. The universality of the model and system will enable the application to the IS regardless of the size, type and function of the system itself.*

Keywords: Multi-criteria decision making, information system, Analytic Hierarchy Process method, Expert Choice, security vulnerability, assessment, criterion, sub-criterion, alternative, universality of application, decision.

1. INTRODUCTION

Management of complex systems is the most complex and difficult task of a manager. Their success in realizing that task depends to a large extent on the quality of the decisions they make. The results of managerial decisions are a direct measure of the success of management. Decisions are the basis of everyday managerial activities. A quality decision requires more and more comprehensive preparation, and the decision-making process itself, as a result, is becoming more and more formalized.

Decision makers need to be able to participate in the creation of the model. In this way, it will be easier for them to explain their decision, to be more confident about it and for their decision to be understandable to other actors in the decision-making process. Making a decision implies the choice of one of the alternatives with which we solve a certain problem. During decision-making, we have the goal that we want to achieve with the decision, the criteria used to measure the achievement of that goal, the weight value of the criteria, which reflects their importance, and alternatives to the problem solution [1].

The research examined the problem of MCD and overcoming the problem through the realization of MCA according to the AHP method, with the aim of making a quality, non-subjective decision in the assessment of the threat of the information system.

2. MULTI-CRITERIA DECISION-MAKING

In order to achieve the goal, making a decision represents the choice of the most acceptable alternative among the offered alternatives and the criteria used in the selection.

The goal represents the state of the system to which we are aiming by making a decision.

Criteria are attributes with which we describe alternatives, and which directly or indirectly provide information on the extent to which a particular alternative achieves the desired system goal.

All criteria are not of the same importance, and the very objectivity depends on the decision maker. For this reason, it is necessary to assign a weight of importance to the criteria. When making a decision, it is necessary to have data on alternatives.

The AHP method is one of the most well-known methods, and in recent years it has been used the most for multi-criteria decision-making. The AHP method represents a hierarchical structure in which the goal we strive for is at the very top, followed by criteria at the first level, sub-criteria at the next level, while alternatives are found at the bottom level, Figure 1.

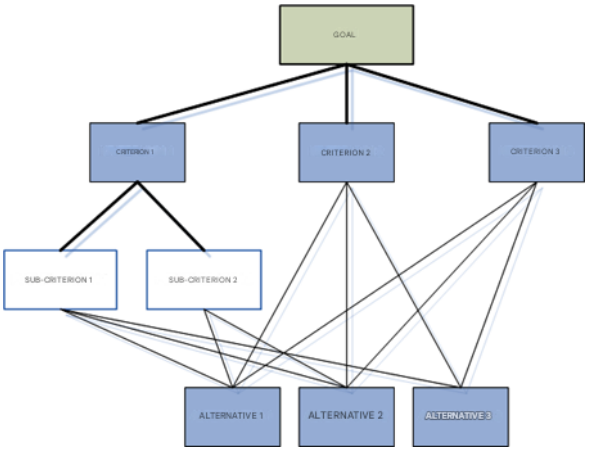


Figure 1. Example of hierarchical structure in AHP method

3. MULTI-CRITERIA DECISION-MAKING USING THE AHP METHOD

Continuous development and intensive use of IS requires the existence of a secure environment in which IS will function. Creating a secure environment requires continuous analysis of IS and environment vulnerability assessment.

The presented example of the application of multi-criteria decision-making is hypothetical, it is not related to a specific case, which contributes to the generality of the solution and the universality of its application to any information system, for various sources of threat and for numerous various vulnerabilities of the information system.

Business intelligence and a decision support system in further integration with information systems provide unprecedented possibilities of application in forecasting, planning, implementation and control of the protection of information systems.

Further steps in the research are reflected in the development of an application to support management that, by objective decision-making, choosing an adequate mathematical model and forming a database on information systems, can realize the process and functions of managing the information security of information systems, with the aim of timely choosing the optimal solution in order to prevent the violation of the integrity of the IS itself, to prevent the alienation-theft of information assets: hardware, software, codes, documentation and others, as well as the protection of data in the IS. In order to achieve the desired goal, it is necessary to provide the decision-maker with an objective and timely assessment of IS threat, according to the defined sources of threats, and based on the criteria.

The development of the model for MCD using the AHP method is basically realized in four basic steps:

1. By defining the input data, criteria and alternatives, based on which the hierarchical structure of the model for MCD is created.
2. By comparing elements in pairs at each level of the hierarchical structure of the AHP method, the decision-maker provides data on the importance of one element in relation to another, and the ratio of elements is shown with the help of the corresponding Saaty table of relative importance.
3. By calculating the weight of criteria, sub-criteria and alternatives, after the evaluation of the relative importance of elements by levels of the hierarchical structure.
4. By creating a sensitivity analysis.

3.1 Hierarchical structure of the model for MCD - definition of input data

In the first step of creating a model for MCD, we define the input data for creating an IS security vulnerability assessment. It is necessary that, in addition to defining the sources of threats, we also define the criteria on the basis of which we will evaluate the security threat of IS.

For the purposes of looking at the multiple problems in this research, as sources of threats to IS and information goods and resources, input data were defined:

- Employees,
- Visitors or Guests and
- Undesirable persons.

According to possible alternatives, and in order to analyze the sources of threats, we set basic criteria:

- Expertise,
- Access,
- Support,
- Risk tolerance,
- Intensity,
- Invisibility and
- Unwanted condition.

An unwanted condition, as a criterion, has sub-criteria and that:

- Alienation,
- Modification,
- Deleting and
- Preventing the use of resources.

Based on the defined input data and set basic criteria according to possible alternatives, we create a hierarchical structure of the model for MCD, according to the hierarchy levels, Figure 2.

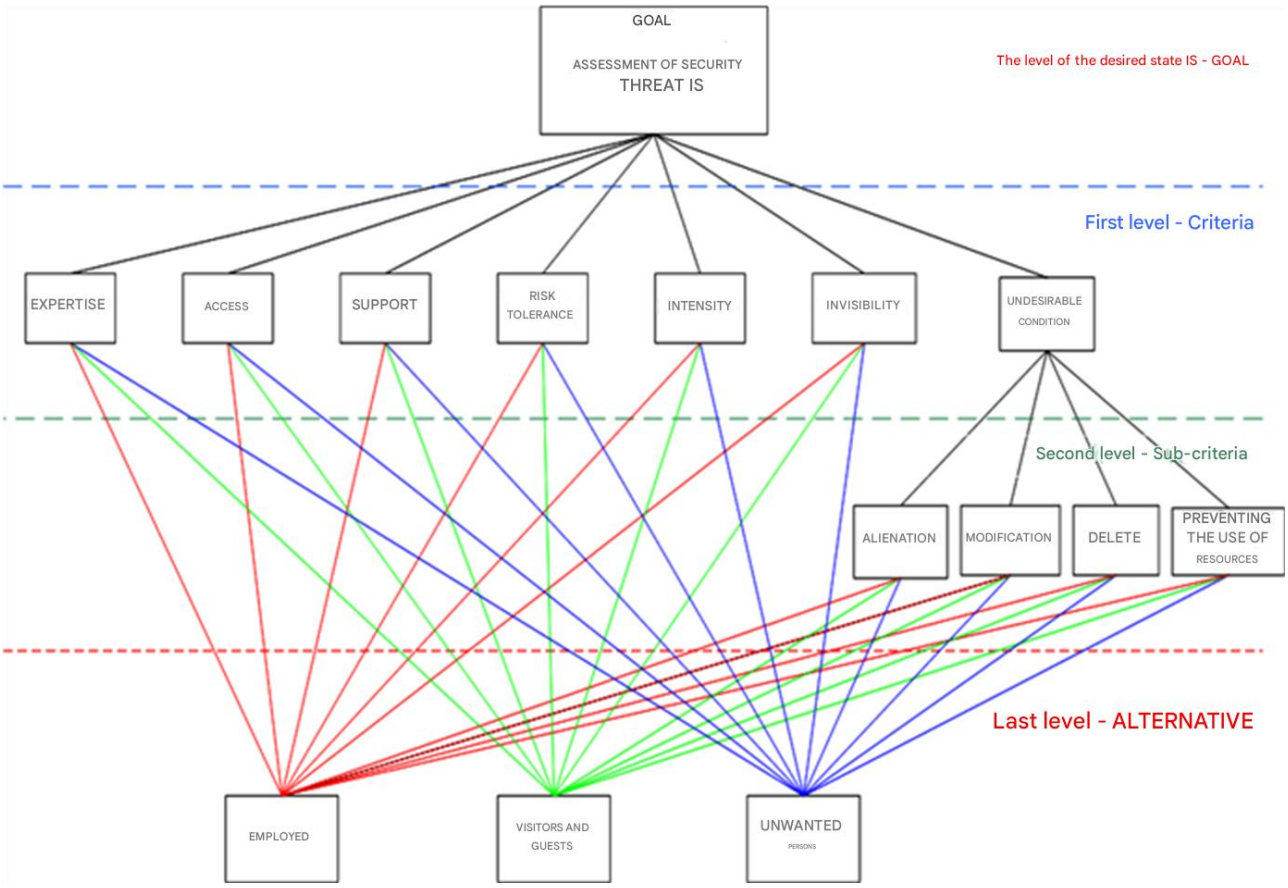


Figure 2. *The hierarchical structure of the MCD [2]*

The hierarchical structure of the MCD model includes the following levels:

- the level of the desired IS state - Goal,
- first level - Criteria,
- second level - Subcriteria and
- the last level-Alternative.

3.2 Development of a mathematical model for MCD using the AHP method - comparing elements and calculating weight criteria

In order to avoid subjective influence on the creation of the model, the AHP method enables monitoring of the consistency of the assessment at every moment of the procedure of comparing pairs of elements. Consistency is monitored using the consistency index (CI):

$$CI = \frac{(\lambda - n)}{(n-1)}. \quad (1)$$

According to the obtained consistency index CI, we calculate the size of consistency CR:

$$\mathrm{CR} = \frac{\mathrm{CI}}{RI} \leq 0.10 \quad (2)$$

where Random Index Inconsistency (RI) is the consistency index for matrices of order n randomly generated by pairwise comparison. For RI values, we use a table with calculated random values, Table 1.

Table 1. *Values of RI random indices (Saaty, T.L., The Analytic Hierarchy Process, , New York, NY, U.S.A. 1980., McGraw-Hill International)[3]*

n	1	2	3	4	5	6	7	8	9	10
R.I.	0.00	0.00	0.58	1.90	1.12	1.24	1.32	1.41	1.45	1.48
n	**11**	**12**	**13**	**14**	**15**					
R.I.	1.49	1.51	1.56	1.57	1.59					

Table 2 shows the adapted value intensity scale applied in the assessment of information system threats.

Table 2. *Adjusted value intensity scale RI*

intensity of importance	Definition	Explanation
1	low level	criteria in relation to each other are the same in importance
3	intermediate level	one criterion is somewhat more important than the other criterion
5	high level	extremely important criterion in relation to the other criterion
2.4	among values	

We further compare the criteria according to the values from Table 2, the criterion level 1 according to the alternative level, and then we compare the two criteria and assigning weight ratios, we approach the calculation of the weight vector:

$$\overline{\text{tv}} = \frac{a_{if}}{\Sigma \text{a}} \quad (3)$$

The weighting ratio of the first level criterion is calculated according to the principle of importance of one criterion in relation to another criterion. Table 3 is given in the form of an n×n matrix, while the sum of the columns is given in a separate line "TOTAL". We need the sum obtained in this way to calculate the weight vector of the first-level criteria. An overview of the ratio of the weight criteria of the first level is given in the Table 3.

Table 3. *The ratio of the weight criteria of the first level - Criteria*

	Expertise	Access	Support	Risk tolerance	Intensity	Invisibility	Unwanted condition
Expertise	1.00	3.00	1.00	3.00	3.00	5.00	5.00
Access	0.33	1.00	3.00	1.00	1.00	3.00	3.00
Support	1.00	0.33	1.00	3.00	3.00	1.00	1.00
Risk tolerance	0.33	1.00	0.33	1.00	3.00	1.00	1.00
Intensity	0.33	1.00	0.33	0.33	1.00	5.00	5.00
Invisibility	0.20	0.33	1.00	1.00	0.20	1.00	1.00
Unwanted condition	0.20	0.33	1.00	1.00	0.20	1.00	1.00
TOTAL	**3.20**	**6.67**	**6.67**	**9.33**	**11.20**	**16.00**	**17.00**

After obtaining the values of the ratio of the weight criterion and the sum for each column, we proceed to the calculation of the weight coefficient for the first level criterion.

We assign a value of 0.1 for the consistency index. With that index, we achieve the absence of subjectivity in making an assessment of the ratio of the weighting coefficient.

If the obtained result is equal to or less than the consistency index, we consider that the calculation of the weight coefficient for a certain criterion was made objectively and is acceptable as such.

The calculation of the weight coefficient for the given criterion is obtained on the basis of the quotient of the values from Table 4 for the criterion divided by the sum of the column of the compared criterion.

Table 4. *Calculation of the weight coefficient for the criterion of the first level - Criteria*

by criterion: EXPERTISE	EMPLOYED	VISITORS AND GUESTS	UNDESIRABLE PERSONS	**PRIORITY**
EMPLOYED	1.00	1.00	1.00	**1.00**
VISITORS AND GUESTS	1.00	1.00	1.00	**1.00**
UNDESIRABLE PERSONS	1.00	1.00	1.00	**1.00**
TOTAL	3.00	3.00	3.00	

After assigning the weight vector, the weight coefficient is calculated for each criterion individually. The weighting coefficient PV is obtained by calculating the sum of the weighting vectors row by row, dividing the result by the number of criteria n:

$$PV = \frac{\Sigma a_{if}}{n} \quad (4)$$

In our model, the value of λ = 0.1 was taken as the consistency index, and we consider results in the range equal or less consistent. The following results were obtained for the calculation of the weighting coefficient of the first level criterion:

- I_{max} = 7,0564,
- CI = 0.0094 – consistency index,
- CR = 0.0071 – degree of consistency.

where the degree of consistency is CR < 0.1 and we consider the result to be consistent, i.e. subjectivity in decision-making 0,7 %.

From the above data, we conclude that the consistency index obtained from the results of the weighting coefficient of the criteria meets the set condition of 0.1, which indicates that the procedure for assigning weighting coefficients was done objectively. Otherwise, the feedback mechanism is activated, and it is necessary to return to the assignment of comparing the two criteria that need to be corrected. The procedure is repeated for all levels of criteria and levels of sub-criteria of the hierarchical model of MCD.

The procedure for calculating the weighting coefficients for alternatives is performed in the same way as the calculation of the weighting vector for criterion levels.

Table 5 shows the ratio of alternatives with the calculated weight coefficient according to the given criterion.

Table 5. *Calculation of the weight vector for each alternative according to the given criteria*

	Expertise	Access	Support	Risk tolerance	Intensity	Invisibility	Unwanted condition	TOTAL	**PV- weight coefficient**	**in %**	
Expertise	0.31	0.45	0.15	0.32	0.27	0.31	0.29	2.1084	**0.30**	30.12	7.0280
Access	0.10	0.15	0.45	0.11	0.09	0.19	0.18	1.2646	**0.18**	18.07	7.0254
Support	0.31	0.05	0.15	0.32	0.27	0.06	0.06	1.2231	**0.17**	17.47	7.1948
Risk tolerance	0.10	0.15	0.05	0.11	0.27	0.06	0.06	0.8005	**0.11**	11.44	7.2772
Intensity	0.10	0.15	0.05	0.04	0.09	0.31	0.29	1.0358	**0.15**	14.80	6.9052
Invisibility	0.06	0.05	0.15	0.11	0.02	0.06	0.06	0.5088	**0.07**	7.27	7.2689
Unwanted condition	0.06	0.05	0.15	0.11	0.02	0.09	0.06	0.5356	**0.08**	7.65	6.6951
								7.4768	1.0681	106.81	

The procedure for calculating the weight vector of the alternative is repeated separately for all criteria.

Based on the calculated weight coefficients of the criteria, as well as the priority of the coefficient, we create a table to display the results of the alternatives according to the given criteria. We calculate the value of the total priority of alternatives:

$$UPA = \frac{\Sigma(PV_i - PR_i)}{n} \quad (5)$$

Where is it:

- UPA – the overall priority of the alternative according to the criteria
- PVi – the weight coefficient of the criteria
- PRi – the priority value of the alternative according to the given criterion
- n– number of criteria (alternative).

The obtained results are ranked in descending order, the highest value in our case is ranked by number 1.

The obtained results are shown in the Table 6.

Table 6. *Overall priority of alternatives*

	Criteria and their weights										Overall priorities of alternatives (UPA)	rank of alternatives
	Expertise	Access	Support	Tolerant. at risk	Intensity	Invisibility	Alienation	Modification	Deletion	resource usage prevention		
PV- weight coefficient	**0.30**	**0.18**	**0.17**	**0.11**	**0.15**	**0.07**	**0.49**	**0.23**	**0.13**	**0.14**		
employed	1.00	0.78	0.78	1.00	0.78	1.00	0.56	0.56	0.78	1.00	**0.1528**	3
visitors and guests	1.00	1.00	1.00	0.78	1.00	1.00	1.67	1.67	1.00	1.00	**0.2450**	2
undesirable persons	1.00	1.67	1.67	1.67	1.67	1.00	1.67	1.67	1.67	1.00	**0.2976**	**1**
UPa	**0.3012**	**0.2074**	**0.2006**	**0.1313**	**0.1699**	**0.0727**	**0.6389**	**0.3014**	**0.1528**	**0.1416**		
	2	5	6	8	7	10	**1**	3	4	9		

•**UPa** – total priority of alternatives according to the given criteria

The security of the observed IS is threatened to the greatest extent by *undesirable persons*. The stated security threat source is the highest-ranking alternative, while as the highest-ranking IS security threat, the criterion is *alienation*

For the decision-maker, the results of the analysis indicate that IS is primarily a security threat from *undesirable persons* and that there is a pronounced risk of theft of information goods and resources.

It is necessary to make an adequate decision in order to take measures to improve the physical and technical protection of IS and the environment.

Continuous development and intensive use of IS requires the existence of a safe environment in which IS will function. Creating a secure environment requires continuous analyzes of IS vulnerability assessment and information assets and resources.

5. CONCLUSION

Further steps in the research are reflected in the development of an application to support management so that through objective decision-making, the selection of an adequate mathematical model and the formation of an IS database, they can realize the process and functions of IS information security management, and in order to timely choose the optimal solution in order to prevent the violation of the integrity of the IS itself, to prevent the alienation-theft of information assets: hardware, software, codes, documentation, etc., as well as the protection of data in IS information assets and resources.

REFERENCES

[1] Čupić M., Suknović M., *Odlučivanje,* FON, Beograd, 2010.

[2] Vujatović, B. & Kršljanin, D., 2014. Primena programa Expert Choice u proceni bezbednosne ugroženosti informacionog sistema. *FBIM Transactions,* 15 07, 2(2), pp. 318-334.

[3] Saaty, T.L., *The Analytic Hierarchy Process,* 1980., New York, NY, U.S.A., McGraw-Hill International

3.

Information Technology and Applications

EXPLORING THE APPLICATION OF BLOCKCHAIN AND SMART CONTRACTS IN CONSTRUCTION PROGRESS PAYMENTS

Paolo Eugenio Demagistris, Politecnico di Torino, paolo.demagistris@polito.it
Filippo Maria Ottaviani, Politecnico di Torino, filippo.ottaviani@polito.it

Abstract: *In construction project management, advancements in digital technology have undoubtedly improved access to progress data and automated payment systems. However, despite these developments, many financial applications still rely on inefficient and time-consuming procedures and documentation. Recent literature has highlighted the potential of blockchain and smart contracts in the construction sector, and this study aims to explore their application in this field. By facilitating autonomous processes and bridging the gap between payments and progress assessments, blockchain and smart contracts can revolutionize the management of construction progress payments. The paper proposes a method for formalizing the execution of smart contracts on a decentralized blockchain-based system to automate construction payments. This approach offers a secure, transparent, and efficient way to manage construction payments, ultimately improving project management and reducing delays and disputes.*

Keywords: *Construction, Project Management, Blockchain, Smart Contract, Payments.*

1. INTRODUCTION

Efficient payment management is essential for successful project execution, preventing cash flow disruptions, and ensuring the financial stability of all stakeholders [1]. However, the construction industry continues to rely on traditional payment systems that are time-consuming and manual processes. This results in payment delays and non-payments that can cause significant financial challenges for project stakeholders [2]. Simultaneously, the construction industry has heavily become credit-dependent, and any disruption to cash flow can significantly impact debt repayment. Payment issues can have severe consequences for suppliers and sub-contractors, who rely on timely payments to maintain financial stability [3]. To prevent these issues, it is crucial to implement efficient and streamlined payment processes to minimize payment delays and ensure timely payment to all stakeholders, ultimately improving the project's financial performance and success.

