GODINA 6, BROJ 6 (2023)

ISSN 2566-4522

VISOKA ŠKOLA
INTERNACIONALNA
POSLOVNO – INFORMACIONA
AKADEMIJA
TUZA

ZBORNIK RADOVA

Book of Proceedings

6. MEĐUNARODNA NAUČNA KONFERENCIJA
O DIGITALNOJ EKONOMIJI DIEC 2023

6th INTERNATIONAL SCIENTIFIC CONFERENCE
ON DIGITAL ECONOMY DIEC 2023

TUZLA, 2023. GODINA

GODINA 6, BROJ 6 (2023) ISSN 2566-4522

VISOKA ŠKOLA
“INTERNACIONALNA POSLOVNO
– INFORMACIONA AKADEMIJA” TUZA

ZBORNIK RADOVA
Book of Proceedings

6. MEĐUNARODNA NAUČNA KONFERENCIJA O DIGITALNOJ EKONOMIJI DIEC 2023

6th INTERNATIONAL SCIENTIFIC CONFERENCE ON DIGITAL ECONOMY DIEC 2023

Tuzla, 2023. godina

Izdavač / Publisher
Visoka škola za savremeno poslovanje, informacione tehnologije i tržišne komunikacije
"Internacionalna poslovno - informaciona akademija" Tuzla

ISSN 2566 - 4514 *(Print)*
ISSN 2566 - 4522 *(Online)*

Contents

Dr Branka Rodić[1]
Prof. dr. Aleksandra Labus[2]
Prof. dr Marijana Despotović-Zrakić[3]
MSc Petar Lukovac[4]
BSc Milica Simić[5]

Keynote paper

AN ECOSYSTEM FOR SMART CITIES BASED ON BLOCKCHAIN

Abstract

This paper analyses the impact of the digital transformation of cities affected by rapid urbanization that tend to endanger their environmental and economic sustainability. Such a transformation is possible through the concept of a smart city. We investigate the opportunities of using blockchain technologies in the realm of smart cities. The paper's main goal is to propose a new business model for blockchain use in the smart city ecosystem that will provide a solution for a sustainable urban environment and improve citizens' life. Smart city ecosystem consists of building blocks: infrastructure, development and self-sustainability, stakeholders and their relationships. Stakeholders can be different subjects, but most often they are government authorities, service providers, blockchain technology providers, IoT device manufacturers, and citizens. Blockchain-based systems facilitate increased citizen engagement and participation. Citizens can provide feedback, contribute data, and interact with smart city services through decentralized applications. The ecosystem operates in an iterative and adaptive manner continuously learning and improving based on the data and feedback received. Insights gained from the blockchain data and citizen interactions drive ongoing enhancements to the smart city infrastructure and applications. The proposed model will, on the other hand, show sustainability by citizens through a reward system using a digital wallet. Citizens actively engaged in energy management or ridesharing platforms can be rewarded with tokens to use for discounts or health check-up services. The proposed ecosystem could serve as a ground for the adoption of blockchain in smart city ecosystems in different countries.

Key words: *Blockchain, Smart City, Smart Contracts, Digital Transformation.*

1 Professor of applied studies, Academy of Applied Studies Belgrade, Serbia, The college of Health Sciences, Cara Dusana 254, Zemun-Belgrade, brodic@gmail.com
2 Full professor, Faculty of Organizational Sciences, University of Belgrade, Serbia, aleksandra@elab.rs
3 Full professor, Faculty of Organizational Sciences, University of Belgrade, Serbia, maja@elab.rs
4 Teaching associate, Faculty of Organizational Sciences, University of Belgrade, Serbia, petar.lukovac@elab.fon.bg.ac.rs
5 Teaching associate, Faculty of Organizational Sciences, University of Belgrade, Serbia, milica.simic@elab.fon.bg.ac.rs

1. Introduction

Today, more than a half of the world's population lives in lives in urban areas. There is a report from the United Nation where is stated that 68% of the global population is going to live in cities by 2050 (United Nations, 2018a). And this trend is expected to continue. Growth of the urban population leads to challenges to a city's sustainability and management. As population grows, citizens' welfare is affected by increased traffic jams, air pollution, difficult management of waste disposal, jeopardizes public safety, health services, etc. The solution to these problems as well as providing efficient services are feasible but with a proper management of environmental, social and economic sustainability of resources. Many cities that have encountered similar problems have applied modern technologies such as: Internet of Things (hereinafter: IoT), wearable computing, machine learning, artificial intelligence (hereinafter: AI), blockchain, etc., in order to provide more efficient and accessible services to their citizens during their daily activities. Technologies like Internet of Things, big data, machine learning, wearable computing, crowdsourcing, cloud computing, intelligent devices, etc., enable easy implementation of different services in private or public homes, offices, streets, hospitals and other community places and services and which is why they get the label "smart". Many researchers defined the concept of a smart city, but the common attitude of definitions and researchers is the application of ICT for the purpose of delivering the smart city benefits to its citizens united with aim to increase the quality of citizens' life (United Nations, 2018b)(Jezdović et al., 2021).