Smart contracts (SCs) have emerged as a promising solution to simplify contract management. SCs analyze the relationships between contract participants and contractual data to model traditional textual contracts in XML format, allowing for automated contract management and execution [4]. While SCs are primarily used in the IT industry, they can also enhance the construction industry by enabling automated construction payments, benefiting all stakeholders, including creditors, owners, construction companies, subcontractors, vendors of materials, and rental equipment companies. Automation of construction payments using SCs can help reduce costs, time, and payment delays, which are major risk factors in the construction industry [5]. These improvements can prevent cost overruns, delays, and loss of trust, negatively impacting payment processing and creating an unsafe loop that undermines confidence [6].

Recent trends in the construction industry have increasingly emphasized tools such as machine learning and Building Information Modeling to support automation [7,8]. However, payment automation remains a challenge due to the limitations of existing payment systems that do not allow for automated progress data. SCs supported by blockchain technology offer promising solutions to address these payment systems' inefficiencies. Nevertheless, there is still a need for greater clarity on blockchain's requirements and implementation challenges within construction projects, highlighting the importance of addressing the fundamentals of blockchain and SCs.
This study investigates the obstacles to automation in construction payments and suggests the adoption of SC architectures based on blockchain technology to overcome these barriers and enhance payment governance. Specifically, the research seeks to ascertain the feasibility and benefits of implementing blockchain-supported SCs for automating construction payments and to explore the potential for digitizing construction contracts through blockchain applications. By providing empirical evidence and practical insights, the study aims to pave the way for the broader adoption of digital payment automation and blockchain technology in construction project management.

2. REVIEW

2.1 Construction Contracts

Contracts provide a framework for establishing performance compensation within social structures. Their efficacy in conception, implementation, and enforcement relies on the conventions of individuals and the collective intentionality of project members. In the construction industry, contracts outline specific rights for project participants, particularly with regard to payments.

A major constraint in current contract documents and payment requests is that they are mostly made of regulatory regulations, not constitutive regulations [9]. In effect, they rely on centralized systems to collect, model, and transmit information on the project progress and financial compensation. Additionally, the centralized nature of these systems means that there are no self-executing mechanisms to ensure guaranteed execution, posing challenges to timely and accurate payment processes. Therefore, there is a need for constitutive regulations that bridge the gap between the physical reality of product flow and the social reality of cash flow. By enabling self-executing contract codes that can monitor progress without human subjectivity, constitutive regulations can facilitate a more streamlined and efficient payment process, leading to enhanced financial outcomes for all stakeholders involved in construction projects.

2.2 Centralized Payment System

Effective management of interim payments in construction projects requires close collaboration between independent parties with competing business objectives in a highly centralized environment [10]. Payments are subject to centrally trusted preparation, review, approval, implementation, and enforcement procedures (as shown in Fig. 1). However, this high level of centralization poses significant challenges to the automation of payments, making it difficult to implement self-executing mechanisms that can guarantee timely and accurate payments.

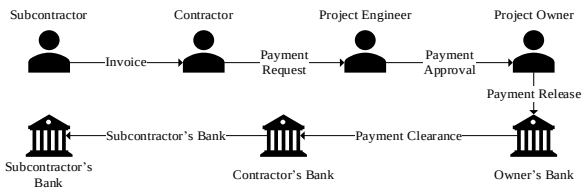


Figure 1. Construction progress payment: traditional payment flow.

External stakeholders, particularly banks, play a crucial role in collecting, storing, and interpreting cash flow data for construction projects. In addition, banks participate as trusted intermediaries in the construction industry to process cash flow and transactions alongside project parties. However, this dependence on banks also adds constraints to a comprehensive integration [11]. It is worth noting that financial institutions themselves rely on an intermediary network, which can add another layer of complexity to payment processing [12].

The central role exerted by banks can significantly reduce efficiency and create obstacles that can hinder payment processing, particularly when it comes to verifying the validity of the information. Furthermore, this centralization may trigger unequal access to information, resulting in information asymmetry and opportunistic behaviors. The resulting lack of trust and confidence can make it challenging to automate payment processes as parties must constantly verify the validity of information [13].

2.3 Trust Issues in Payment Execution

The traditional form of contractual documents in construction projects can limit relational governance and create a heavy reliance on central bodies for contract enforcement, resulting in delays, non-payments, or defaults. These limitations erode trust among stakeholders and pose significant challenges to automating payment processes, as timing and the exact amount of payments cannot be guaranteed [14]. This uncertainty can lead to contractors overbilling or reacting to slow-paying clients to avoid negative cash flow situations that could result in insolvency. Such uncertainty is especially problematic for subcontractors, who may only receive payment once the client and general contractor are compensated. Despite the benefits of timely reimbursement for all project partners and stakeholders [3], no contractual provision guarantees timely payments. Furthermore, payments to suppliers or subcontractors may be delayed even after the owner pays the contractors due to time-consuming lien waivers or the contractor's lack of cash flow management.

2.4 Smart Contracts

Szabo (1994) proposed the concept of Smart Contracts (SCs) as a computer-based transaction protocol that automatically executes predetermined conditions, reducing exceptions and transaction costs by eliminating intermediaries in contract enforcement. SCs formalize human interests and enhance the security of contractual relationships and agreements. Compared to traditional paper contracts, protocols that operate on a public network

provide a more efficient and secure way to formalize connections [15]. Despite its potential benefits, the adoption of SCs failed to gain momentum due to the limited real-world implementation of smart contracts. However, the invention of Bitcoin by Nakamoto (2008) and the emergence of blockchain technology in 2010 renewed interest and led to the development of SCs.

2.5 Blockchain

Blockchain technology has not only revolutionized the world of cryptocurrencies [16] but it has also shown potential for numerous other applications, including construction administration [17]. By creating a secure, tamper-proof ledger that can be shared across multiple nodes, blockchain technology creates decentralized systems that eliminate the need for intermediaries and increase transparency and accountability in the construction industry [18]s. These systems can streamline payments, procurement, and project management, reducing delays and increasing efficiency. In addition, the immutability of the blockchain can provide an unalterable record of construction activities, increasing trust and reducing disputes among project participants [19].

2.6 Smart Contracts for Construction Projects

SCs offer multiple advantages for the construction industry [17]. For example, decentralized digital contracts are expected to reduce building industry expenses by up to 9% [20]. Token-based payment systems have also been identified as one of the various potential areas for intelligent contracts and blockchain [21]. Research has also brought attention to the potential of blockchain and SCs to improve financial monitoring and enhance the credibility of project data, complementing current information modeling techniques [22].

Although SCs can extend BIM methods [23], some researchers argue that this integration is not entirely suitable in the short-term [24]. Nonetheless, research has also explored the potential benefits of using BIM and blockchain for post-disaster recovery [25], highlighting the advantages of BIM's adjustable, immutable, and distributed perspective [26]. Despite the multiple advantages of SCs [27], some research indicates that they may not be suitable for complex construction projects in their current form [24].

However, the adoption of blockchain technology in the construction industry faces relevant challenges due to the need for a deeper understanding of the links between industry issues and the essential aspects of this technology [28]. Although blockchain-based SCs can enhance the automation of interim processes, it remains to be seen how this technology distinguishes itself from computerized payment systems or other possible automated payments [29]. Therefore, examining the underlying barriers to automation and their relationship to the distinguishing features of blockchain and programmable contracts is crucial in payment mechanization, an area currently lacking in the literature.

2.7. Decentralization of Smart Contracts

To improve the efficiency of advance payments, automating contract documents may not be sufficient for two primary reasons. Firstly, the conventional methods of executing, controlling, modeling, and communicating such payment flows are typically centralized, which limits their effectiveness. Secondly, a lack of contractual assurance can lead to unforeseen outcomes. Addressing these challenges requires establishing constituent rules for effective advance payment automation. Blockchain-enabled SCs can overcome these issues by enabling decentralized payment execution, ensuring contract provisions are followed, and eliminating unforeseen results.

It is important to note that these characteristics distinguish SCs from other technologies that can be utilized for self-payment. To illustrate this point, Fig. 2 compares the system architecture of two automated payment applications: one that operates without SCs and another that uses SCs. In both cases, contract documents are digitized and converted to executables, which settle payment amounts based on input progress data: centralized control automation and decentralized automation of SCs.

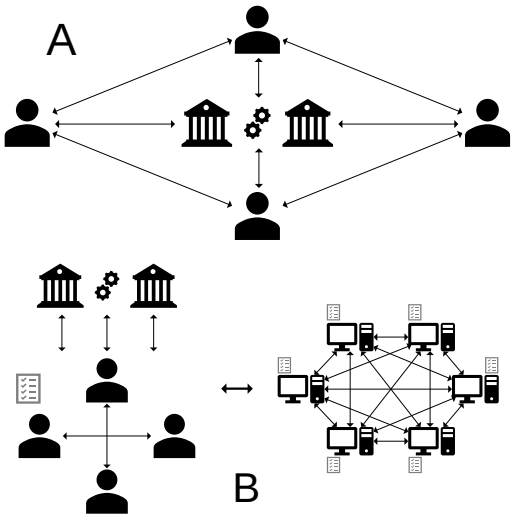


Figure 2. Smart contract-based payment system without (A) and with (B) blockchain.

2.8. Centralized Control Automation

An automated payment system without SCs relies on a single Project Member responsible for implementing contract coding and distributing calculation outcomes to the P2P project network (Fig. 2A). This leads to banks and financial institutions processing monetary transactions and utilizing information about accounts to process payments, resulting in a client-server architecture with a single entity centralizing code executions, authentication, and permissions, typically the owner.

However, current contract documents' lack of independence and centralization presents a significant challenge. Servers may deny services to other stakeholders, which can cause delays in critical processes, such as transactions considered by suppliers. Additionally, centralized code implementation can result in downtime and increase information asymmetry. Moreover, there is a possibility of amending the code underlying the project and rewriting historical data, including built-in BIM and acquired progressive data. Consequently, the current automatic payment system without SCs lacks trustworthiness.

In addition, the centralized control of the server over the execution of current transactions and the ability to modify previous projects introduce opportunities for opportunistic behavior and the centralization of power. This architecture heavily relies on the trust and confidence of stakeholders in a trustless environment where business objectives compete. As a result, this model cannot be considered a truly automated payment option.

2.9. Decentralized Automation of Smart Contracts

The digitized contract-based setting (Fig. 2B) involves the contract implementation and execution of contracts on an open blockchain instead of a P2P project network. Each node executes the SC in this architecture and publishes the simulation outputs to the ledger's bottom line. Once the SC is implemented, project stakeholders have no control over its implementation and cannot change or terminate payment administration. This represents a decentralized control mechanism, and contracts based on the smart public blockchain are guaranteed to be executed.

Blockchain technology offers several benefits, including disintermediation, which allows for product and cash flow integration on the same platform. It also enhances supply chain integration, increases visibility, reduces transaction commission charges, and reduces processing time. However, this approach introduces a new challenge for P2P networks in that money is a social construct that relies on financial institutions to function and has an international role that does not interact directly with cash flow between different components. The blockchain-based system has addressed this challenge by allowing periodic interim payments through cryptocurrencies and providing protocols for unique crypto-asset design.

3. IMPLICATIONS AND LIMITATIONS

Integrating SCs and blockchain technologies can transform the construction industry with significant implications for computer science, conflict resolution, and contract management. These technologies enable automation and provide a shared, independent view of project information, reducing the need for trust and promoting stakeholder autonomy. This creates a single source of truth that can facilitate cooperation among stakeholders and improve contract conduct.

The unique characteristic of SCs is that their rules are hardcoded into the system, making compliance by stakeholders self-enforcing. This decreases the dependency on reciprocal trust and promotes the implementation of further technologies that encourage cooperation between stakeholders. As a result, the independence enabled by secure protocols minimizes the need to verify data accuracy manually. This feature has broader implications for the construction industry beyond just automation. It also facilitates conflict resolution and contract conduct, as stakeholder cooperation will have more autonomy and require less trust. Additionally, it promotes an application-independent, life-cycle approach to shared project information, thereby creating a single source of truth [30].

Autonomous contract management and decentralization serve as corporate regulators, reducing friction and preventing unforeseen outcomes [31]. Each project participant agrees to the contractual conditions in a digital agreement that controls project delivery, providing a seamless and efficient process [32]. The autonomy of contract management, coupled with SC legacy, provides an effective enforcement mechanism that ensures compliance with standards and best practices.

Despite the advantages SCs and blockchain offer, it is essential to acknowledge their limitations. Implementing a decentralized system can have significant impacts not only on payment workflows but also on the roles of stakeholders. Failure to recognize this evolving dynamic can pose a significant risk to the adoption of SCs. Additionally, the irreversible nature of computational

outcomes means that improper coding can jeopardize the integrity of project information and lead to substantial financial losses. To mitigate this risk, stakeholders must ensure the computerized code is sound before deploying it. The academic community has developed verification and validation approaches for verifying and validating SCs to enhance their safety [33].

4. CONCLUSION

Despite the many advantages and the vast amount of digital progress data available, payment automation has yet to be achieved in the construction industry. This leaves it to rely on slow and inefficient traditional payment applications. This approach exposes projects and involves stakeholders to many payment risks, including delayed or non-paid transactions, the possibility of a lien, diminished confidence, and overrunning costs/programs.

Several factors need to be considered to adopt smart contract-based payment systems. Firstly, the security and verification of the smart contract itself are paramount. The contract must be tamper-proof and secure, ensuring the terms and conditions are executed as intended. Secondly, the impact of smart contracts on incentive frameworks should be assessed. Implementing SCs can lead to changes in how incentives are structured and distributed, which can significantly impact stakeholder behavior. Finally, the characteristics of decentralized contract administration and project fulfillment methods must be considered. This includes identifying potential challenges in implementing decentralized systems and developing mitigation strategies. Additionally, it is important to ensure that the smart contract aligns with the needs and goals of all project stakeholders. Overall, the successful adoption of smart contract-based payment systems requires a comprehensive understanding of the technology and its implications and a willingness to adapt and evolve traditional payment systems to meet the changing demands of the construction industry.

The paper presents a compelling argument that existing computerized applications for payment operations and associated contract documents cannot support progress payments automatically. This is due to two critical restrictions: the reliance on central methods of control and implementation and the absence of assured operation. However, despite these difficulties, the advantages of blockchain and intelligent contracts are presented. The potential for payment automation has been analyzed in both blockchain-based and non-blockchain-based systems, highlighting the benefits of adopting a decentralized and secure approach to payment processing.

One of the most significant implications of SCs and blockchain technology is the introduction of zero-trust computing, which is made possible by using autonomous and automated code. This has important implications for settling disputes and ensuring contractual compliance, as it enables the creation of life-cyclical, application-independent, immutable, and fully audited project information. By implementing mechanisms that foster trust, reduce the potential for opportunistic behavior, and establish a single source of truth that all stakeholders can access, SCs and blockchain promote dispute resolution and enhance accountability in project management.

REFERENCES

[1] R. Navon, COMPANY-LEVEL CASH-FLOW MANAGEMENT By R . Navon , l Member , ASCE, J. Constr. Eng. Manage, 122, 22–29, 1996.
[2] E. Peters et al., Late Payment and Nonpayment within the Construction Industry: Causes, Effects, and Solutions, Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, 11, 1–12, 2019.
[3] A.P. Kaka, The case for re-engineering contract payment mechanisms, 17th Annual ARCOM Conference, 1, 371–379, 2001.
[4] P. Virtanen et al., SciPy 1.0: fundamental algorithms for scientific computing in Python, Nature Methods, 17, 261–272, 2020.
[5] S. Durdyev, M.R. Hosseini, Causes of delays on construction projects: a comprehensive list, International Journal of Managing Projects in Business, 13, 20–46, 2020.
[6] E. Manu et al., Trust influencing factors in main contractor and subcontractor relationships during projects, International Journal of Project Management, 33, 1495–1508, 2015.
[7] M. Bilal et al., Big Data in the construction industry: A review of present status, opportunities, and future trends, Advanced Engineering Informatics, 30, 500–521, 2016.
[8] R. Santos et al., Bibliometric analysis and review of Building Information Modelling literature published between 2005 and 2015, Automation in Construction, 80, 118–136, 2017.
[9] J. Talbot-Jones, J. Bennett, Toward a property rights theory of legal rights for rivers, Ecological Economics, 164, 106352, 2019.
[10] G.R. Bitran et al., The Need for Third-Party Coordination in Supply Chain Governance, MIT Sloan Management Review, 2007.
[11] R. Silvestro, P. Lustrato, Integrating financial and physical supply chains: The role of banks in enabling supply chain integration, International Journal of Operations and Production Management, 34, 298–324, 2014.
[12] M.R. Fellenz et al., Requirements for an evolving model of supply chain finance: A technology and service providers perspective, Innovation and

Knowledge Management in Twin Track Economies Challenges and Solutions - Proceedings of the 11th International Business Information Management Association Conference, IBIMA 2009, 1–3, 1171–1179, 2009.
[13] M. Feldmann, S. Müller, An incentive scheme for true information providing in Supply Chains, Omega, 31, 63–73, 2003.
[14] PWC, Annual global Working Capital Study 2018/19, Pwc, 2018.
[15] N. Szabo, The Idea of Smart Contracts, 1997.
[16] V.V. Buterin, Ethereum: inteligentny kontrakt nowej generacji i zdecentralizowana platforma aplikacji, Whitepaper, 1–36, 2014.
[17] J. Li et al., Blockchain in the Construction Sector: A Socio-technical Systems Framework for the Construction Industry, Advances in Informatics and Computing in Civil and Construction Engineering, 51–57, 2019.
[18] M. Swan, Blockchain: Blueprint for a New Economy, O'Reilly, 2015.
[19] P. Vigna, M.J. Casey, The Age of Cryptocurrency: How Bitcoin and the Blockchain Are Challenging the Global Economic Order, Picador, 2016.
[20] Z. Dakhli et al., The potential of blockchain in building construction, Buildings, 9, 2019.
[21] J.J. Hunhevicz, D.M. Hall, Managing Mistrust in Construction Using Dlt: a Review of Use-Case Categories for Technical Design Decisions, Proceedings of the European Conference on Computing in Construction, 100–109, 2019.
[22] Ž. Turk, R. Klinc, Potentials of Blockchain Technology for Construction Management, Procedia Engineering, 196, 638–645, 2017.
[23] J. Mason, Intelligent Contracts and the Construction Industry, Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, 9, 1–6, 2017.
[24] H. Gabert, Blockchain and smart contracts in the Swedish construction industry - An interview study on smart contracts and services, 2018.
[25] N.O. Nawari, S. Ravindran, Blockchain and Building Information Modeling (BIM): Review and applications in post-disaster recovery, 2019.
[26] H. Hamledari, M. Fischer, Construction payment automation using blockchain-enabled smart contracts and robotic reality capture technologies, Automation in Construction, 132, 103926, 2021.
[27] J. Mason, BIM Fork: Are Smart Contracts in Construction More Likely to Prosper with or without BIM?, Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, 11, 1–5, 2019.
[28] J.J. Hunhevicz, D.M. Hall, Do you need a blockchain in construction? Use case categories and decision framework for DLT design options, Advanced Engineering Informatics, 45, 101094, 2020.
[29] R. Yang et al., Public and private blockchain in construction business process and information integration, Automation in Construction, 118, 103276, 2020.
[30] G.M. Gad et al., Rethinking Trust in Construction Contract Formation: Dispute Resolution Method Selection, Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, 8, 1–10, 2016.
[31] K.M. Nyandongo, J. Lubisi, Assessing the use of project management information systems and its impact on project outcome, Proceedings of the International Conference on Industrial Engineering and Operations Management, 1501–1512, 2019.
[32] M.-A.U. Abdul-Malak, J.M.K. Hamie, Proposed Framework for the Rendering of Construction Contract Document Interpretations by Engineering Professionals, Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, 11, 2019.
[33] K. Bhargavan et al., Formal verification of smart contracts: Short paper, PLAS 2016 - Proceedings of the 2016 ACM Workshop on Programming Languages and Analysis for Security, Co-Located with CCS 2016, 91–96, 2016.

ENHANCING LITERATURE REVIEWS A TOOL FOR DISCOVERY AND ANALYSIS

Nikola Vojičić, Belit d.o.o. (Ltd.), nikola.vojicic@belit.co.rs
Davor Sekulski, Belit d.o.o. (Ltd.), davor.sekulski@belit.co.rs
Vladimir Urošević, Belit d.o.o. (Ltd.), vladimir.urosevic@belit.co.rs

Abstract: *This paper introduces a custom-built Literature Review Tool desinged to discover, extract, and rank relevant content from a diverse range of online sources using advanced web scraping and contextual full-text search techniques. The tool enhances the efficiency and accuracy of literature reviews by enabling comprehensive analysis of both scientific publications and grey literature, including blogs, informal reports, and government documents. The paper presents an overview of the tool's core functionalities, including source discovery, article extraction, and content analysis.*

Keywords: *Web scraping and content extraction, full-text search, relevance scoring and highlighting, literature analysis, grey literature.*

1. INTRODUCTION

The surveying, discovery, and systematization of relevant grey literature materials "produced on all levels of government, academics, business and industry in print and electronic formats, […] which is not controlled by commercial publishers" [1] – such as technical reports, project reports, working papers, white papers, government documents, and other forms – is highly significant [2] for mapping the state of the art with a more balanced view [3], particularly in applied research and innovation, yet it is largely overlooked or unsupported by major academic search engines and structured content repositories, such as Scopus, Lens, ScienceDirect, and Web of Science.

In the absence of efficient tools or structured registries, literature reviews of this kind often rely on either manual web searching or interaction with LLM-based interfaces (such as OpenAI ChatGPT [4]). However, these approaches remain highly unreliable for tasks that demand deterministic responses and fully accurate, complete results, due to issues such as hallucinations or confabulations [5] and inherent biases [6].

Manual web searches are effective for relatively simple tasks, such as gathering information on straightforward, narrowly focused topics or addressing specific problems with widely accepted answers and minimal conflicting viewpoints. The limitations of manual searching become evident when conducting extensive and systematic grey literature reviews, especially those that require diverse sources, multiple perspectives, and cover different time periods. Manual searching in such cases is time-consuming and labor-intensive, often necessitating a well-coordinated team, thorough planning, and systematization of results.

Even when relevant documents are found, the outcomes of manual searches often fail to justify the time and effort invested. This is especially true when results, despite being well-documented and structured, are not stored in databases that support complex evaluations, aggregations, and analyses. While ad-hoc scripts may assist with some preliminary tasks, they only partially address the challenge of assembling a relevant corpus. Significant additional effort is still required to thoroughly read through these documents and select the most relevant ones.

Among all these activities, only two truly require human effort: defining search queries and reading the discovered articles. Everything else can be automated, including ranked searches across the internet for websites and within websites for articles, scraping article content, storing data in structured, queryable database, and visualizing, filtering, aggregating scores, and ordering the data. Even the manual tasks can be optimized: search queries can be prioritized based on the scores of retrieved results, and reading can be minimized by using contextual full-text search to highlight only the most relevant paragraphs and keywords within the extracted article contents.

This article describes a tool for automated literature discovery and review designed to address key challenges in the field. Developed by a dedicated project team, it is actively used in the ongoing FishEUTrust project to explore, discover, and systematize grey literature on several of its core topics and research questions, such as barriers to and drivers of seafood purchasing and consumption behaviour. The tool's development was motivated by the clear absence of any suitable existing solutions at the time (mid-2023).

2. MAIN FEATURES AND WORKFLOW

The Literature Review Tool is designed to overcome the challenges of manual internet article searches by automating the discovery of relevant articles and sections, while also supporting user collaboration during content analysis. The workflow consists of four key stages:

1. Website search which involves searching websites as sources of specific articles. This step is optional, as users can manually provide a set of websites if they already know where to search.

2. Article search on specific websites involves searching for articles within the subset of websites identified in step 1, websites manually entered by the user, or both.

3. Paragraph search within articles takes place after step 2, once articles have been collected and the search is complete. The tool downloads content from the top 4,000 ranked articles, extracts and indexes their content, and enables full-text search on that data.

4. Tagging websites and articles with statuses such as relevant, potentially relevant, or not relevant to helps with collaboration among multiple users. This tagging can be done at any stage in the workflow.

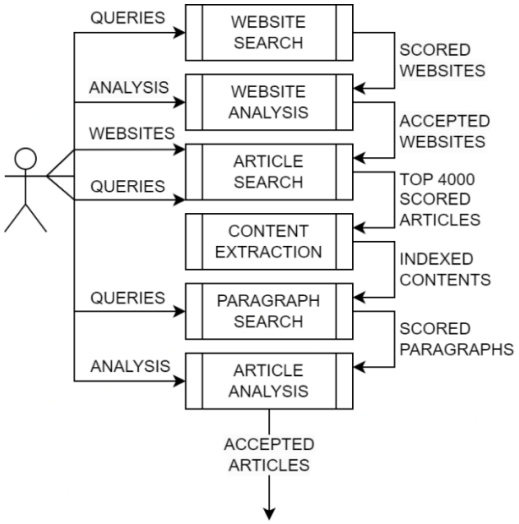


Figure 1. Literature Review Tool workflow

Figure 1 illustrates the possible steps in this workflow, detailing the inputs and outputs for each stage. Discovering websites involves website searching and analysis. The article search is performed on the identified relevant websites to collect material for content extraction. Paragraph search locates relevant sections within documents, reducing the need for reading the full text.

2.1 Discovering Sites

Searching the entire internet for articles on a specific topic is challenging. The vast amount of information often causes search engines to favor higher-ranked sites optimized for search, which may not always be the most relevant. This can narrow the diversity of results. To address this issue, it is necessary to restrict the search to a predefined set of relevant websites.

In some cases, users may already know the specific websites to target for article searches. In other cases, additional websites need to be identified to expand the source pool. This tool conducts website searches by scanning the internet and scraping context paths from the first five pages of search results. Users provide search queries, and each search result is stored as a triplet consisting of site, query, and page.

For analysis and visualization, the flat rows are grouped by site, with scores aggregated by summing individual contributions and queries aggregated into sets. Each appearance of a site on a page contributes

$$\frac{10}{page\ number} \tag{1}$$

to the total score of that site.

For example, if a site appears four times on the first page, its score will be 40, and if it appears once on the second page, it will add 5 to the score.

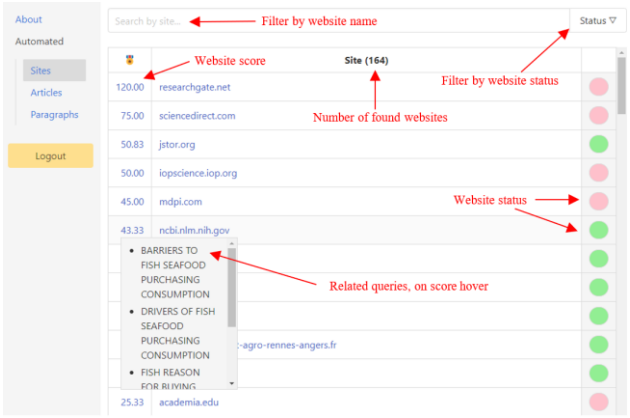


Figure 2. Left column of the site discoverer page with websites and scores

Hovering over the score number, as shown in Figure 2, opens a dropdown list displaying all the queries for which the site appears. Sites can be marked with the following statuses: “rejected” (red), “uncertain” (yellow), and

"accepted" (green). Users can also add custom statuses – for example, Figure 2 shows an additional status, "academic" (pink), used for websites containing academic literature. Once a site is marked as "accepted," it is automatically queued for article search (see the next chapter), while other statuses remain descriptive and searchable only.

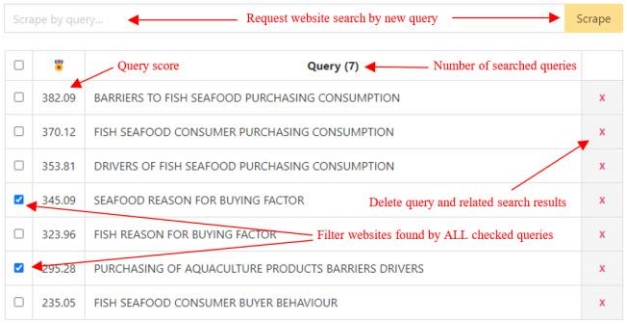


Figure 3. Right column of the site discoverer page with queries and scores

Since this process involves searching across the entire internet, queries should be longer and more specific to narrow the results. The query score helps guide users in refining their queries. For each query, the score is calculated as the sum of

$$\frac{1}{site\ rank} \tag{2}$$

for each site found by that query, where the site with the highest score is assigned rank 1 and subsequent sites receive incrementally higher ranks. This sum is then multiplied by 100.

Queries can be deleted, which also removes all associated results. This action cannot be undone, although users can manually re-enter the same query if needed. Checking the boxes for specific queries filters the websites listed in the left column, showing only those with scores that include the selected queries (see Figure 3). Additionally, users can perform a fuzzy search by site or combine these filters.

2.2 Discovering Articles

After optionally searching for and analyzing websites, and marking some as accepted, the next step is to search for articles. If websites were not previously identified through a search, they must be manually entered, since both websites and queries are required inputs for the article search. This search then looks for articles matching the specified queries on the designated websites.

For the initial search, both a site and a query are required. Subsequent searches allow entering either or both. When a new site is added, all previous queries will be searched on that site. When a new query is added, it will be searched across all previously specified sites. If both a new site and a new query are provided, the new query will be searched across all existing sites, and all previous queries will be searched on the new site. Searches for existing site-query pairs are not repeated. To refresh results, users must remove and re-enter existing entries. This approach ensures consistent scoring and relevant results.

The article scraper extracts article URIs and titles from the top three pages of search results. Each site-query pair triggers three scrapes, one for each page. Limiting extraction to the first three pages has proven sufficient, as the search is focused on specific websites rather than the entire internet, resulting in less bias compared to the site search phase.

The outcome of each search contains: site, query, page, scraped article URI and title. These flat rows are grouped by article, scores are aggregated by summing individual contributions, while queries and sites are combined into sets. Each appearance of a URI on a page contributes

$$\frac{10}{page\ number} \tag{3}$$

to the article's total score. For example, an article that appears twice on the first page will have a score of 20, and a score of 5 if it appears once on the second page.

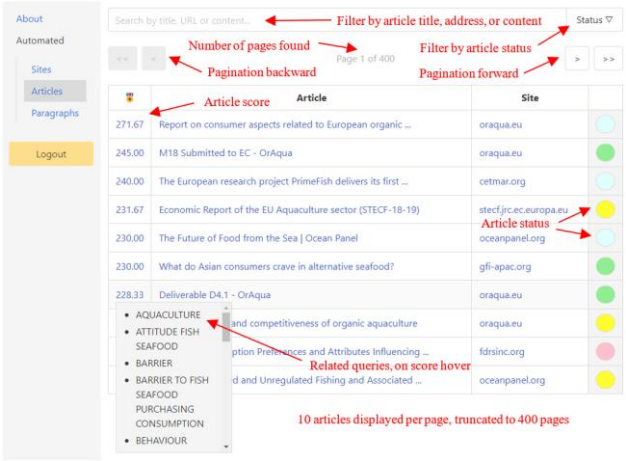


Figure 4. Left column of the article discoverer page with articles and scores

Hovering over the score number opens a dropdown listing all queries for which the article was found. Like websites, articles can be marked with statuses such as "rejected"

(red), “uncertain” (yellow), and “accepted” (green). Users can also add custom statuses – for example, Figure 4 shows an additional status, “integrated” (light blue), which denotes manually imported articles that were also found by the tool. These statuses are descriptive and can be used to filter articles.

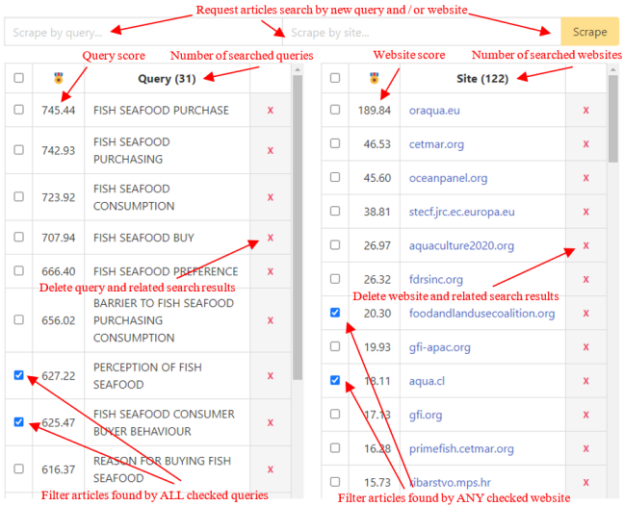


Figure 5. Right column of the article discoverer page with queries, websites, and scores

Practical use has shown that queries for article searches should be shorter than those for website searches. Because the search is already limited to specific websites, there is less need for highly specific queries.

Queries and sites can be deleted which also removes all associated results. This action cannot be undone, although the same query and/or site can be manually re-entered if necessary. Removing a site found by the tool, removes its “accepted” status from the Website Discoverer page.

Ticking the checkboxes for queries, as shown in Figure 5, filters the results to display only articles with scores that include the selected queries. Selecting checkboxes for sites shows only articles from those sites. Users can also search by title, URL, or content, or combination of these inputs.

2.3 Discovering Paragraphs

Once all relevant websites and search queries for article discovery are entered and the search is completed with all relevant article URIs collected, the retrieval of articles from these URIs can be automated. Their content is then extracted and indexed, enabling full-text search within the retrieved files. This enhances the Article Discoverer’s ability to filter by article content and provides the foundation for paragraph searches, including highlighting matching words and scoring search results.

Paragraph discovery simplifies the article review process by reducing the need to download, open and read entire articles. Identifying a relevant paragraph is often sufficient to extract valuable information or decide if an article is worth further consideration. Additionally, the full-text search functionality offers more capabilities than typical searches supported in HTML, PDF, or DOCX readers.

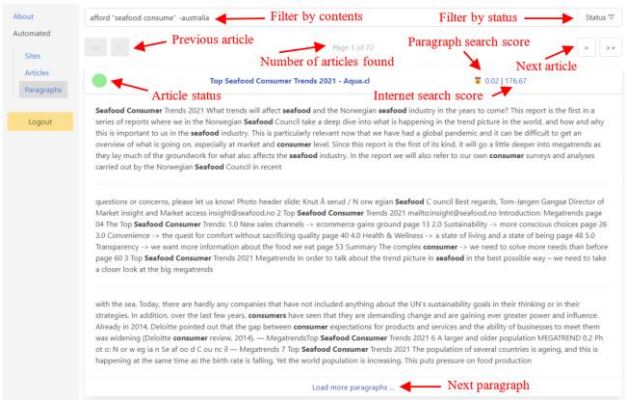


Figure 6. Left column of the paragraph discoverer page with Paragraphs and Scores

The system searches for articles containing content that matches the provided query, displaying results sorted by full-text search score and article score based on the result page, as shown in Figure 6. Initially, only the first paragraph of each article is retrieved, with an option to load up to 20 additional paragraphs. Matching query terms are highlighted in bold.

Full-text search identifies natural language texts that match the query in a fuzzy manner, ranking and highlighting relevant sections based on their similarity to the query. Indexing article contents generates a sorted list of distinct lexemes – normalized word forms that group different variants of the same term.

Supported query syntax includes:

- Unquoted text searches for lexemes in any order.
- "Quoted text" searches for lexemes in the given order.
- Dash (-) as a prefix excludes that lexeme from results.
- OR acts as the logical operator for combining queries.

Both the Paragraph Discoverer and the content search within the Article Discoverer are built on full-text search. This functionality applies only to successfully downloaded and indexed articles, with up to 4000 of the top-scoring articles (first 400 pages) being downloaded and indexed.

Another advantage of indexing article content is the automatic availability of lexeme frequencies across all

documents. Irrelevant lexemes can be excluded from the frequency table, as shown in Figure 7 below.

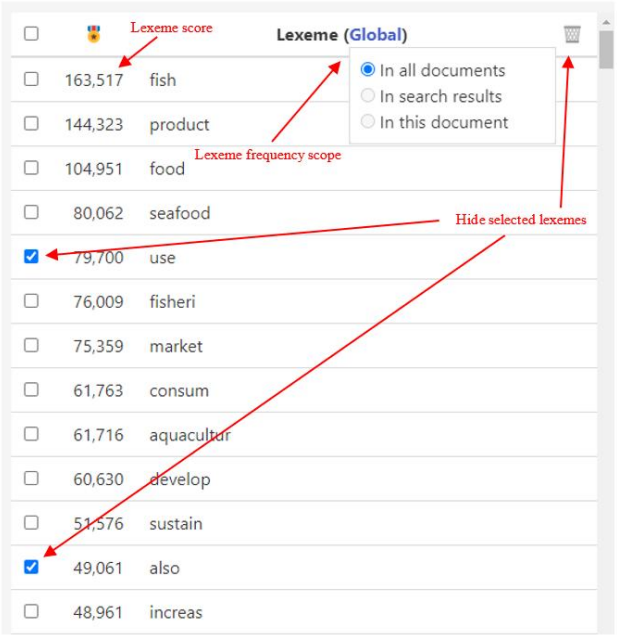


Figure 7. Right column of the paragraph discoverer page with lexemes and scores

There are three modes for displaying frequencies: (1) Global – showing frequency across all documents; (2) Search – displaying frequency within documents resulting from a paragraph search; and (3) Document – showing frequency in the currently displayed document on the left.

This feature helps users identify the general theme of a document or collection of documents, inspires the formulation of search queries, and can be used to generate word clouds, among other applications.

3. CONCLUSION AND FUTURE WORK

The Literature Review Tool began as a set of simple utility scripts aimed at streamlining the process of searching for and documenting useful links and content from the internet, with minimal complexity and a low learning curve. Over time, it evolved into a more advanced system, with features such as scoring mechanisms, automated content retrieval, and full-text search, significantly reducing the need for manual effort.

Future enhancements aim to expand the tool's capabilities to include data interpretation. Features currently under development include:

- Multilingual support by language metadata extraction and leveraging relevant dictionaries for advanced features such as synonym matching across different lexemes in multiple languages.
- Image extraction from documents and search, like *Images* tab in Google search.
- Results version management for tracking changes across different versions of results.
- Grouping search queries and results by conceptual topics for improved organization and analysis.
- Leveraging found documents, extracted content, queries, and scores as inputs for AI tools such as ChatGPT. AI-generated responses can be stored as supplementary metadata linked to the corresponding documents. While some of these capabilities are currently achievable using external tools – such as RAG (Retrieval-Augmented Generation) frameworks like Quivr – the goal is to provide tighter integration.

4. ACKNOWLEDGMENTS

This innovative development work has been financially supported by the European Union's Horizon Europe research and innovation framework programme Grant Agreement 101060712 - FishEUTrust project.

REFERENCES

[1] V. Garousi, M. Felderer, and M. Mäntylä. 2019. "Guidelines for including grey literature and conducting multivocal literature reviews in software engineering". *Information and Software Technology* 106 (feb 2019), 101–121. https://doi.org/10.1016/j.infsof.2018.09.006

[2] F. Kamei, I. Wiese, G. Pinto, M. Ribeiro, and S. Soares, 2020. "On the Use of Grey Literature: A Survey with the Brazilian Software Engineering Research Community". In *34th Brazilian Symposium on Software Engineering* (SBES '20), October 21–23, 2020, Natal, Brazil. ACM, New York, NY, USA, 11 pages. https://doi.org/10.1145/3422392.3422442

[3] A. Paez, 2017. "Gray literature: An important resource in systematic reviews". *Journal of Evidence-Based Medicine* 10, 3 (aug 2017), 233–240. https://doi.org/10.1111/jebm.12266

[4] V. Jain, H. Rai, et al.: "The Prospects and Challenges of ChatGPT on Marketing Research and Practices". *SSRN*, March 23, 2023. http://dx.doi.org/10.2139/ssrn.4398033

[5] Farquhar, Kossen, J., et al. 2024. "Detecting hallucinations in large language models using semantic entropy." Nature 630: 625–630. https://doi.org/10.1038/s41586-024-07421-0

[6] Tech Reader, 2024. "Confabulation and ChatGPT: How Truthful Are AI Models?" https://www.tech-reader.blog/2024/06/confabulation-and-chatgpt-truthful.html (accessed May 2025)

STUDY ON 5G-ADVANCED FINIOT PLATFOM IN EMERGING FINANCIAL USE CASES

Carol Edrich, DanceGRIST, London, UK, carole@dancegrist.com
Dragorad Milovanović, University of Belgrade, Serbia, dragoam@gmail.com
Drago Indjić, UCL, London, UK, d.indjic@ucl.ac.uk

Abstract: *We aim to provide cross-disciplinary overview of advanced communication technology integration across multiple financial sectors. FinTech apps are expected to implement the native 5G technology, and continue enhancing the mobile customer experience and financial services coverage. The 3GPP Release-18 5G-Advanced specifications are expected to deliver a new generation of IoT solutions offering the intelligent, massive connectivity. Our review charts the directions of a new FinTech generation of IoT payments and insurance platforms enabled by the novel 5G technology.*

Keywords: *5G-Advanced, RedCap, FinTech, FinIoT, BIoT*

1. INTRODUCTION

Financial technology (FinTech) domain merges digital networks and data science driving innovations across multiple retail financial sectors. The regulatory policy push to improve the customer outcomes and promote competition through the Open Banking across the EU and digital banking licenses in the Asia have disrupted traditional financial service providers, well-known household names in banking and insurance. Increasing consumer adoption of various e-mobility and Internet of Things (IoT) solutions is driven by the Artificial Intelligence (AI)-at-the-edge of leading contemporary mobile devices, enhancing the user centricity and delivering more personalized, localized and interactive user experience combined with superior digital platform economics.