The concept of smart city allow citizens and local government authorities to work together to improve the efficiency of city services, and implicitly improve the living welfare and wellbeing of its citizens (Nam & Pardo, 2011) (Tabane et al., 2017). One of the most important aspects of a smart city is its sustainability. Sustainability is also a big challenge that needs to be solved in order to implement centralized and non-fragmented smart city services and maintain and sustain citizen welfare. Blockchain has been proven to facilitate transparency, ensure a secure and efficient dissemination of data, centralization and elimination of intermediaries (Mohd Shari & Malip, 2022) (Alnahari & Ariaratnam, 2022).

In this paper we propose a new business model for an ecosystem for smart cities based on blockchain. The ecosystem consists of infrastructure and interaction among different stakeholders such as government authorities, service providers, providers of blockchain technology, IoT device manufacturers, and citizens (Mohd Shari & Malip, 2022).

The rest of the paper is organized as follows: section 2 gives the theoretical background on the smart city concepts, application domains and blockchain-based services in the smart city; section 3 presents smart city business model based on blockchain and section 4 presents an ecosystem for smart cities based on blockchain. Finally, we give conclusions and implications in section 5.

2. Smart city application domains based on blockchain

Although the concept of a smart city dates back to the 90s of the last century (Attaran et al., 2022), it is written and talked about a lot, and is still a current topic (Albino et al., 2015). Urban problems, today, can be solved by constructing a city based on available resources and smart technologies in a coordinating manner (Bhushan et al., 2020). In its narrow meaning smart city is based on organization, human and technology (Sun et al., 2016) (Tabane et al., 2017). Technology includes modern information-communication technologies, human dimension is based on people or knowledge, and organization is related to government and policy and institutional relationship (Sun et al., 2016).

Recently, more and more importance has been given to several attributes including smart city sustainability, quality of citizens' life and the inclusion of the component of smart people in the concept of a smart city (Tabane et al., 2017) (Chang & Smith, 2023) (Attaran et al., 2022). Thus, an interesting definition that we can refer to is that smart city investments in human and social resources with traditional and modern communication infrastructure fuel sustainable economic development and high life standards (Caragliu et al., 2011). An overview of the main dimensions will be given in the following chapters.

2. 1. Smart cites application domains

Throughout the literature, different models and application domains of the smart city concept are distinguished. Certain dimensions are common to almost all researchers, while some mention other aspects that are not widespread or often implemented, but are no less important. In paper (Sun et al., 2016) the following dimensions are specified: smart governance, smart mobility, smart living, smart citizens, and smart economy. Some other (Mohd Shari & Malip, 2022) includes smart healthcare, smart education, smart energy, smart building, smart education, smart communication, smart services, etc. and this list will increase. Therefore, smart city dimensions features are proposed below, to better understand its peculiarities.

Smart government. Usually delivers administration and services to citizens, like identity management and authentication, and tax collection. There is a need for improvement in public administration so that the transmission of important data from citizens' administration and vice versa is at the highest level of security and privacy.

Smart living. When smart living is mentioned, its description should include smart homes, smart government, smart education, smart buildings, etc., because all of them are involved in improving the quality of life of the citizens. In smart homes and smart buildings different actuators, sensors, and smart devices provide automated services for the users, helping them in their daily tasks. Smart living services and location-based services also play a big role in citizens' welfare because they provide better experience, new education, and offers based on tracking users' flows and behaviours (Bellini et al., 2022).

Smart energy. As the population grows, expectedly, there is increased demand for energy. In conscious and responsible cities there are efforts to consumption of low-cost energy. It is necessary to achieve communication and good cooperation between suppliers and consumers via smart grids and smart meters. The consumer would have the opportunity to measure consumption through a smart meter, and the supplier would be forwarded the electricity consumption during certain periods. This kind of simultaneous communication would be a benefit for both consumers and suppliers because they would be able to manage consumption and reduce energy losses (Mohd Shari & Malip, 2022)(Bellini et al., 2022). Decision makers, therefore, will have precious data to measure levels of demand and supply.

Smart education. It enables a different approach to education. The traditional way has been replaced by learning at any location and at any time (Mohd Shari & Malip, 2022). This is a kind of non-binding learning and education that way enables greater interaction and response of interested parties. Learning environments should improve the realization of the learning process, by advanced multimedia technologies that increase the efficiency of the process of knowledge transfer (Simic et al., 2016).