The fifth generation (5G) mobile networks already enable permanent online availability of different devices, whereby consumers remain always connected to the underlying platform markets. The 5G IoT enabled services will offer additional flexibility and increased speed, radically changing the engagement of users. However, the development of FinTech initiatives depends on many factors including regulatory quest are telco or banking regulatory policies applicable for mobile digital wallets [1-5].

The emerging FinTech use cases are calling for careful consideration of the 5G technology capabilities. The more reliable point-to-point connections, significantly higher data flows with low latency are facilitating even more radical perspective of various digital platforms and markets. In particular, the continually evolving 3GPP 5G-Advanced specifications have just been approved. The Release-18 RedCap technology is designed to bridge the gap between conventional 5G and IoT applications [6, 7].

We are focusing on the anticipated prospects and benefits of the updated 5G mobile networks supporting novel digital platforms: a new generation of FinIoT digital platforms would provide the payment and digital identity rails for an increasing number of hyper-connected apps, venturing beyond traditional banking verticals into micro-lending, parametric on demand insurance, changing the outreach of the entire FinTech ecosystem and producing even more inputs for data-hungry AI infrastructure.

In the first part, an overview of integration 5G IoT connectivity platform across multiple financial vertical is outlined. In the second part of paper, transformative power of 5G RedCap advanced connectivity and FinIoT case study is presented.

2. COMMON INFRASTRUCTURE FOR OPEN PLATFORMS

Traditionally, finance industry is a technology- and data-driven, and usually an example of early adopters. The advent of non-banking financial service providers over the last decade has dramatically changed the provision of financial services across the globe: across many OECD markets, the consumer-friendly FinTech-enabled competition have established the dominant position in traditional banking verticals. The financial institutions have struggled to compete or transform itself into open platform-based ecosystems.

A typical digital platform connects the providers and the end-consumers by offering a set of valuable economic services; most importantly, the trusted framework and effective regulations necessary for a proper function of a two-way market. There are many examples of the market failure in various non-traditional asset domains (real estate, venture finance) that have been addressed by innovative platform economics. The most successful platforms offering transparency, information sharing, price discovery and dispute resolution have induced a strong positive feedback loop and created new, often global sector

winners. In financial services, the quest for a flexible architecture that can allow financial products, vendors and services to interface using the common infrastructure is underway [8, 9, 10].

The mobile devices in various tech ecosystems become full-featured platforms supporting FinTech software stacks. A new mobile ecosystems such as HarmonyOS and HyperOS explicitly target IoT and 5G connectivity, whereby a mobile device can handle multimodal data, network scalability, processing, storage, accurate location, smart decision-making, energy efficiency, and data analytics are all necessary for implementation. The non-card and the account-to-account payments have already made the decades-old MasterCard/Visa duopoly redundant, and the abundance of geolocation and multimodal data is making strides in the non-life insurance sector. The virtual affinity, fan and loyalty digital credentials are expected to disrupt the large venue and open-air event experience thanks to massive connection density, whereby 5G can significantly reduce service interruptions and server overloads by supporting a high number of concurrent users.

As urban centers begin to embrace the concept of smart cities, 5G systems with IoT capabilities can combine different services, such as parking charges, waste management services, and transportation ticketing, into a single digital platform. The 5G is transforming urban landscapes into personalized and peer-driven ecosystems supported by economic fundamentals, providing context-aware, real-time creative experience and monetization for various levels of actor and participant engagement, making provisions for ordinary citizens and intangible cultural benefits (*livability*).

- The mobile phones and wearables are offering various emerging capabilities thanks to ability to capture and parametrize the performer's and the participants physicality in the immediate vicinity. The precise mapping of the real-time physical movements for both sides of the stage (*creative platform*) results in seamless digital twin of the creative process, as well as offering an exceptionally convenient experience to the observers and performers. We have explored the use of wearable technology (*weartech*), such as fitness bands and smartwatches to capture various aspects of creative performing art experiences [11].
- We envisage the official act of a hybrid (utility and digital value) token generated by the FinIoT platform, thanks to the forward-looking regulation of digital assets in the Republic of Serbia [12]. The legal counsel has indicated that *white paper* for FinIoT-generated tokens can be compiled to satisfy the current regulation, representing the sixth regulatory approval of a digital asset in the Serbia.

3. TRANSFORMATIVE POWER OF 5G NETWORKS

5G technology of mobile networks is designed to improve the speed and responsiveness of wireless networks significantly. This enables a more reliable connection on mobile devices. There are now a significant number of papers in the literature that discuss 5G systems support for vertical industries, including FinTech. The main characteristics of these systems are rapidly becoming open ecosystems built on top of common infrastructure [13-15]. Mobile devices becomes full-featured platforms for financial services based on the innovative FinTech solutions. Highly reliable and secure 5G connectivity, a device that can handle multimodal data, network scalability, processing, storage, accurate location, smart decision-making, energy efficiency, and data analytics are all necessary for implementation. IoT offers advanced connectivity of devices, systems, and services.

The adoption of IoT in FinTech is accelerated by 5G capacity to link a large number of devices at once, resulting in creative services and solutions. However, the convergence also presents a unique set of difficulties. In addition, it is required compliance with financial and data protection regulations across different markets.

- FinIoT technologies enable the use of all connected devices that are always relevant, always accurate, always personal supporting personalized services (solutions and advice, customer service assistance).
- FinIoT technologies make it possible to anticipate user needs, form a financial profile, and target categories (personalized advice, communication and offers).
- FinIoT technologies represent the basis of adaptive and intelligent inter-platforms that improve the customer experience, provide enhanced insights from a risk, increase agility and speed to market, strengthen customer engagement, reduce operating costs, increase revenues.
- Some of the technological issues surrounding IoT are identity management, energy efficient sensing, greening IoT, scalability, security and privacy, communication mechanism, integration of smart components and global cooperation. The scientific challenges include data exchange between heterogeneous elements, effectively handling uncertain information and service adaptation in the dynamic system environment.

The integration of 5G with IoT provides the ability to link a large number of devices with high-speed, low-latency connectivity. The convergence of technology has made banking and finance more accessible, allowing financial services to be seamlessly integrated into our homes and offices while providing always-on connectivity.

- Taking into account smart houses, owners may use their smart appliances to monitor and control power usage, which in turn allows them to directly control utility bills, mortgage payments, home insurance, and other recurring

costs. Furthermore, users may carry out banking tasks including bill payment, money transfer, and even financial planning with integrated voice assistance.
- As urban centers begin to embrace the concept of smart cities, 5G systems with IoT capabilities can combine different services, such as parking charges, waste management services, and transportation ticketing, into a single digital platform. Essentially transforming cities from networked urban landscapes into ecosystems supported by finance, providing context-aware, real-time FinTech services at every stage of citizen participation.
- FinTech has a potential as wearable technology, such as fitness bands and smartwatches, becomes more widely used. These devices can provide fast access to essential financial services, such as managing personal finances and making mobile payments, because they are nearly always in the user's immediate vicinity. This would result in seamless financial transactions, offering an exceptionally convenient experience to the end-user.
- Another use case is in the insurance sector. Improved risk data profiles on consumers can be obtained through the usage of IoT in wearables and telematics in vehicles. Insurance companies will encourage low-risk behavior, and smart home platforms will be able to offer data about how houses and apartments are managed.

3.1 3GPP 5G-Advanced RedCap connectivity

The 3rd generation partnership project (3GPP) completed the first release of the fifth-generation (5G) of mobile communications in its Release-15 in June 2018, which laid the basis for commercial 5G deployments worldwide. Release-16 introduces several major enhancements that improve existing features and address new use cases and deployment scenarios. The main new use cases and deployment scenarios addressed in Release-16 include enhanced support of ultra-reliable low-latency communications URLLC and industrial Internet of Things (IIoT). 3GPP's submission to International Mobile Telecommunications-2020 (IMT-2020) contained Release-15 and Release-16 functionality. Since then, 3GPP has been working on evolving 5G technology in its releases to improve performance further and address new use cases. In Release-17, the main new use cases and deployment scenarios include support for IoT reduced capability (RedCap). Initial Release-18 for 5G-Advanced was functional frozen in March 2024 and published specification in June 2024 [16, 17].

The RedCap Release-18 technology is designed to bridge the gap between conventional 5G and IoT, focusing on application scenarios that require moderate data rates, low power consumption, low costs, and native 5G features like network slicing. RedCap offers several benefits for IoT applications [18], including:

- Higher peak data rate. RedCap supports applications that require more data throughput, such as video surveillance.
- Lower latency. RedCap supports applications that require near real-time data communication, such as industrial automation and smart grid applications.
- Improved power consumption. RedCap can help to improve the power efficiency of IoT devices, which can extend the battery life of these devices. This is important for applications that use battery-powered devices, such as wearables or sensors.

3.2 BoT use case

BoT enables customization of bank transactions according to the needs and usage patterns of its clients by gathering and analyzing vast amounts of data from the social and personal environments. Expanded capacity, adaptable business scenario support, and real-time response in low-latency situations are necessary for accessing a variety of devices, processing and analyzing information. This poses huge challenges to device access management, information transmission, information processing, and architecture cost. The two layer architecture of mobile Internet cannot deal with mass connections. Information processing for existing IoT devices, IP-capable devices and low power devices requires IoT platform gateway, distributed and layered cloud storage, elastic host and function computing, and cloud analysis services [19].

- Support mass connections. IoT sensor communication eliminates the requirement for real-time response and has high frequency and small message volume. File transfers, standard message queues, and traditional web services are not applicable. Instead, message queues that allow time sequences and scale out should be used to transport data to a collection cluster. There are three ways to divide up message queues: source, destination, and subject. Because the collecting nodes are independent of the business and data analysis layers and are stateless, the cluster can grow almost linearly in all directions.
- Fully automated device access management. Manual tasks configurations, device registrations, and device upgrades become unfeasible as the number of devices rises. Thus, in order to increase productivity and save time, all of these procedures need to be automated. Devices should be equipped with necessary functions to facilitate the automation of the first startup.
- Device edge cloud elastic processing architecture. BoT financial services are a part of everyday life and a number of industries. Billions of connections and responses are too much for the mobile Internet's device cloud two layer architecture to handle. The distributed processing architecture of the edge cloud is better suited for applications requiring low latency, mass connections, and complexity. Both the edge and cloud have distributed

elastic scaling capabilities, and support different deployment modes.

- Scalable architecture. Resource utilization is improved while construction and usage costs are decreased through the use of 5G slicing networks, tiered storage, and elastic cloud computing, which distribute resources according to service values and requirements. Message queues, analysis, function computing, and elastic cloud servers are all included in elastic cloud computing. As needed, these cloud services can be scaled up or down. In order to lower storage costs, tier data storage organizes data by layers according to features and goals including processing speed, storage capacity, and usage frequency. Using 5G network slices (NS), networks with varying costs can be constructed according to various values, SLA requirements, and requirements.

FinIoT bridges the digital and physical worlds with a multitude of smart devices and encourages deep integration and communication between digital information systems and physical systems [20]. FinIoT platforms rebuild economic structures in which the supply-demand or demand-driven modes are giving way to a new mode of operation with supply-demand collaboration and integration R&D, products and financial institutions.

4. CONCLUDING REMARKS

This study addresses the impact of the 5G IoT in the FinTech ecosystem. Financial institutions are making investments in digital technology to take advantage of various advancements in digital processes, products, and services. An important turning point in the development of the FinTech sector is the introduction of 5G technology. Its unparalleled speed, low latency, and ability to connect a wide range of devices will drive innovation across various aspects of financial technology.

5G technology is changing how financial services are delivered and consumed, from improved mobile banking experiences to the emergence of AR and VR apps. According to the study, 3GPP 5G-Advanced RedCap technology hold potential to enhance the integration of IoT and advanced data analytics capabilities in FinTech personalized and secure services by focusing on application scenarios that call for moderate data rates, low power consumption, and low costs. In order to build a more innovative and efficient financial ecosystem, next-generation FinTech companies need to investigate the prospects given by this revolutionary technology as 5G networks roll out over the world.

The future of financial services is mobile. With the continuous development of 5G technology and mobile internet, cloud computing, Big data, application costs are gradually reduced, and the application potential in the financial sector is gradually becoming more prominent.

REFERENCES

[1] R.Vannithamby, A.Soong, *5G Verticals: customizing applications, technologies and deployment techniques*, Wiley-IEEE Press, 2020.

[2] B.Nicoletti, *The future of FinTech: integrating finance and technology in financial services*, Spriner 2017.

[3] J.R.Bhat, S.A.AlQahtani, M.Nekovee, "FinTech enablers, use cases, and role of future Internet of Things", *Computer and Information Sciences*, vol.35, no.1, pp. 87-101, 2023.

[4] P.P.Barman, G.Hallur, "A study on the impact of 5G on the banking industry: an economic impact perspective", in Proc. International Conference DASA 2022.

[5] P.Ajmani et al., "Impact of AI in financial technology - a comprehensive study and analysis", in Proc. 6th International Conference IC3I 2023.

[6] M-W. Tian et al., "Research on financial technology innovation and application based on 5G network", IEEE *Access*, vol.7, 2019.

[7] H.Holma, A.Toskala, T.Nakamura, 5G technology: 3GPP evolution to 5G-Advanced, Wiley 2E, 2024.

[8] Y.Kannan, D.Kapil, "Next-Gen Fintech: exploring the potential of 5G and the role of network engineering", *Journal of Artificial Intelligence, Machine Learning and Data Science*, vol.1, no.3, pp.1-6, 2023.

[9] M.Maiti, U.Ghosh, "Next Generation Internet of Things in Fintech ecosystem", *IEEE Internet of Things Journal*, vol.10, no.3, pp.2104-2111, 2023.

[10] V.Dineshreddy, G.R.Gangadharan, "Towards an Internet of Things framework for financial services sector", in Proc. 3rd International Conference RAIT 2016.

[11] C.Edrich, D.Indjic, "Cultural micro-nodes for Smart Cities", in Proc. *Marketing and Smart Technologies*, SIST vol.280, pp.51-61, Springer, 2022.

[12] SEC Serbia, *Law on Digital Assets*, RS Official gazette, no.153, 2020.

[13] D.Milovanovic, P.Fowdur, Z.Bojkovic (Eds.), *Driving 5G mobile communications with Artificial Intelligence towards 6G*, CRC Press 2022.

[14] ITU-T FG DFS, *Digital Financial Services: identity and authentication*, 2017.

[15] PSR&FCA Call for Information, *Big tech and digital wallets*, 2024.

[16] 3GPP TS 38.875, Release 17 *Study on NR devices supporting reduced capability*, 2022.

[17] 3GPP TR 21.918, Release 18 Description, *Summary of Rel-18 Working Items*, Aug. 2024.

[18] GSMA, 5G RedCap Case studies, June 2024.

[19] Huawei, *Bank of Things: next-generation financial infrastructure*, white paper, 2020.

[20] HKIMR, *The metaverse opportunities and challenges for the financial services industry*, June 2024.

PROCESS OF MIGRATING SINGLE PAGE APPLICATIONS TO META FRAMEWORKS LIKE NUXT

Petar Kresoja, Singidunum University, pkresoja@singidunum.ac.rs
Marko Šarac, Singidunum University, msarac@singidunum.ac.rs
Mladen Veinović, Singidunum University, mveinovic@singidunum.ac.rs

Abstract: *This paper presents a practical overview of migrating Vue 3-based Single Page Applications (SPA) built with TypeScript and Axios to the Nuxt meta framework. It explores the core advantages of such a migration, including automatic routing, meta tag manipulation, and server-side rendering with Nitro. Special emphasis is placed on the Nitro server engine's capability to run at the edge, including on devices such as MikroTik routers, FortiGate appliances, and pfSense firewalls. Additionally, the paper outlines methods for API backend integration, the principles of edge computing, serverless architecture, and practical benefits of Nuxt's approach to request handling and deployment.*

Keywords: *Nuxt 3, SPA migration, Vue 3, edge computing, Nitro server*

1. INTRODUCTION

Single Page Applications (SPAs) developed using Vue 3 and TypeScript offer high flexibility, smooth client-side transitions, and modular codebases. However, they often suffer from limitations in search engine optimization (SEO), initial load time, and lack native server-side capabilities. Meta frameworks like Nuxt address these challenges by introducing server-side rendering (SSR), static site generation (SSG), and enhanced developer ergonomics.

This paper presents a migration pathway from a standard Vue 3 + Axios SPA to Nuxt 3 and explains the benefits from both technical and deployment perspectives, especially in the context of modern hosting paradigms such as edge computing and serverless infrastructure.

2. BENEFITS OF MIGRATING TO NUXT

The Nuxt framework is designed to bridge the gap between frontend and backend responsibilities by introducing intelligent defaults, built-in server capabilities, and seamless integration with serverless and edge environments.

Feature Comparison: Traditional SPA vs. Nuxt 3		
Feature	**Traditional SPA**	**Nuxt 3**
Server-Side Rendering	No	Yes
Meta Tag Management	Manual	Automatic
Routing	Manual	File-Based
HTTP Header Control	Manual	Declarations
Edge/Serverless Deployment	Limited	Supported
Backend API Support	Custom	Built-in

Figure 1 – Feture comaprison

2.1 Server-Side Rendering and SEO Enhancements

Server-Side Rendering (SSR) refers to the process of rendering HTML on the server instead of relying solely on the client browser. In SPAs, content is often generated dynamically via JavaScript, making it difficult for search engines to index the content properly.

Search Engine Optimization (SEO) improves a website's visibility in search engines by enhancing how pages are crawled and ranked. SSR addresses SEO limitations by delivering fully rendered HTML, ensuring that metadata and content are visible to crawlers even before JavaScript is executed. Nuxt automates this SSR process and optionally allows static generation (SSG) for performance-optimized delivery.

2.2 Header Manipulation and Meta Management

Nuxt allows dynamic control over HTTP headers and meta tags using composables like useHead(). This is critical for applications that require:

- Rich social media previews (Open Graph tags)
- Dynamic language alternates
- Content Security Policy (CSP) enforcement

Instead of hardcoding headers in HTML templates or configuring them manually at the server level, Nuxt enables declarative definitions per route, component, or layout, simplifying compliance and consistency.

2.3 Integrated File-Based Routing

With Nuxt, developers benefit from automatic route generation based on the file system. Each *.vue* file placed in the */pages* directory becomes a route, reducing boilerplate configuration and improving code readability and structure. This is especially beneficial in medium to large-scale applications where maintaining router files becomes cumbersome.

3. NITRO SERVER AND EDGE DEPLOYMENT

The introduction of the Nitro server engine in Nuxt 3 marks a pivotal shift in how web applications can handle backend logic. Unlike traditional Node.js servers or third-party backend services, Nitro is designed to be lightweight, flexible, and optimized for deployment in modern environments. This includes not just serverless platforms but also edge locations where computation needs to occur close to the user for latency-sensitive operations.

By abstracting away the complexities of backend configuration and offering support for diverse runtime environments, Nitro empowers developers to unify their frontend and backend development under one cohesive architecture. This section will explore the capabilities of Nitro and how it enables cutting-edge deployment scenarios, including edge computing on networking hardware and integration with serverless infrastructure.

3.1 The Nitro Engine

Nitro is the lightweight server engine that powers Nuxt 3. It abstracts away low-level server management and supports deployment across various runtime environments like Node.js, Cloudflare Workers, Netlify Functions, and Deno.

This enables a **serverless architecture**, where backend logic is deployed as isolated functions that scale automatically and are invoked only when needed—reducing resource usage and cost. Nitro functions support caching, streaming, and advanced request handling out-of-the-box.

3.2 Edge Computing

Edge computing refers to the practice of processing data closer to the source (i.e., the user or device), rather than relying on distant central servers. This minimizes latency and improves responsiveness, especially in real-time applications.

With Nitro's universal compatibility and small deployment footprint, it becomes feasible to deploy logic directly to edge devices or edge-capable services like:

- **MikroTik Routers**: Using RouterOS container features to host minimal APIs
- **FortiGate Firewalls**: When paired with VM capabilities or external edge nodes
- **pfSense Systems**: Through FreeBSD jails or dockerized environments
- **CloudFlare Platform**: Using the power of content delivery networks

This allows services like user authentication, telemetry data parsing, and request proxying to be performed directly at the network edge, offloading the core backend.

4. API BACKEND INTEGRATION OPTIONS

With Nuxt, API integration becomes a seamless and flexible experience, supporting both traditional REST-based workflows and modern composable paradigms. Developers can choose between using familiar tools like Axios or leveraging Nuxt's built-in capabilities to create and consume backend services with minimal configuration. The following section outlines the core options available for connecting Nuxt applications to various backend systems, whether external or internally defined.

4.1 Axios and Runtime Configuration

Axios remains a flexible and widely-used HTTP client. In Nuxt, it can be configured globally through runtime configuration settings in *nuxt.config.ts*. Developers can define environment-specific base URLs and credentials that adapt seamlessly across staging, production, and local development.

4.2 Composable API Calls with *useFetch()*

Nuxt offers a built-in *useFetch()* composable that simplifies both client-side and server-side data fetching. Unlike traditional Axios calls tied to component lifecycles,

useFetch() integrates with SSR and hydration, ensuring content is loaded and rendered on first paint. It supports error handling, caching, and auto-refresh features, which are especially useful for dashboard or analytics applications.

4.3 Built-in API Routes via Server Directory

Nuxt allows developers to define backend API endpoints in the *server/api* directory. These endpoints are auto-registered and can perform logic like:

- Authenticating users
- Forwarding requests to external APIs
- Reading from or writing to a database

This eliminates the need to maintain a separate backend service for basic needs and aligns with serverless and jamstack architectures where frontend and backend logic reside in the same codebase but are executed on demand.

5. TESTING AND OBSERVED RESULTS

To evaluate the practical benefits of migrating from a Vue 3 Single Page Application (SPA) to Nuxt 3, we conducted an internal case study using a mid-sized client portal previously deployed as a traditional Vue 3 + Axios project. The site was restructured using Nuxt 3 with minimal changes to styling and layout to ensure a fair comparison. All tests were conducted in a controlled environment and simulated across multiple global locations using Lighthouse and external tools such as web.dev and GTmetrix.

5.1 Page Load Time and Performance Metrics

Performance was measured in terms of *First Contentful Paint* (FCP), *Time to Interactive* (TTI), and *Largest Contentful Paint* (LCP). The results clearly showed a significant reduction in page load times, particularly for users on slower networks:

Page Load Times			
Metric	**Vue 3**	**Nuxt 3**	**Improvement**
FCP	2.7s	1.1s	~59% faster
TTI	4.5s	1.8s	~60% faster
LCP	3.8s	1.5s	~61% faster

Figure 2 – Page Load Times Improvements

The use of server-side rendering (SSR) and static optimization allowed Nuxt to deliver critical HTML and metadata almost instantly, bypassing the need for client-side hydration delays seen in SPA models.

5.2 SEO Indexing and Ranking Improvements

We submitted both versions of the application to Google's Search Console and analyzed crawling behavior over a 14-day observation period.

- **Vue 3 SPA version**: 63% of pages were indexed; many were delayed due to JavaScript-rendered content.
- **Nuxt 3 version**: 100% of pages were indexed within 48 hours.

In addition, Lighthouse SEO scores increased:

SEO scores			
Metric	**Vue 3**	**Nuxt 3**	**Change**
SEO Score	69	97	+28
Crawl Delay (avg)	1.4 days	0.3 days	~79% faster
Metadata Visibility	Low	High	Fully visible at load

Figure 3 – SEO Related Scores

The transition to SSR made metadata available in the initial HTML response, allowing search engines to extract content, titles, descriptions, and alternate language tags instantly.

5.3 Social Sharing and UX Enhancmenets

One of the most noticeable user experience improvements post-migration was the **enhanced social link** previews. By integrating Open Graph and Twitter card meta tags per route using Nuxt's *useHead()* composable, shared URLs across Facebook, Twitter/X, LinkedIn, and Discord instantly generated rich previews with:

- Dynamic titles based on the page content
- Contextual images and descriptions
- Correct canonical links and language markers

This led to higher engagement on shared links and eliminated the common "generic site title" issue often encountered when using SPAs.

6. CONCLUSION

Migrating Vue 3 SPAs to Nuxt 3 offers a forward-looking upgrade path that enhances SEO, developer productivity, and scalability. Features like SSR, automatic routing, and metadata handling reduce boilerplate and improve application accessibility. The Nitro engine extends Nuxt's reach to the edge and serverless platforms, enabling high-performance deployments on unconventional hardware like routers and security appliances.

Nuxt also simplifies backend integration through composables and file-based APIs, promoting a unified full-stack development model. For teams aiming to modernize or future-proof their applications, Nuxt 3 provides a robust, flexible, and production-ready solution that addresses today's performance, scalability, and DevOps challenges.

REFERENCES

[1] Nuxt Documentation: https://nuxt.com/docs

[2] Vue 3 Guide: https://vuejs.org/guide/

[3] Nitro Server Engine: https://nitro.unjs.io/

[4] Mikrotik Container Documentation: https://help.mikrotik.com/docs/display/ROS/Container

[5] pfSense Packages and jails: https://docs.netgate.com/pfsense/en/latest/

[6] Google Search Central SEO Starter Guide: https://developers.google.com/search/docs/fundamentals/seo-starter-guide

[7] Cloudflare Workers: https://developers.cloudflare.com/workers/

[8] Jamstack Architecture: https://jamstack.org/what-is-jamstack/

MODERN APPROACHES TO WATER SYSTEM SECURITY: INTEGRATION SCADA SYSTEM AND BLOCKCHAIN

Irena Tasić, The College of academic studies „Dositej“, Belgrade, Serbia,
irena.tasic@vsdositej.edu.rs; irena.tasic67@gmail.com
Srđan Tasić, The Academy of Applied Technical and Preschool Studies, Niš, Serbia,
srdjan.tasic@akademijanis.edu.rs

Abstrakt : *The emergence of smart grids and the growing adoption of artificial intelligence (AI) have necessitated significant modifications to systems like SCADA to address evolving security and privacy challenges. In this context, blockchain technology presents a promising solution not only by enhancing the protection and privacy of data transmission in next-generation SCADA systems but also by offering a range of additional benefits.*
On the other hand, it is increasingly evident that security breaches are becoming more frequent not only in systems like SCADA and smart cities but also across broader digital infrastructures. Such vulnerabilities can have severe consequences, particularly when considering their potential impact on the global economy and human life. Therefore, it is essential to build environments that are compact, automated, and resilient, supported by secure and immutable systems for data collection and processing. This paper presents a case study on enhancing the security of SCADA systems through blockchain integration, specifically focusing on improving the resilience of water infrastructure. Beyond SCADA systems, blockchain technology has wide-ranging applications across numerous sectors, including cryptocurrencies, automotive networks, smart cities, healthcare, e-commerce, and more.

Keywords: *smart grids, SCADA systems, blockchain, security, safety*

1. INTRODUCTION

Water supply networks are a vital component of critical infrastructure, essential to human health and well-being using a direct impact on public safety. The possibility of these systems being compromised whether through physical or cyber attacks highlights the urgent need to prioritize their security. Continuous monitoring and control are therefore crucial to minimizing the risk of potential threats and ensuring reliable operation.

There are several examples of cyber attacks in the water sector. Here are a few examples:

- In March 2018, a ransomware attack in Atlanta disrupted city operations, preventing 8,000 employees in a metropolitan area of approximately 6 million people from accessing the system for two weeks. The attackers demanded a ransom of $50,000, which was to be paid in Bitcoin [1].
- In November 2024, nearly all major media outlets reported a cyberattack in Hungary. According to government sources cited by Daily News Hungary, the international hacking group Inc. Ransomware targeted the Hungarian Defense Procurement Agency (DPA), demanding a $5 million ransom to prevent the release of sensitive information [2].
- Serbia has not been immune to cyberattacks. According to reports submitted to the National CERT of the Republic of Serbia, the damage caused by cyber incidents in the first nine months of 2024 amounted to 54 million dinars [3].
- In Serbia, an incident was recorded involving an individual's attempt to contaminate the water sources and products of the Vlasinska ROSA factory, owned by Coca-Cola HBC [4].
- A study from 2021 revealed that cybercrime incurs global costs of $1,797,945 per minute [5]

While the development of artificial intelligence and smart networks enhances everyday life, it also expands the potential for cyberattacks and data misuse. Ensuring a high level of security relies heavily on the effective operation of technologies such as SCADA systems, programmable logic controllers (PLCs), pumps, and other industrial control components.

2. AUTOMATED REAL-TIME DRINKING WATER QUALITY MONITORING

2.1 *SCADA* systems

A SCADA system collects data from sensors and instruments at remote stations, then transmits and displays it at a central control station, where it is typically monitored and analyzed using one or more computers.

A SCADA system comprises integrated hardware and software components engineered to configure, acquire, and manage a customizable set of process measurement parameters for real-time monitoring and control.

The SCADA system mainly consists of:

- Master Terminal Units (MTU),
- Human-Machine Interface (HMI),
- Logic controllers,
- Communication hardware and
- Sensors

A SCADA system is primarily a software platform that interfaces with hardware through Programmable Logic Controllers (PLCs) specialized industrial computers designed to process large volumes of real-time data. The processed data is then communicated to relevant personnel within the management or control system for decision-making and operational oversight.

Communication in a SCADA system is typically facilitated through LANs, public telecommunications networks, or radio links, as these systems often span extensive geographic areas sometimes over several kilometers. Remote monitoring and control can be performed from any authorized computer connected to the network. Due to this connectivity, cybersecurity is critical; SCADA systems must implement robust security measures such as firewalls, encryption, authentication, intrusion detection systems (IDS), and network segmentation to protect against unauthorized access and cyberattacks.

2.2 Automated monitoring of water quality on the example of "GO Systemelektronik"

The automated real-time water quality monitoring system developed by “GO Systemelektronik” GmbH [6] offers an efficient, scalable, and long-term solution for online monitoring of the water supply network and water quality parameters. The system features a modular and scalable architecture, supporting access via smartphones, PCs, and tablets. In the presented example, the BlueGate cloud data service (Figure 1) enables automatic data backup and secure remote access through any standard web browser [6]. The platform provides real-time data visualization, monitoring, and export capabilities for all recorded measurements. All network communications are fully encrypted, ensuring secure data transmission and protection against unauthorized access.

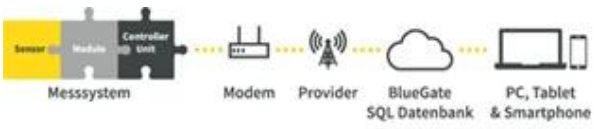


Figure 1. *Cloud data service “BlueGate”* [6]

The presented automated system can monitor 17 water quality parameters in real-time. It also includes an advanced "Contamination Alarm" feature, which is triggered when any known or previously unrecognized parameter reaches or exceeds a predefined critical threshold. This alarm is activated in response to any significant deviation from the normal water composition. This functionality is particularly important, as it enables the early detection of anomalies that might otherwise remain undetected in traditional periodic laboratory analyses.

The system is equipped with an immersion UV/Vis spectrophotometer (ISA) and a suite of sensors for continuous monitoring of key parameters within the water supply network (Figure 2).

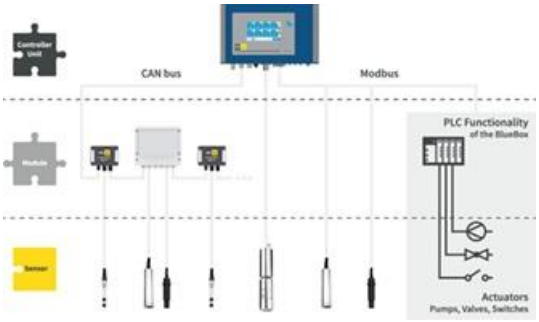


Figure 2. *"BlueBox"* systems [7]

SCADA software performs control, monitoring, and data acquisition functions, along with additional capabilities such as communication, report generation, and result printing. It interfaces with hardware through a PLC that executes programs developed according to the IEC 61131-3 standard. Communication between the PLC and PC uses the RS-232 protocol, exchanging messages formatted as ASCII character strings. The SCADA system’s functionality is implemented using the Delphi programming language and leverages component libraries included in the Borland Delphi 6.0 development environment [8].

The described automated monitoring system has applications beyond water supply networks. Legislative amendments in the Republic of Serbia could facilitate the establishment of a real-time, automated water quality monitoring network. Such a system, based on continuous measurement and data transmission via SCADA, would provide competent institutions with timely and reliable water quality information [9].

3. BLOCKCHAIN TECHNOLOGY IN SMART GRIDS

Blockchain technology enables peer-to-peer transactions within a decentralized, intermediary-free network. All transactions are securely recorded in an immutable, distributed ledger. The technology is fundamentally based on four key aspects:

- Consensus mechanisms, such as Proof of Work (PoW) or Proof of Stake (PoS), validate and verify actions on the network.
- A ledger that provides complete transaction details within networks in an immutable manner
- Cryptography, by which all data in the ledger and network is encrypted and
- A smart contract is used to verify and validate network participants. [10].

There are two types of blockchain networks: public and private. A public blockchain is accessible to anyone on the network, allowing open participation. In contrast, a private blockchain restricts access, requiring permissions to read data or add new blocks, thereby limiting the parties involved in transactions. The use of smart devices can enhance the scalability and privacy of these networks.

Blockchain constructs fixed-size blocks of data using cryptographic hash functions. Each new block is irreversibly encrypted through a hash function, producing a fixed-length output known as the block's hash. This process ensures the blockchain contains an encrypted, tamper-evident record of the entire history of all blocks. Because cryptographic hash functions are one-way and generate unique outputs, it is practically impossible to reverse engineer or predict the hash length when attempting to decrypt the blockchain. The development of Ethereum aligns with the advancement of the SHA-3 standard. Specifically, the Ethereum blockchain employs SHA3-256, a variant of SHA-3 commonly referred to as Keccak-256 [11].

Blockchain security relies on encryption through the use of public and private key pairs. These keys are long, randomly generated strings of numbers. The public key identifies a user on the blockchain, while the private key which must be kept confidential is used to digitally sign transactions, ensuring both traceability and data integrity.

Figure 3 illustrates how each block in the blockchain contains a cryptographic hash of the previous block, creating an unalterable chain. Each new block reinforces the validation of the preceding block and enhances the overall security of the blockchain. As additional blocks are added, the reliability and integrity of the blockchain increase.

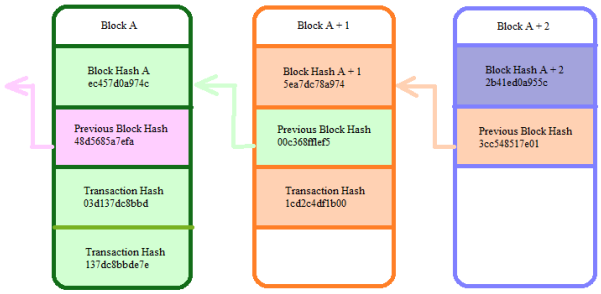


Figure 3. The order of hash values in the blockchain

Figure 4 illustrates the signing and verifying blocks in a blockchain, which relies on public/private key cryptography. Each transaction is verified with the public key of the previous block owner and signed with their private key. The hash function guarantees data integrity by producing irreversible, unique outputs.

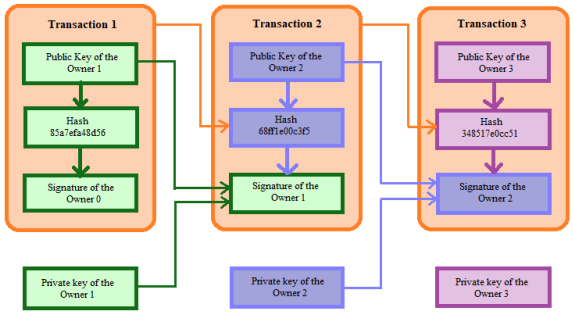


Figure 4. Signing and verification in blockchain

Blockchain can be integrated with smart grids in water utilities across four key segments:

1. Monitoring water consumption data from customers' smart meters to prevent duplication or manipulation by malicious actors,
2. Observing data from hydraulic sensors to prevent unauthorized changes to measurement data,
3. Enabling secure data transfer across different sectors and

4. Monitoring water quality and quantity data measurements to ensure transparency of the operational process.

Integrating blockchain into the previously mentioned applications can significantly enhance security and user trust. Key advantages include preventing duplication of water consumption data, ensuring a high level of protection of identification and authentication for sensor nodes, and enabling secure data transmission. Importantly, this approach helps prevent data loss caused by unauthorized manipulation, maintaining high data integrity. However, some challenges must be considered, such as the substantial computational overhead, increased network complexity affecting scalability, and higher energy consumption. Additionally, the absence of a universal standard for data communication protocols means that commonly used protocols must be adopted for interoperability.

Several techniques can be integrated with blockchain to ensure data tracking while maintaining anonymity alongside operational processes. The most notable among these are:

1) User Identity Protection: Three main techniques are employed to safeguard user identity [12]: virtual ring [13], anonymization [14], and pseudonymization [15]. In this work, blockchain is specifically adapted to enable decentralization, preventing unauthorized data modification.
2) User Data Protection: Three key techniques can be employed to protect user data [12]. These three techniques are: in-house reinforcement [16], data aggregation [17], and key-based technique [18].

4 . DISCUSSION

This paper presents a model of integration between SCADA systems and blockchain technology. Further questions will relate to the feasibility of writing codes that can work on private and public networks.

Key benefits of blockchain include decentralization, immutability, non-repudiation, anonymity, and auditability [19]. Some blockchains, such as Ethereum, offer additional capabilities that enable integration with broader digital infrastructures. Specifically, smart contracts operate autonomously on the blockchain, executing automatically once predefined conditions are satisfied, without the need for human intervention.

The primary disadvantages of blockchain include its high electricity consumption, driven by the significant computational power required for consensus processes, and the challenge of balancing the number of nodes with user cost efficiency [20]. Quantum computing is a potential future solution to address the intensive resource demands of blockchain technology.

To enable integration between SCADA systems and blockchain, it is important to note that blockchain operates primarily at the application layer, while SCADA protocols span multiple ISO/OSI layers. Therefore, integration can be achieved by transferring blockchain data from the application layer down to the transport layer, allowing the data to adopt the format and communication standards typical of SCADA protocols.

Additionally, blockchain enables decentralized business and technical models by distributing the computing load across multiple nodes. This reduces the strain on individual hardware resources, improving the efficiency of each node. Thanks to its scalability, the system can operate continuously even if one or more nodes fail.

5. CONCLUSION

Real-time automated monitoring of water systems provides a reliable solution for simultaneously delivering analysis results to all relevant stakeholders.

The proposed integration of SCADA systems with blockchain technology offers a modern approach to enhancing the security of water supply systems. Unlike traditional laboratory analyses, this method provides faster and more cost-effective results particularly due to its capability for continuous, around-the-clock monitoring and control throughout all seasons.

The described automated monitoring system would be valuable not only for water supply networks but also for broader applications. Amendments to legislation in the Republic of Serbia could enable the implementation of a real-time, automated water quality monitoring network. Such a system, based on continuous measurement and data transmission via SCADA, would allow relevant institutions to receive timely and accurate water quality data.

REFERENCES

[1] A. Blinder, N. Perlroth, „A Cyberattack Hobbles Atlanta, and Security Experts Shudder“, The NewYork Times, 2018 [*online*], Available on: https://www.nytimes.com/2018/03/27/us/cyberattack-atlanta-ransomware.html

[2] Sajber napad trese Mađarsku, Blic 2024 [*online*], Available on: https://www.blic.rs/vesti/svet/hakerska-grupa-inc-ransomware-iznudila-pet-miliona-dolara-od-madjarske-agencije-za/drrrdss

[3] A. Jovanović,“Šteta od sajber napada u prvih devet meseci oko 54 miliona dinara“ RTV, 2024 [*online*], Available on: https://www.rtv.rs/sr_lat/drustvo/steta-od-sajber-napada-u-prvih-devet-meseci-oko-54-miliona-dinara_1578367.html

[4]RTS, „Uhapšen zbog pokušaja iznude“. Radio televizija Srbije 25.09.2012. [*online*], Available on:

http://www.rts.rs/page/stories/sr/story/135/hronika/1179960/uhapsen-zbog-pokusaja-iznude.html

[5] RiskIQ, „RiskIQ's Evil Internet Minute Report Illuminates 648 Cyber Threats Happen Every Minute, Costing Organizations $1.79 Million“, 2021 [*online*], Available on: https://www.globenewswire.com/news-release/2021/07/08/2259604/0/en/RiskIQ-s-Evil-Internet-Minute-Report-Illuminates-648-Cyber-Threats-Happen-Every-Minute-Costing-Organizations-1-79-Million.html

[6] GO Systemelektronik GmbH (2025): *Bluegate Cloud Service* [*online*] Available on: https://www.go-sys.de/en/bluegate/

[7] GO Systemelektronik GmbH (2025): *Bluegate Cloud Service* [*online*] Available on: https://www.go-sys.de/en/bluebox/

[8] D. Beljić, „Razvoj SCADA sistema pomoću objektno orjentisanih programskih jezika“, Book of Abstracts, „Telekomunikacioni forum TELFOR“ 21-23 novembar 2006, Beograd, Srbija, str. 557-560

[9] I. Tasić, M. Kokanović, S. Tasić, V. Tasić, „Informacione tehnologije i automatizovan monitoring kvaliteta vode za piće u realnom vremenu“, Zbornik radova, „Inženjerski menadžment u zaštiti vodnih resursa“, 16th Oktobar 2018., Srbija, str. 65-75

[10] M. Singh, A. Singh, S. Kim, „Blockchain: A game changer for securing IoT data“, IEEE 4th World Forum on Internet of Things (WF-IoT), Singapore, pp 51-55, 2018

[11] Ethash, 2025 [*online*]. Available on: https://ethereum.org/en/developers/docs/consensus-mechanisms/pow/mining-algorithms/ethash/#sha3

[12] Z. Guan et al., „Privacy-Preserving and Efficient Aggregation Based on Blockchain for Power Grid Communications in Smart Communities“, IEEE Communications Magazine, vol. 56, no. 7, pp. 82-88, 2018

[13] M. Badra, S. Zeadally, „Design and Performance Analysis of a Virtual Ring Architecture for Smart Grid Privacy“, IEEE Trans. Info. Forensics & Security, vol. 9, no. 2, pp. 321-329, 2014

[14] C. Efthymiou, G. Kalogridis, „Smart Grid Privacy via Anonymization of Smart Metering Data“, Proc. 1st IEEE Int'l. Conf. Smart Grid Commun., pp. 238-243, 2010

[15] X. Tan et al., „Pseudonym-Based Privacy-Preserving Scheme for Data Collection in Smart Grid“, Int'l. J. Ad Hoc and Ubiquitous Computing, vil. 22, no. 2, pp. 120-127, 2016

[16] X. Du et al., „A Routing-Driven Elliptic Curve Cryptography Based Key Management Scheme for Heterogeneous Sensor Networks“, IEEE Int'l. Conf. on Communications, Glasgow, pp. 3407-3412, 2007

[17] K. Wang et al., "Mobile Big Data Fault-Tolerant Processing for eHalth Networks“, IEEE Network, vol. 30, no. 1, pp. 36-42, 2016

[18] S. Han et al., „ PPM-HDA: Privacy-Preserving and Multifunctional Health Data Aggregation with Fault Tolerance for Cloud Assisted WBANs“, IEEE Trans. Info. Forensics and Security, vol. 11, no. 9, pp. 1940-1955, 2015

[19] E. Leka, B. Selimi, L. Lamani, „Systematic literature review of blockchain applications: Smart contract“, Int.'l. Conf. on Information Technologies, pp. 1-3, 2019

[20] J. Golosova, A. Romanov, „The advantages and disadvantages of the blockchain technology“, IEEE 6th workshop on advances in information, electronic and electrical engineering, pp. 1-6, 2018

4.

Management and Information Systems

ASSESSMENT OF THE USE OF INFORMATION AND COMMUNICATION TECHNOLOGY ON THE EXAMPLE OF AN AGRICULTURAL FARM

Miroslav Nedeljković, Institute of Agricultural Economics, Belgrade, Serbia, e-mail: miroslavnedeljkovic2015@gmail.com

Slađana Vujičić, Faculty of Business, Economics and Entrepreneurship, Belgrade, Serbia, e-mail: sladjanakonto@gmail.com

Cvijetin Živanović, Faculty of Organizational Studies "Eduka", Belgrade, Serbia, e-mail: cvijetin.zivanovic@vos.edu.rs

Abstract: *This paper applies the innovative multi-criteria decision-making method SiWeC (Simple Weight Calculation) to select ten criteria for the evaluation of an information and communication device (soil moisture sensor) on an agricultural farm. The objective was to select the predetermined factors in the form of criteria and, through their obtained weights, determine their importance in the usage of the given device. This, in turn, justifies the role of the applied method and its fuzzy logic approach. The results showed that criteria such as adaptability to working conditions and speed of obtaining information were given the highest weights by experts, suggesting that the acquisition of such devices should be focused on these characteristics. This encourages future research that should emphasize the inclusion of more criteria in the evaluation and the refinement of the existing method for further selections, given the dynamic nature of agricultural production and agribusiness in general.*

Keywords*: Information and communication technology, agricultural farm, fuzzy logic, SiWeC method*

1. INTRODUCTION

The application of information and communication technology (hereafter referred to as ICT) is inevitable in modern business conditions. The complexity of market conditions necessitates its use, and ICT plays a particularly crucial role in agricultural production. Compared to conventional agriculture, modern (precision) agriculture demands the use of advanced tools and, therefore, requires access to more essential information. According to Jurišić et al. (2015), it is based on newly developed IT systems programmed for exploitation potential, a small number of high-reliability devices, and advanced technological capabilities. Pavlović (2015) notes that advanced producers in developed countries already routinely apply technological possibilities offered by information and communication devices. Choudary et al. (2022) states that the application of new information systems in agriculture enables farmers to improve productivity and efficiency, while simultaneously reducing operating costs. Mirković and Mirković (2023) emphasize that communication technologies play a crucial role in modern industry and, consequently, in agriculture. According to them, ICT enables rapid and efficient communication between farmers and other stakeholders in the production and trade chain.

Moreover, several previous studies by domestic and international authors have addressed the use and importance of ICT in agriculture and agribusiness (Karadžić and Babić, 2007; Kim et al., 2019; Messina and Modica, 2020; Panday et al., 2020; Stojanović et al., 2021). In recent research in agriculture and agribusiness, multi-criteria decision-making methods have shown a useful role (Nedeljković, 2022; Nancu et al., 2022; Nicolae et al., 2023; Puška et al., 2023; Nedeljković et al., 2024; Nedeljković et al., 2024a). Their role is particularly justified when it comes to the application of information and communication technologies. Based on a rational selection, the use of a particular device yields timely and beneficial results, and its advantages and disadvantages can be easily detected through the evaluation of its criteria. In this paper, the subject of the research is smart sensors (for moisture) used on an agricultural farm to monitor essential factors affecting the production process itself. Data are tracked and analyzed via computer systems and provide insights into soil condition, the amount of fertilizer used and needed, water quality, temperature, and more. The aim of this study is to analyze and identify key criteria in the use of these devices by users, in this case, an agricultural farm. Thus, a sub-goal is to test the application of the used multi-criteria research method, specifically the fuzzy logic approach to evaluation under conditions of uncertainty.

2. METHODOLOGY

The methodological procedure consists of several phases:

- Defining the criteria for analysis;
- Forming the model;
- Selecting experts;
- Evaluating the criteria;
- Ranking the criteria.

The first phase involves defining the criteria considered when evaluating using the applied method. The criteria were selected based on the experience of decision-makers (experts) in the field. Their overview and meanings are presented in Table 1.

Table 1. Overview and description of the used criteria

ID	Criteria	Description of Criteria
1.	Speed of Information Acquisition	The time it takes for the necessary information to reach the user
2.	Ease of Handling	The method and manner of handling for different users
3.	Availability of Required Data	Provision of necessary data to the service user
4.	Reliability of Received Information	Accuracy of the information received from the used device
5.	Compatibility with Other Devices	Compatibility with other devices in use
6.	Procurement Method	Possibility of procurement from certain markets
7.	Procurement Cost	Price of the devices being used
8.	Durability	Lifespan of the device being used
9.	Adaptability to Working Conditions	Ability to operate under various conditions for specific activities
10.	Additional Services Available	Upgrade options and specialized device features for specific activities

Source: Authors

After selecting and clarifying the criteria used, the next step involves forming the selection model as well as choosing the decision-makers who will determine the importance (weight) of the given criteria. In this case, six experts provided their assessments of the criteria using linguistic values through a survey. The decision-makers are experts with extensive experience in their respective fields, specifically in the use of such and similar devices on their own and clients' farms. The linguistic values were transformed into corresponding fuzzy numbers using Table 2, where they were assigned their quantitative expressions. The actual evaluation and ranking of the criteria are presented in the following chapter, "Results."

Table 2.

No	Linguistic value	Fuzzy numbers
1	Very low -VL	(1, 1, 2)
2	Low -L	(1, 2, 4)
3	Medium low -ML	(2, 4, 6)
4	Medium -M	(3, 5, 7)
5	Medium good -MG	(5, 7, 9)
6	Good -G	(7, 9, 10)
7	Very good -VG	(9, 10, 10)

For the evaluation (selection) of criteria, we used the innovative multi-criteria decision-making method SiWeC (Simple Weight Calculation). It was developed by Puška et al. (2024) and is characterized by its simplicity and precision of the obtained results. To ensure the experts' decisions were as accurate as possible under the given conditions, we used its fuzzy variant, whose steps are outlined below:

Step 1. Expert decision for each individual criterion.

Step 2. Transformation into fuzzy numbers and that:

$$\tilde{x}_{ij} = (x^{l}_{ij}, x^{m}_{ij}, x^{u}_{ij})$$

where is x^{l}_{ij}, x^{m}_{ij} and x^{u}_{ij} fuzzy numbers

Step 3. Normalization of fuzzy numbers according to:

$$\tilde{n}_{ij} = \frac{x^{l}_{ij}}{\max x^{u}_{ij}}, \frac{x^{m}_{ij}}{\max x^{u}_{ij}}, \frac{x^{u}_{ij}}{\max x^{u}_{ij}}$$

Step 4. Determining standard deviation

Step 5. Weighting of normalized grades:

$$\tilde{v}_{ij} = \tilde{n}_{ij} \times st.dev_{j}$$

Step 6. Sum of weighted values for each individual criterion:

$$\tilde{s}_{ij} = \sum_{j=1}^{n} \tilde{v}_{j}$$

Step 7. Calculation of the fuzzy weights:

$$\tilde{w}_{ij} = \frac{s^{l}_{ij}}{\sum_{j}^{n} = 1 s_{ij}^{u}}, \frac{s^{m}_{ij}}{\sum_{j}^{n} = 1 s_{ij}^{m}}, \frac{s^{u}_{ij}}{\sum_{j}^{n} = 1 s_{ij}^{l}}$$

When one remains only on the assessment of the importance of the given criteria, they are dephased according to the following statement in step 8.

Step 8. Defuzzification of the weights criteria.

$$w_{jdef} = \frac{w^{l}_{ij} + 4 \times w^{m}_{ij} + w^{l}_{ij}}{6}$$

3. RESULTS

As an example of evaluating an ICT device (soil moisture sensor), an average-sized agricultural farm (around 5 ha) engaged in crop production (grains) was selected. The previous production methods were based on conventional agricultural mechanization techniques, which in certain years incurred excessive costs for soil preparation. In order to increase the efficiency of business processes and primary soil preparation, it was decided to introduce a device for monitoring factors affecting soil preparation and sowing (sensor). This also necessitated their rational use and the selection of significant factors. By involving expert evaluations, an attempt was made to obtain a rational decision regarding the purchase and use of the device.

After the evaluation by the selected experts, an initial decision-making matrix was formed, where the values were presented in the form of linguistic expressions in the following Table 3. By transforming the linguistic values into corresponding fuzzy numbers, we obtain quantitative expressions for the evaluation of the given criteria, based on which further calculations are performed (Table 4).

Table 3. Initial matrix

Expert	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
E1	VG	M	MG	VG	ML	ML	MG	M	G	M
E2	ML	ML	ML	G	ML	ML	G	MG	G	L
E3	G	MG	M	VG	ML	L	G	ML	G	ML
E4	VG	ML	ML	G	M	M	G	L	G	M
E5	G	MG	M	VG	M	VG	M	M	G	L
E6	G	ML	ML	VG	L	G	G	M	MG	ML

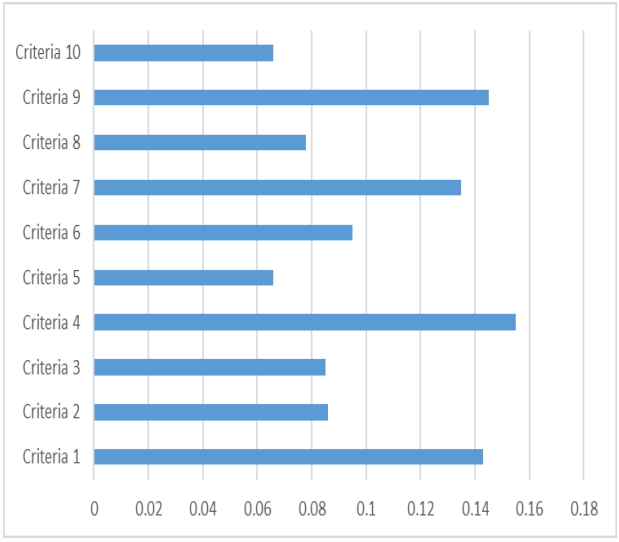
Source : Authors

Table 4: Fuzzy decision matrix

	C 1	C 2	C 3	C 4	C 5	C 6	C 7	C 8	C 9	C 10
E1	9,10,10	3,5,7	5,7,9	9,10,10	2,4,6	2,4,6	5,7,9	3,5,7	7,9,10	3,5,7
E2	2,4,6	2,4,6	2,4,6	7,9,10	2,4,6	2,4,6	7,9,10	5,7,9	7,9,10	1,2,4
E3	7,9,10	5,7,9	3,5,7	9,10,10	2,4,6	1,2,4	7,9,10	2,4,6	7,9,10	2,4,6
E4	9,10,10	2,4,6	2,4,6	7,9,10	3,5,7	3,5,7	7,9,10	1,2,4	7,9,10	3,5,7
E5	7,9,10	5,7,9	3,5,7	9,10,10	3,5,7	9,10,10	3,5,7	3,5,7	7,9,10	1,2,4
E6	7,9,10	2,4,6	2,4,6	9,10,10	1,2,4	7,9,10	7,9,10	3,5,7	5,7,9	2,4,6
w_{ij}	0,143	0,086	0,085	**0,155**	0,066	0,095	0,135	0,078	0,145	0,066

Source: Author

After the necessary calculations based on the predetermined statements, we arrive at the results visually represented in the following Graph 1. Specifically, the highest weight was given to criterion 4, “reliability of obtained results.” This is immediately followed by criteria 9 and 1, “adaptability to working conditions” and “speed of obtaining information.” The criteria rated the lowest by the experts were “compatibility with other devices” and “availability of additional services.” This indicates that rapid information access and the ability to operate in various conditions are particularly important in agricultural production. Interestingly, the criterion “cost of acquisition” was not considered the most important, given that these devices still have a high market price compared to the modest financial conditions in which most agricultural farms in our region operate.



Graph 1: Ranking criteria

4. CONCLUSION

Based on the previously stated information in the paper, we can conclude that the use of information and communication technology (ICT) is indispensable today, especially in the context of agriculture and agribusiness. Numerous factors influence the proper use of ICT devices, but to make a correct (rational) decision about their use, it is necessary to select these factors (criteria) using appropriate multi-criteria decision-making methods. The study demonstrated the justified role of fuzzy logic and the applied method when selecting the subject device. The results showed that adaptability to working conditions and the speed of obtaining information took precedence over other factors (criteria). A solid foundation has been established for future research, which should include a larger number of decision-makers and a broader range of criteria to be evaluated, based on a sample larger than one agricultural farm.

Acknowledgment

This paper is part of research financed by the MSTDI RS, as per decision no. 451-03-136/2025-03/200009 from 4.2.2025.

REFERENCES

1. Choudary, P., Sharma, S., Kaswan, P., Jat, R. (2022). Use of Computer in Agriculture, Sri Karan Narendra Agriculture University
2. Jurišić, M., Šumanovac, L., Zimmer, D., Barač, Ž. (2015). Tehnički i tehnološki aspekti pri zaštiti bilja u sustavu precizne poljoprivrede, Poljoprivredni fakultet u Osijeku, Časopis „Poljoprivreda“ broj 21
3. Karadžić, B., Malinović, N., Meši, M., Mehandžić, R., Turan, J., Anđelković, S. (2007). Automatsko vođenje mašina pri međurednoj obradi ratarskih kultura. Savremena poljoprivredna tehnika, 33(3-4).
4. Kim, J., Kim, S., Ju, C., & Son, H. I. (2019). Unmanned aerial vehicles in agriculture: A review of perspective of platform, control, and applications. IEEE Access.
5. Messina, G., & Modica, G. (2020). Applications of UAV Thermal Imagery in Precision Agriculture: State of the Art and Future Research Outlook. Remote Sensing, 12(9).
6. Mirković, V., Mirković, N. (2023). Primena informacionih tehnologija u poljoprivredi kao mera za rast efikasnosti i nezavisnosti, Zbornik radova, međunarodni skup „EconBiz“, ISBN: 978-99955-45-42-0, УДК: 338.43:004.4
7. Nancu, D., Mieila, M., Manole, A. M., & Isbăşoiu, G. D. (2022). Regional analysis of direct gross domestic product from tourism in Romania during 2014-2019. In Proceedings of the International Conference on Business Excellence (Vol. 16, No. 1, pp. 356-366).
8. Nedeljković, M. (2022). Criteria for sustainable supplier selection in agroindustrial complex, Western Balkan Journal of Agricultural Economics and Rural Development (WBJAERD), 4(1), pp. 49-64.
9. Nedeljković, M., Puška, A., Jeločnik, M., Božanić, D., Subić, J., Štilić, A., Maksimović, A. (2024). Enhancing fruit orchard establishment: A multicriteria approach for plum variety selection, YUJOR, 34(2), pp. 355-380.
10. Nedeljković, M., Puška, A., Štilić, A., Maksimović, A. (2024a). Examining of the sustainable rural tourist potential of Semberija using multi-criteria analysis methods, Environment, Development and Sustainability, pp. 1-19, Springer Netherlands.
11. Nicolae, I., Nancu, D., Manole, A. M., Isbasoiu, G. D. (2023). Domestic Tourist Consumption for Tourist Destinations in Romania in the Period 2014-2019. In Proceedings of the
12. Panday, U. S., Pratihast, A. K., Aryal, J., & Kayastha, R. B. (2020). A Review on Drone- Based Data Solu- tions for Cereal Crops. Drones, 4(3).
13. Pavlović, N. (2015). Tehničko – tehnološki činitelji sjetve i sadnje primjenom GIS tehnologije – precizna poljoprivreda, diplomski rad, Sveučilište Josipa Jurja Strossmayera u Osijeku, Poljoprivredni fakultet u Osijeku.
14. Puška, A., Nedeljković, M., Pamučar, D., Božanić, D., & Simić, V. (2024). Application of the new simple weight calculation (SIWEC) method in the case study in the sales channels of agricultural products, MethodsX, 13
15. Puška, A., Nedeljković, M., Stojanović, I., Božanić, D. (2023). Application of fuzzy TRUST CRADIS method for selection of sustainable suppliers in agribusiness, Sustainability, 15(3), MDPI
16. Puška, A., Štilić, A., Pamučar, D., Božanić, D., & Nedeljković, M. (2024a). Introducing a Novel multi-criteria Ranking of Alternatives with Weights of Criterion (RAWEC) model , MethodsX, 2/22.
17. Stojanović R., Stajnko D., Rakun J., Tekinerdogan B., Catal C., Valente J., Popović T., Čakić S., Maraš V., (2021). Viral, Vitalising ICT Relevance in Agricultural Learning. Praktični vodič, za upotrebu informacijskih i komunikacijskih tehnologija (IKT), u poljoprivredi i obrazovanju u poljoprivredi (AET).

MODELS OF MANAGEMENT ORGANIZATIONAL CHANGES

Biljana Ilić, Faculty of Project and Innovation Management, Belgrade, biljana.ilic@pmc.edu.rs
Slavica Anđelić, Faculty of Management Sremski Karlovci, slavica.andjelic@famns.edu.rs
Sanja Stojanović, Faculty of Project and Innovation Management, Belgrade, sanja.stojanovic@pmc.edu.rs

Abstract: *Organizational change management models are explained in this article. The reasons for change are first discussed, followed by the sorts of organizational changes and how they are managed. Levin's model, Kotter's model, ADKAR model, 7S model, transition model, Weissbord's model, and general models are the organizational change models selected as typical for this study. Additionally, the "Zdravlje Leskovac" company's change management methodology was introduced. The company's evolution over time, the privatization process, and its operations following the adoption of the change management model are all detailed.*

Keywords: *organization, management, organizational changes, models.*

1. INTRODUCTION

The corporate world of today has advanced greatly and functions in a contemporary, dynamic, and uncertain atmosphere. For business systems to be able to respond promptly, market elements must be monitored. The business system acting preventively in this way, anticipating future changes in elements, is an even more advantageous scenario. All of this necessitates that businesses undergo ongoing change procedures. Modern systems now experience changes daily. For changes to have the best possible effects and to guarantee the company's potential for future advancement, expansion, and development—and most importantly, its continued existence in the marketplace—they must be managed. Organizational change management is a particularly important process for managing the effects of new business processes, changes in the organizational structure, or cultural changes within the company. Every organization periodically goes through changes during its existence. These changes can have a significant impact on the business and its processes, results, people, and other stakeholders. In some cases, the effect might be detrimental to the business's profits or reputation. In other situations, the adjustments can result in increased productivity, more sales, or new business prospects. An organization may need to implement a systematic change management approach to handle change efficiently while reducing any potential negative effects. So far, several preferred ways of managing change have been identified. Thus, the good practices of action in this context were translated into change management models, which are the subject of this paper.

The paper's main goal is to demonstrate, both theoretically and practically, why it is preferable to manage changes in modern organizations.

2. CHANGES AND CAUSES OF THE CHANGES

The applied science of management involves crucial procedures that are necessary for the business to accomplish its objectives in the best possible way. An organization is a well-coordinated collection of separate components with established links between them that guarantee the possibility of its operation as a whole. Regardless of an organization's size or activity, managing these operations is one of its fundamental components [1]. The field of change management started to take shape in the 1950s. To find a suitable response to the shifting needs of the market, customers, and employees, it can be described as a process of ongoing renewal of organizational direction, structure, and capabilities [2]. Organizational change is a strategy for adjusting to shifting internal or external environmental situations. It is the adoption of novel concepts or organizational practices [3].

The process of change is more prevalent now than it has ever been. One may argue that they are the only thing that is certain in the corporate world because they occur frequently. Changes reflect how many organizations operate and operate. To be able to meet the needs and desires of customers, any firm must adapt continuously [4]. Changing an organization's current state to make it more effective is referred to as an organizational transformation [5]. Planned or unplanned changes brought about by internal or external forces are referred to as organizational changes. A significant portion of organizational changes are the result of a strategic choice to alter the business model itself [6]. Other elements like leadership, communication, vision, and mission are necessary for change to be successful [7]. The current state shows how the organization was functioning before the changes were introduced. The future state shows how the organization will function after the introduction of changes, and the transition from the present to the future state represents the

process of introducing changes [8]. A new situation always emerges as a result of or in conjunction with change. Every aspect of life, including organizational business, is undergoing ongoing change [9]. You shouldn't be terrified of them. The adjustments will eventually result in improvements for the company if they are handled properly. Changes occur frequently in the fast-paced world of today, and these changes have an impact on organizational changes [10].

Change is required because the current state of affairs is unsustainable for the organization. When there is a difference between desired events—something you want to happen—and actual events—something that is happening right now—changes are required [11]. Organizations introduce changes in response to changes in their environment, to maintain their competitiveness and improve their business, so organizational changes can be planned or just as a reaction to the environment. Despite frequent changes, maintaining a certain stability is important for an organization. There can be many factors that force some degree of change in an organization. These factors can be: external and internal [12].

Changes in a company's leadership or team structure are examples of internal factors that make organizational change necessary. The adoption of new business or operating models, innovation or process improvements, and organizational growth are other factors that cause internal change. Ineffective internal communication, product withdrawals, and process failures may require changes. Change can occur due to external factors such as technological advances and changes in market conditions. The emergence of new competitors, socio-political-economic changes in the company's operating region or target markets, regulatory changes, and changes in customer preferences are other examples of external causes of organizational change. The main causes of changes are the constant increase in the dynamics of events in companies and outside them, and the increase in the complexity of business systems and environments. Changes are inevitable: you should constantly expect them and prepare for them. For companies to survive in a changing market, it is necessary to anticipate the changes. Due to major changes in the external environment, organizations are forced to implement changes to adapt, maintain their competitiveness, improve work efficiency, and respond to customer demands. These changes in the external environment can be a problem for the organization, but they can also be an opportunity to be seized. Changes from the external environment should be recognized. Today's time is characterized by the continuous improvement of techniques and technology, work methods, modern information tools, and the improvement and development of social relations. An organization in such an atmosphere must adapt to changes and be as dynamic as possible, changing the content to achieve optimal results.

3. TYPES OF ORGANIZATIONAL CHANGES

Regardless of the cause, organizational changes can be adaptive and transformational [13]. Adaptive changes are changes that address evolving needs. These changes require incremental adjustments and are usually not difficult to implement. An example of an adaptive change is a software upgrade or a modification to a lead generation form. Updating a company's website, making small adjustments to an existing product in response to customer feedback, and hiring a new employee to fill an existing role are other examples of adaptive change [13]. For effective adaptive change management, managers need to initiate and control the change process. First, they need to see the bigger picture and understand why small adaptations are necessary for the long-term success of the organization. Next, they need to convince their employees and key stakeholders that what may seem like a small change will benefit the organization as a whole, to gain the buy-in necessary for success. Managers need to be methodical in how they plan, implement, and review the steps of adaptive change to ensure that the change is effective, sustainable, and worthwhile. Transformational changes are large in scope and more difficult to implement and adapt. These changes could lead to significant changes in the way the company operates and competes in its industry. To successfully implement transformational change, organizations must be prepared to make major updates to their business processes, culture, strategy, or technology. Common examples of transformational change include:

- replacing the entire team of human workers with software through robotic robots for process automation,
- implementation of a completely new tool or technology that requires significant testing and training,
- Complete restructuring of the customer or employee involvement process,
- establishment of a new department,
- opening of a new office,
- acquisition or merger with another company,
- a complete overhaul of the company's website, social media presence, or application.
- Adopting an optimal approach to sales, service, and support [13].

The need for transformational change is often triggered by a major external factor, such as a new competitor or acquisition. While adaptive change requires managers to be methodical and analytical, transformational change requires them to be persuasive and visionary. A manager's primary responsibility is to get employees to believe in change, align them with the new vision, and motivate them to succeed.

4. ORGANIZATIONAL MANAGEMENT CHANGES

Change is an inevitable part of business. When change occurs, it can lead to problems such as disunity and low morale, or it can provide an invaluable opportunity for lasting improvement. That second scenario is ideal, but it usually doesn't happen by accident, but requires careful planning and guidance. This is where organizational change management is particularly important. Organizational change management refers to all activities and practices that enable the company to prepare and adapt to changes with minimal negative consequences. An appropriate change management framework demonstrates that the organization is committed to creating and adapting to change, especially if that change is expected to have a positive impact. Demonstrating such commitment allows management to implement appropriate strategies that could minimize resistance, garner the support of the entire organization, and raise employee morale and job satisfaction [13].

The concept of change management implies that changes are observed and introduced in: the organizational structure of the company, the company's production and market strategy, the company's development strategy, the way of management, the use of personnel and other resources, the introduction and use of knowledge, training people, etc. [14]. This process is of great importance in maintaining the trust of customers and third parties such as vendors and suppliers. When these parties know that the company has an effective process for dealing with change, they are less likely to worry about the effect of change on their processes or profitability, and are more likely to remain loyal. Their loyalty and support can directly affect the profitability, scalability, and growth of the firm.

Change management refers to all adjustments to the company's operations in the process of change. It can happen indirectly, or it can be planned and introduced slowly. Change is necessary for businesses to grow and remain competitive in today's changing market, but it is not always easy. Employees will sometimes have to adapt quickly to a new environment or organizational structure. The change management team or change manager should focus on a smooth transition to meet the organization's goals while avoiding disruption. In addition, a good change management plan can help employees understand and adapt to the new way of working. Change management within an organization becomes necessary for various reasons, such as reorganization, response to change, and adaptation. To remain competitive, a company will usually implement a change plan. This plan helps address past changes that did not meet goals and may result in more successful outcomes. When implementing changes, business systems must communicate with employees in advance [15]. Different members of the organization can play an important role in effective change management. Everyone from executives to HR professionals to middle managers can help lead positive change and ensure a successful transition.

In some cases, organizations bring in an outside expert qualified to help them navigate the transition or lead an improvement initiative. These professionals may have titles such as change manager, change management consultant, transformation manager, or change agent. Even when a person or team leads organizational change, every member of the company can play a key role in making the change successful. The best organizations reject the traditional top-down approach to leading change and instead rely on their workforce to lead the process. Even if the change is badly needed and beneficial to everyone in the company, people tend to resist. The reality is that change is uncomfortable. Effective change management is about helping people overcome discomfort and the unknown to embrace something new. The practical ways this plays out can vary depending on the company and the type of change being implemented, but often involve:

- defining goals and creating a plan for achieving them,
- engaging stakeholders and promoting buy-in throughout the leadership team,
- communicating the reasons for changes with employees and encouraging acceptance at all levels of the organization,
- training of employees in new processes,
- establishing a supportive environment that empowers individuals and teams to successfully implement change,
- listening to feedback and solving problems to keep the company on track,
- evaluating and reporting on progress towards goals [16].

All changes, big or small, benefit from well-thought-out change management. Change management is the key to successful change implementation. This process must be approached in a comprehensive, systematic, and

continuous way, so that it can manifest all its effects in the right measure. The benefits of an organization-wide change management solution include:

- proactive fight against internal resistance to change,
- sets clear goals for change initiatives,
- allowing companies to track results,
- creates strategies for effective implementation of changes that can be standardized and applied to various change projects throughout the organization,
- addresses and balances multiple aspects of change, such as people, processes, technology,
- empowers individuals and employees to move faster through changes, enabling them to be more productive and faster.
- Facilitates the success of change projects, enabling organizations to reach higher levels of profitability [17].

Change management is defined as a set of processes that includes the methods and ways in which a company describes and implements changes within its internal and external processes. This includes preparing and supporting employees, establishing the necessary steps for change, and monitoring pre- and post-change activities to ensure successful implementation. When an organization's goals, processes, or technologies are transformed, the change can be challenging and require the collaboration of various independent entities within the organization. Developing a structured approach to change is critical to ensure a beneficial transition while mitigating disruption.

Change management depends on specific teams or working groups, and leadership commitment and organizational support are critical to success. Successful change management practices require that the culture of the organization be open to change, as well as ensuring that people respond optimally to change. Lack of effective change management processes can lead to job dissatisfaction, mistrust, and loss of productivity in any organization when faced with change, which ultimately negatively affects quality and customer loyalty.

5. MANAGEMENT MODELS OF CHANGES

5.1 Lewin's model of change

Lewin's model refers to planned changes in the organization. It implies that every change and its management must go through three phases, namely: unfreezing: (announcing the change, motivating people to accept the changes, melting previous attitudes and beliefs); change (implementation of change, introduction of new values, knowledge and behavioral models); freezing: (supporting new patterns of behavior, stabilization of changes) [16]. The need for change is becoming apparent, and most employees are ready for change. In the second phase, a new model of behavior is developed. There must be an agent of change, whose task is to establish a new system of values. In the freezing phase, the new behavior model turns into norms [17].

In companies, there are two groups of forces: forces of inertia that tend to keep the organization in an existing, stable state, and forces that tend to make changes. The forces of inertia are always stronger than the forces that want change.

Change agents can choose several strategies to implement that change. In the first phase, there is a possibility of employee aversion to change. Employees must accept new practices. They must be encouraged to leave their comfort zone and adapt.

Limitations of the model occur in the form of anxiety and risks associated with uncertainty, which can lead to unconstructive employee behavior. The overall mode is a framework for understanding organizational change and is not an implementation plan. It helps managers in the context of considering changes and creating a plan.

These three stages of the process relate to employees and their behavior. In the first phase of this process, employees are referred to the problem for which they are trying to introduce a change, so that they recognize the need for it. In this way, employees are ready for changes. Precisely because the employees were previously informed about the situation and that it was explained to them that the change is the best solution, the thawing phase increases the chances of successful implementation of that change.

The next phase is related to the implementation of change - changing the way employees work through changes in the structure, technology, human resources, products, or culture of the organization. The goal of refreezing is to strengthen the changes made so that they are stabilized by institutionalization.

The goal is for change to become a natural, self-sustaining state. This is achieved by applying support mechanisms such as culture, structure, policy, and norms, which reinforce the new organizational state. This phase includes the evaluation of the process of introducing the change and its results, and leaves room for possible modifications. For the change process to be as successful as possible, and the resistance to them as low as possible, it is important that employees accept the changes that companies want to implement.

5.2 Kotter's model of change

Kotter, as a necessity in the sense of change management, requires identifying everything that could hinder the change. After that, recommendations for successful management of changes, that is, for overcoming problems. Change can be hindered by: a situation where there is a high degree of complacency, as a result of which there is a lack of awareness of the necessity of change, lonely individuals, regardless of their ability and charisma, never have all the potential necessary to overcome tradition and inertia, without a proper vision, an attempt to transform can easily lead to confusion, communication is carried out both through words and actions, obstacles sometimes exist only in people's heads, most people are not inclined to engage in some activities in the long term, if they do not see their effects, until changes are made embedded in organizational culture and structure, new approaches are subject to regression, change can only be sustained when it becomes part of the organization's culture [16].

It is important to implement changes through the following activities: developing awareness of the importance of change - increased awareness of the importance of change requires removing sources of complacency, creating a leading coalition - teamwork is possible when teams have the appropriate composition, where there is mutual trust and where all members want to achieve the same goal, i.e. where there is synergy, development of vision and strategy - a good vision must determine the general direction of change, motivate people to take actions in the right direction and help coordinate activities, communication skill of change - the power of vision exists only if the majority of people, who are part of the organization, understand its direction and goals in the same way, empowering employees for broad action - spreading the vision through communication with employees, adapting the structure to the vision, training employees, adapting information and personnel systems to the vision, as well as confronting those personnel who hinder changes, achieving short-term successes - organizational transformation can be risky if short-term successes are not taken into account. They provide evidence that change leads to the better, consolidating the achieved advantages and initiating further changes - new forms of behavior can be very sensitive until they reach a new balance and become part of the organizational culture, instilling new approaches into the organizational culture - activities on the processes of culture change begin at the beginning of the transformation, but new approaches find a place in the culture only when it becomes clear that they function successfully and are superior [16]. It is important to recognize the importance of teamwork and the strength of leadership as basic elements in the process of successfully leading change. The model is easy to implement for most organizations. It is essential to take advantage of his achievements to make it easier for companies to face the complexity of the change management process. The recommendations are timeless and have given many good results in practice over the past years.

The following principles can help ensure that changes are implemented effectively and that business systems improve the chances of achieving the desired results:

- Management + leadership: Companies must combine management stability and leadership innovation to take advantage of opportunities.
- Head + heart - it is important to convey the logic behind different ideas and appeal to people's desire to contribute to important things.
- Must + want to - it is important to create an environment in which employees feel inspired to volunteer for important business activities,
- choose a few + diverse many - some tasks must be performed by a specific group of experts, while others require the participation of several people [15].

5.3 ADKAR model

The ADKAR model is a change management framework that focuses on five stages of individual change. The stages of this model are:

- Awareness - why does the company have to change?
- Desire - what will be gained from it?
- Knowledge - forces of organizational change?
- Ability - implementation and achievement of the desired change?
- Reinforcement - rewarding and appreciation of sustainable changes? [16]

Changes will only be successful if all five steps are completed. If some of the steps are missed, the changes will be slower or incomplete [14].

5.4 Model 7S

The 7-S model recognizes seven interrelated elements that must be aligned and integrated to achieve a cohesive and effective organizational strategy. They are:

- Strategy: the organization's plan for achieving its goals,
- structure: formal organizational hierarchy and reporting relationships,
- systems: processes and procedures of the organization for performing work,
- common values: basic values and culture of the organization,

- Style: leadership style and approach to management,
- personnel: employees in the organization and their skills,
- skills: abilities and competencies of the organization [18].

This model has a wide application in practice. A large number of organizations have recognized its efficiency and effectiveness in various business contexts.

5.5 Transition model

This model indicates that in typical change attempts, 90% of the time, leaders focus on promoting solutions, while 10% of attention is given to solving problems. The model proposes to reverse this relationship. The stages of the model are: end, loss and letting go: recognizing the need to let go of old ways and behaviors, neutral zone: a period of confusion and uncertainty between the old and new ways of working, new beginning: accepting the new way and making it a permanent part of the organization's culture [19].

5.6 Weisbord's model

Weissbord's model is made up of six blocks that represent possible problem areas in the organization, which should be analyzed. Thus, it is possible to diagnose problems in the organization. In this way, the changes that should be made are recognized according to the nature and type of identified problems [20]. The central block is leadership. It is surrounded by five interconnected blocks. They relate to purpose, structure, connections, mechanisms that help, and rewards [5]. Weissbord defined the basic questions for each block. The goal is to use them to identify problems and define changes as easily as possible. The questions are:

- Purpose - Are the purpose and mission of the organization clear to the employees, and do they support them?
- Structure – Is there an appropriate connection between the purpose and mission of the organization and the organizational structure?
- Connections – what is the quality of the connections and are there conflicts between individuals, between groups or organizational parts, then between the individual and the demands of his job?
- Mechanisms that help - which processes and procedures help and which hinder the performance of employees?
- Rewards – are there differences between what the organization rewards and punishes and what employees expect as rewards or punishments?
- Leadership - do managers notice problems with all blocks and do they maintain a balance between them [6]?

5.7 General models

General models are related to all those models that are based on the application of some general theoretical assumptions of management and organization. Based on those achievements, a recommendation was created in the form of good practice. There is a special emphasis on examining and identifying the causes of changes, on managing the implementation of changes by managers, overcoming resistance to changes, controlling the implementation of changes and their results, etc. Emphasis is also placed on solving problems that may arise during the management and implementation of changes. The general model serves for research, diagnosis, and application of solutions in change management [5].

The stages of this model are:

- collection of the necessary data (research and determination of the organization's performance),
- analyzing the collected data (diagnosing the causes, importance, and goals of changes),
- identification of solutions (definition of necessary activities, modification of policy and strategy, introduction of new methods and techniques),
- action planning (planning time and all necessary resources for the implementation of changes and budget allocation),
- monitoring and control of the implementation of planned activities [5].

6. CHANGE MANAGEMENT MODEL IN „ZDRAVLJE LESKOVAC“ COMPANY

Organizational changes from May 10, 2021, mark the beginning of a successful path towards the realization of the vision and mission of the „Zdravlje Leskovac“ company. Kiren Naidoo takes over the position and responsibilities of the General Director, and Levent Selamoglu is appointed as the Chairman of the Board of Directors of Zdravlje [21]. Zdravlje is organized into three business divisions:

- organization of contract production and development,
- commercial sector,
- strategic projects [22].

Zdravlje has acquired several product registrations from Teva/Actavis in the areas of central nervous system, cardiology, and women's health. The contract manufacturing and development organization continues to successfully supply Teva, with new contracts signed and

technology transfer activities initiated with several high-profile multinational companies. Health is launching a new form of COVID-19 treatment in major markets such as Poland [23].

„Zdravlje Leskovac“ concludes a historic partnership with Medicines Patent Pool to develop, manufacture, and launch an authorized generic version of Paxlovid (developed by Pfizer), a novel therapy for COVID-19. Commercial operations continue to increase the number of Zdravlje products with the successful launch of a series of advanced nutritional supplements that proudly represent the Zdravlje brand (Imunex, Neurocalm, Normonerv) [23].

The company has more than 360 employees and supplies over 40 countries worldwide. Markets in which it operates include:

- Europe,
- United Kingdom,
- Latin America,
- Asia-Pacific region,
- Africa [24].

The company supplies the market with high-quality pharmaceutical products from production facilities by good manufacturing practice (EU GMP certificate) [22]. The company's strategy is to respond to unmet medical needs through the delivery of innovative and differentiated products in the growing markets of Central and Eastern Europe. It is focused on prescription drugs and nutritional supplements, as well as therapies for chronic diseases and therapies for narrow therapeutic areas. It is a trusted partner to companies looking for reliable, high-quality development and manufacturing services and those looking to access high-value markets throughout Central and Eastern Europe, the former Yugoslavia, and the CIS [24].

The company launches various biotechnological and biological projects to make innovative therapies more accessible to patients in Europe, as well as in developing countries. The main focus is on monoclonal antibodies, vaccines, insulin, blood products, and immunotherapies. [23]. Highly qualified and dedicated employees make top-quality products by domestic, European, and international standards of good manufacturing practice. The company continues to nurture its legacy of providing effective and safe products at affordable prices to consumers around the world. The company's vision is to be a reliable pharmaceutical leader built on the foundations of quality, innovation, and trust [25; 26; 27]. The company's mission is to [24]:

- enable the highest level of clinical excellence with the full trust of partners, doctors, and patients,
- acts with integrity and maintains the highest standards of quality, ethics, and compliance,
- remains a desirable employer in Serbia with a highly motivated and well-trained workforce,
- be consistent in efforts to expand reach and capabilities,
- remain flexible and respond quickly to a dynamic market, to support the communities in which it operates, and ensure sustainable growth.

7. CONCLUSION

Organizational change is inevitable in modern, changing market conditions. It is essential that the company adapts to its external environment and maintains a stable growth path. Without an optimal change management system, companies cannot achieve success in the context of change. The change could affect their existing production levels, reducing their profitability and competitiveness. Unexpected or unplanned changes can reduce employee morale and weaken company culture.

A systematic approach to the entire flow of changes can prevent such problems. The approach is particularly useful when change requires people in the organization to learn new behaviors and skills. By formally setting expectations, using tools to improve communication, and proactively seeking ways to reduce misinformation, management must help stakeholders embrace change. The entire process requires effective change preparation, change implementation, and strategy monitoring. It is impossible to predict every change that the future may bring. A careful analysis of the internal and external environment of the organization can reveal many changes that the company can plan. A detailed change roadmap, along with an implementation plan for each change, ensures a successful change implementation. The plan should list all the activities that must be done to adopt the change and adapt to its consequences.

A strategy for educating employees about how their daily work will change is particularly important and determines success. It is essential to establish an optimal system for measuring whether the change is successful. Rewards that encourage individuals and groups to take ownership of their new roles and responsibilities can play an important role in the overall process. If used correctly, change management models can help any size organization overcome resistance to change, update outdated processes to move forward, and recognize the need for clear communication and alignment at all levels of the hierarchy.

If used improperly, organizations are likely to continue to struggle with bottlenecks and low productivity or experience frequent employee turnover.

Change management models are good practices that should be used by modern companies. The manager, as a leader and agent of change, should anticipate, recognize, and implement changes, use them to improve the organization, and guide employees through the process of implementing changes while reducing the resistance that could be expressed by their introduction. Today, the company is exposed to numerous changes. Change is a condition for the development of a company, sometimes also a condition for its survival.

The skill of managing change is becoming the most important management skill. „Zdravlje“ is one of the leaders in the pharmaceutical industry of Southeast Europe. Zdravlje has a 70-year history of producing first-class pharmaceutical products according to the highest world standards. As of 2021, Zdravlje operates as an independent pharmaceutical company owned by Frontier Pharma and Baistone Group, experienced British and American pharmaceutical investors and entrepreneurs.

REFERENCES

[1] I. Adižes, *Upravljanje promenama*. Novi Sad: Adižes, 2008.
[2] R. Awati, *Organizational change management (OCM)*. TechTarget, 2024.
[3] F. Bahtijarević – Šiber, P. Sikavica, N. Pološki – Vokić, N., Suvremeni menadžment: *Vještine, sustavi i izazovi*, Zagreb: Školska knjiga, 2008.
[4] K. Blanchard, K., *Rukovođenje na višoj razini*. Zagreb: MATE d.o.o., 2010.
[5] D. Bogdanović, D., *Upravljanje promenama*. Bor: Tehnički fakultet, 2016.
[6] W. Burke, *Organization Change: Theory and Practice*, London: Sage Publications, 2002.
[7] Coursera, *What Is Change Management and How to Use It Effectively*, Coursera, 2024.
[8] R. Daft, R., *Organization theory and design*, Boston: Cengage Learning, 2016.
[9] Ž. Dulanović, O. Jaško, *Projektovanje organizacione strukture*, Beograd: FON, 1995.
[10] G. Hamel, C. Prahald, *Competing for the future*, Boston: Harvard Business School Press, 1994.
[11] E. Kahrović, *Prilog proučavanju organizacionog ponašanja – individualni, grupni i organizacioni nivo*, Društvene & humanističke nauke, Vol. 3, Broj 1., 2020.
[12] B. Kolarić, *Priroda, dimenzije i značaj organizacionih promena*, Ekonomski izazovi, Godina 7, broj 13., 2018.
[13] S. Petar, D. Perkov, *Inteligencija poslovne promjene: Kako upravljati poslovnim promjenama*, Zagreb: Školska knjiga, 2013.
[14] RELOF, Priručnik - *Upravljanje promenama*, Beograd: RELOF, 2019.
[15] M. Roganović, M., *Osnovi organizacije*, Novi Sad: Visoka poslovna škola strukovnih studija, 2022.
[16] Z. Sajfert, Z., *Upravljanje promenama*, Zrenjanin: Tehnički Fakultet „Mihajlo Pupin“, 2008.
[17] J. Todorović, D. Đuričin, S. Janošević, *Strategijski menadžment*, Beograd: Institut za tržišna istraživanja, 1998.
[18] V. Tornjanski, V., *Predviđanje uspešnosti organizacionih promena kvantitativnim Bekard i Harisovim modelom*, Beograd: Fakultet organizacionih nauka2019.
[19] Ž. Vasić, Ž., *Sistem upravljanja realizacijom investicionih projekata u funkciji upravljanja promenama u Elektroprivredi*, Zrenjanin: Tehnički fakultet „Mihajlo Pupin“, 2005.
[20] A. Xhemajli, A, *Upravljanje promjenama*, Pula: Sveučilište Jurja Dobrile, 2019.
[21] https://www.keka.com/glossary/organizational-change
[22] https://privatizacija.privreda.gov.rs/Ministarstvo-privrede/601/Potpisan-kupoprodajni-ugovor-za-Zdravlje-AD.shtml
[23] https://www.actavis.rs/sr/AboutUs/ActavisSerbia/istorijatdo2000.htm
[24] https://zdravlje.co.rs/sr
[25] https://whatfix.com/change-management
[26] https://mvnu.edu/blogs/what-is-organizational-change-management
[27] https://asq.org/quality-resources/change-management

E-HRM LIKE POTENTIAL OF BUSINESS

Julija Avakumović, Akademija tehničko umetničkih strukovnih studija, Beograd, julijaavakumovic@yahoo.com
Jelena Avakumović, College of Academic studies Dositej, Belgrade, jelena.avakumovic@vsdositej.edu.rs

Abstract: *Potential of business is available and relevant developed business opportunities which under certain conditions can affect the results of the business One of the most important potential is human resource. In the age of digital economy, the web sites help in the many modification of management human resource activities, especially of staffing (recruitment and selection) and training and development. The new E-Systems enable to managers of human resources, to provide better service to all stakeholders (candidates, employees and managers), reducing the cost of human resource department, contributing to the creation and development of e-human resource management, like as the creation and development of activities (e-staffing, e-training and development).*

Keywords: *potential of business, human resources, e-HRM, e-staffing, e-training and development.*

1. INTRODUCTION

The success of a business depends of the knowledge of resources and the way how to find the optimum combination of scale, structure and dynamics of available resources by the management of the business. (Avakumović, J., Avakumović, J., 2014)

Every sector, every job, every function, was, is or will be disrupted by Internet. HRM can be defined as "a way of implementing HR strategies, policies, and practices in organizations through a conscious and directed support of and/or with the full use of web technology-based channels".

The nature of work in the 21st century presents many challenges for recruitment: knowledge-based work places greater demands on employee competencies; demographic, societal, and cultural changes are widespread and are creating an increasing global shortfall in the number of qualified applicants; the workforce is also increasingly diverse. (Ruël et al., 2004; Avakumović, 2018)

Chambers et al. (1998) used the term "the war for talents". Talent management consists in identifying the critical positions, knowledge and skills required for these positions and then attracting and retaining individuals corresponding to the established profile. (Avakumović, 2018)

The talent is developing systematically, through the development of innate abilities of the individual, which are arranged in specific activities that someone likes, considered important and in which wants to invest energy. Talent allows to an individual to perform a specific task excellent, much better than other people with the same qualification and experience. Talent allows to an individual consistently to achieve better results in relation to their own personal record. (Avakumović, 2018)

On the May 6th 2014, talent development has become popular term when American Society for Training and Development, like as the largest association in the world in the field of human resource development, changed its name in Association for the Development of the Talent. (www.td.org)

It is indisputable that every employee, who knows how to access and acquire with the new situation is „more profitable" for the organization, because time and other resources which will spent on the training should be reduced, and employees could contribute to the employer in meeting strategic goals and competitive challenges.

2. POTENTIAL OF BUSINESS

Depending on the characteristics and the useful form of potential impact on business results, they can be classified into several groups (Avakumović, J., Avakumović, J., 2014):

- *The human resources* depends more quantity of work, or the number of employees and those who could, under certain conditions, to include the environment in the process of working specific company. The achievement of certain business tasks requires appropriate staff structure. This form of human resources covers the current state of educational backgrounds and those who could, through the education process; we adjust the objective needs of the work. Successful achievement of certain business goals

and results requires adequate professional staff structure.

- *The financial potential* implies the possibility of financing the current, medium and long term business needs. Structure of financial sources may be different, more or less favorable, from the standpoint of their impact on business results.
- *The market* as a potential organizational system affects the business system through: The scope of the possible realization of goods and services in domestic and international markets; Procurement Opportunities; The level of input and output prices; and the level of investment per unit of production volume.
- *The technical and technological potential* are determined by the technical and technological conditions. These include all material inputs and outputs of the process of reproduction in company. The material comes from the process of work produced products and services to its use value, while the material enters the process fixed resources as materials and energy. Technical and technological resources are defined scope and technical and technological characteristics: products, instruments of labor, materials and energy.
- *The information resources* use in the performance of the business of manufacturing activity allows multiple increase productivity, improve business results and contribute to the humanization of work. It includes: elements and subsystems organizational business systems, hardware and software capabilities to handle management information.
- *The social resources* are the mostly constitutional elements of macro-economic system, through the following components: Macroeconomic system; the political system; the education system; the socio-economic development; and the level of globalization.
- *The natural resources* are resulting from natural conditions that affect, or may affect, the results of the business. Natural conditions are formed under the influence of natural laws, such as laws: regeneration of fauna and flora, resistance and elasticity of the material, the movement of air and ocean currents, heat and light, biological and demographic laws of motion and other populations.
- *The knowledge* like as potential is a prerequisite for expansion, activation, balancing and efficient use of all forms of available resources. Scientific potential includes all available basic and application of knowledge to be used, or, under certain conditions, can be used to achieve specific business goals.
- The design through its creative activity changes and regulates the entire financial environment, which determines all the spiritual and physical aspects of human existence is very important potential, too.
- The marketing is the business activities and strategies, which are aimed at an orientation and establishing business relationship with the market and business environment. The research and development. It is important to point out that jointly engage potential marketing research and development in the research of new competitive products, new materials, trends of fashion and the like in order to be systematically directed towards a single goal, and the creation of high quality, competitive and efficient product / service.
- TQM (total quality management) is one of the few phenomena that attract people's attention, because it is involved in all areas of their life and work. It haunted the people of the past, because all the mind and physical work created, it had to meet certain quality criteria. These criteria have changed over time in line with the development of science, technology, art and others.

3. E-HRM LIKE POTENTIAL OF BUSINESS

"Every sector, every job, every function, was, is or will be disrupted by web" (Kalika, 2000; Avakumović, 2018).
The HR sector is undergoing a transformation. In the beginning of 21st century, Monster had over 80 million resume on their entire database. LinkedIn's social network had over 44 million members around the world (Girard, A., Fallery, B., 2010).

HR Function must confront four seemingly contradictory pressures. HR departments are required to be simultaneously strategic, flexible, efficient, and customer-oriented. Certain authors have suggested that the use of technology may enable them to achieve these goals. It is important to distinguish between HRIS and e-HRM. HRIS focus on the HR department itself in order to improve the processes within the function, whereas e-HRM also focuses on the employees and management. E-HRM can be defined as "a way of implementing HR strategies, policies, and practices in organizations through a conscious and directed support of and/or with the full

use of web technology-based channels" (Ruël et al., 2004).

In the words of Ruël et al. (2004), this can be both an innovation and an irritation. It can be an irritation when the project or the goals are unclear or unrealistic, when the type of e-HRM does not satisfy users' needs, when everything is determined by the technology. Yet it can be an innovation because it makes the decentralization of management possible, by giving more responsibilities to local managers and employees. It gives the HR function the possibility of focusing on value-creating activities, right through to the automation and outsourcing of low-value activities. It can thus become a real strategic partner of the organization by developing the intangible capital of the company.

E-HRM has been defined as 'a way of implementing HR strategies, policies and practices in organizations through a conscious and directed support of and/or with the full use of web-technology-based channels' or more recently, and more broadly, as 'the (planning, implementation, and) application of information systems for both networking and supporting actors in their shared performing of HR activities' (Stroehmeier 2007). E-HRM can be used for transactional activities (i.e. those that involve day-to-day transactions and record keeping); traditional HRM activities such as recruitment, selection, training, compensation and performance management and transformational activities that add value to the organisation (Parry, E., 2011), and may be used to manage HR across the whole employee life cycle. E-HRM varies not only in the functions for which it is used, but also in the degree of sophistication which it involves. The development of web-based technology has allowed firms to provide services directly to employees and managers through the use of self-service systems. (Parry, et. al., 2008)

Past research has suggested that e-HRM can increase the efficiency of HR activities, improve HR service delivery and transform the role of the HR function into one that is more strategic (Hendrickson 2003; Ruel et al. 2006; Martin et al. 2008). If this is the case, then the use of e-HRM may allow the HR function to increase its value and contribute to the competitive advantage of the firm, as discussed above. The more extensive deployment of technology and systems in the HR domain could be an additional source of rents.

However, we might expect that technological and system assets would have lower barriers to limitability than, say, know-how advantages embedded in socially complex routines. Although it is safer to assume that even when a firm has deployed e-HRM technologies, they may derive sustained advantages from the interactions between these, possibly imitable resources, and other more complex, path dependent resources. The purpose of this article is to test the proposition that e-HRM can increase its value through the more efficient management of generic labour and effective support of differential labour. We will examine the past literature on e-HRM in order to discuss this proposition and to form hypotheses that we will then test empirically. (Parry, E., 2011)

Azeem and Yasmin (2016) in their article "HR 2.0: linking Web 2.0 and HRM functions". In their study, they focus on the development of the ultimate use of Web 2.0 in the HR function, which they call "HR 2.0". By Web 2.0, they refer to social networking sites (e.g. Facebook), blogs,micro-blogging (e.g. Twitter), wikis (e.g. Wikipedia) and related sites and mobile applications (apps) that enable interaction online (e.g. Instagram, Snapchat, WhatsApp). Additionally, the researchers look at what is known as SLATES, or "search, links, authoring, tags, extensions and signals", which is linked to how organizations use Web 2.0, often referred to as Enterprise 2.0 – this is the now common use of new social software platforms within companies or between companies and their partners or customers.

The two questions that feed the investigation are around whether such Web 2.0 tools actually benefit key HRM activities and how can they be utilized optimally by HR managers. The problem of employees using social media during work hours and being unproductive is probably less of an issue than the theoretical wasted opportunity Web 2.0 affords HRM functions, as the ability to network across multiple platforms – which has now become almost second nature because of the proliferation and use of the likes of Facebook, Twitter and WhatsApp – would be of huge benefit if done proactively for work purposes. Sitting at the nexus of this is LinkedIn, which has all the social media attributes but is designed for firms, organizations and groups, and individuals within them, to comment, tag, share and post within an enterprise context. (Linacre, S., 2017)

4. CONCLUSION

The main objective of the company is to maximize profits from which are derived the other goals. The best way to maximize profits is optimal combination of potentials. In the new age or age of digitalization and expansion of e-resources, managers have to use e resources. One of the most important e-resources is e-HRM.

Organizations should consider the value of the HR function in the adoption of e-HRM and make the effort to design and implement the system in such a way so as to promote and maximize these benefits.

The development and use of modern technology, especially in terms of the digital transformation, should contribute achieving better performance of activities of human resource management in organization, and implicatively of talent management may contribute to the better efficiency of the activities of HRM (employee performance) and to better performance of whole organization.

REFERENCES

[1] Avakumović Julija, Avakumović Jelena: Potencijali biznisa, Ekonomika, broj 1/2014, Niš, 2014

[2] Avakumović, J., "Komplementarnost e-staffing-a, e-obuke i razvoja kao aktivnosti u razvoju e-menadžmenta ljudskih resursa ", Conference EMAN 2018, March 22nd, Ljubljana, Slovenia, 2018.

[3] Avakumović, J. "Talent management implementation in activities of HRM", Conference ERAZ 2018, Jun 07th, Sofia, Bulgaria, 2018.

[4] Chambers, E. G., Foulton, M., Handfield-Jones, H., Hankin, S. M., and Michaels Ill, E. G. (1998).
The War for Talent. The McKinsey Quarterly, 44-57.

[5] Girard, A. and Fallery, B. (2010), "Human resource management on internet: new perspectives", Journal of Contemporary Management Research, Vol. 4 No. 2, pp. 1-14.

[6] Kalika, M. (2000). Le management est mort, vive le e-management! Revue Française de
Gestion, 68-74.

[7] Kavanagh, M.J. and Thite, M. (2009), Human Resource Information Systems: Basics, Applications, and Future Directions, Sage Publications, New York, NY

[8] Martin, G., Reddington, M. and Alexander, H. (2008). *Technology, Outsourcing and Transforming HR*, Oxford: Elsevier.

[9] Malik Faisal Azeem, Robina Yasmin, (2016) "HR 2.0: linking Web 2.0 and HRM functions", Journal of Organizational Change Management, Vol. 29 Issue: 5, pp.686-712,

[10] Ruël, H., Looise, J., and Bondarouk, T. (2004). E-HRM: Innovation or Irritation. An Explorative Empirical Study in Five Large Companies on Web-based HRM. Management Revue, 15,
364-380.

[11] Parry, E. and Tyson, S. (2008), "An analysis of the use and success of online recruitment methods in the UK", Human Resource Management Journal, Vol. 18 No. 3, pp. 257-257

[12] Rita Bissola, Barbara Imperatori, (2014) "The unexpected side of relational e-HRM: Developing trust in the HR department", Employee Relations, Vol. 36 Issue: 4, pp.376-397

[13] Strohmeier, S. (2007). 'Research in e-HRM: review and implications'. *Human Resource Management Review*, 17: 19–37

WORKSHOP

Workshop Title:
Implementation of the ISO/IEC 42001 Standard for AI Management System

Duration: 30-40 minutes

Time and Location: Infotech Conference, in the afternoon

Workshop Description:
The workshop *"Implementation of the ISO/IEC 42001 Standard for AI Management System Implementation"* provides an insight into the key requirements and steps for establishing responsible and secure management of AI systems. Through a concrete example of implementation within a PMO, participants will learn how this standard can enhance control, transparency, and risk management in AI projects. The workshop is intended for professionals who want to align AI practices with existing management systems and regulatory frameworks.

Agenda:

- **Introduction to the Workshop and Objectives**
  Brief introduction of the speaker
  Workshop goals: Why ISO/IEC 42001 is important and who it is intended for

- **Overview of the ISO/IEC 42001 Standard**
  Structure of the standard and key areas
  Differences between ISO 42001 and other relevant standards (ISO 27001, ISO 9001)
  Key concepts: AI governance, risks, ethics, accountability

- **Practical Steps for Implementation**
  Analysis of the current state and GAP analysis
  Defining AI policies and governance frameworks
  The role of the management team and stakeholders
  Integration with existing management systems

- **Example of Implementing Standard Requirements within a PMO**
  The role of PMO in setting AI policies and processes
  How PMO monitors and addresses AI risks
  Control points and evaluation of AI projects
  Ensuring resources for AI projects

- **Discussion and Participant Questions**
  Q&A session
  Sharing participant experiences

AUTHOR INDEX