Smart healthcare. When it comes to healthcare, overcrowded cities offer an environment that can be threatening to one's health as well as opportunities to improve health. Digitally connected smart cities can make health care smarter and more accessible to citizens. Healthcare systems and data can be integrated and interoperable across healthcare system. Integration can facilitate interactions between all the subjects in the healthcare systems (e.g., medical doctors, patients, hospital management, insurance companies, etc.). With the development of sensors and smart wearable devices, it is possible to monitor the patient's vital signs in real time, during daily activities. Analysed results can be shared with their doctors who will respond remotely with appropriate advice or therapy (Tian et al., 2019) (Bellini et al., 2022). the implementation of emerging technologies in the field of healthcare entails issues of security and data security (Kamel Boulos et al., 2018). Healthcare insurance systems can also be a subject of transformation in smart cities; IoT and other smart technologies can bring transparency and security to all parties involved.

Smart transportation. Transportation systems are the fundamental base for the economic growth of the city. A large number of vehicles on the streets cause nervousness among drivers, and consequently more accidents. In addition, the consumption of fuel in the streets is much higher, so the environment is more polluted. It is one of the most important domains in which blockchain technologies can help to achieve road safety, reduce delays, and improve travel efficiency. In cities, a large number of applications for driving delivery vehicles are being developed. They generate a large amount of data that is difficult to manage. Blockchain technologies with modern cryptographic techniques, and IoT computing, make an excellent solution for the implementation of transportation systems in smart city. They can make decentralized, distributed, interoperable, and transportation systems (Mollah et al., 2021) (Guerrero-Ibáñez et al., 2018).

2. 2. Blockchain-based services in the smart cities

In the smart city ecosystem, emerging technologies are used to improve citizens' welfare and city management. Blockchain technology is receiving recently extensive interest from both academic researchers and industry (Zheng et al., 2020)(Ullah et al., 2023). It is a distributed ledger that allows us to record and share information across a distributed network. A lot of researchers believe that blockchain will play a large role in the global economy's long-term growth, raising people's living welfare (Siddiquee et al., 2022).

Some advantages of using Blockchain technology in smart cities are (Mohd Shari & Malip, 2022)(Laufs et al., 2020):

- Blockchain technology functions as a decentralized system without the need for central authority to control the whole network. In the blockchain transactions are validated through a consensus protocol and replicated between peer nodes in the network.
- Features of immutability and enhanced security are one of the key characteristics of blockchain technology. Transaction data are stored in blocks. Each block contains it's cryptographically hash and the hash of the previous block, and any change on a current block will affect all the subsequent blocks. No one in the network can affect network characteristics or performance for their own benefit. This way of transferring information makes blockchain immutable and secure.
- The blockchain ledger provides transparency and publicity, so anyone can access and view the transactions on the network. All changes are publicly visible that makes this system highly transparent and resistant to fraud and corruption.
- Consensus protocol is one of the features that allow users to communicate in a distributed setting without a central authority. All transactions in blockchain can be coordinated through consensus protocol performed by nodes in the network and thus reduce human intervention. In this way, the validity and consistency of transactions are ensured.
- Increased capacity is one of the main features of blockchain. It provides a much stronger system than a few devices in the centralized system and it is expected to grow rapidly. The blockchain network is extremely secure due to a large number of computers, unlike one central server computer.

The features of blockchain boost its application in various sectors in smart city ecosystem. The concept of a smart government comprises ways in which government can serve their citizens through the use of new-age technologies. Today, the participation of citizens in making administrative decisions is also of great importance. Blockchain is widely applied in e-voting. Some research shows that blockchain has the potential to ensure the integrity of the electoral process (Daramola & Thebus, 2020). Also, reducing corruption (Parenti et al., 2022) is a sensitive topic that is gaining more and more importance today, and is based on the transparency of data through the blockchain system. The real estate sector has huge socio-economic value to the nation. Therefore, is not

surprising that one of the blockchain application in smart city ecosystem is real estate and asset registration (Sladić et al., 2021)

Based on a large number of works, we conclude that blockchain has a large application in healthcare sector. The blockchain main and important features make it easy to manage securely with patients' data and enable health researchers to reach the data. Widespread adoption of blockchain technology in healthcare will make healthcare services more accessible and reduce unnecessary costs while improving medical management (Labus et al., 2022). Due to its decentralization nature, blockchain enables management of huge amount of patients data from various resources like wearable devices, sensors or EHRs and this data can be efficiently accessed by different healthcare subjects with need of an intermediary (Mohd Shari & Malip, 2022) (Dimitrov, 2019). In a paper (Griggs et al., 2018) is proposed blockchain-based smart solution with smart contracts that facilitate security in the process of exchange and analysing medical sensor data. Sensors can communicate with smart devices and write measurement data on the blockchain. It is possible in real-time to send notifications to patients and medical professionals. Besides, many issues in drug management can be addressed with blockchain technology. Transparency at any level in drug supply chain is fundamental (Labaran & Hamma-Adama, 2021) and there are proposed blockchain-based methods and models for integrity in clinical trials (Huh et al., 2022) or for product traceability (Mars et al., 2021) in the healthcare supply chain.

Blockchain can be used to manage and track the use of public transportation, helping city management to optimize their transportation systems and reduce congestion. The most common areas where blockchain is implemented are real-time parking management, electronic toll collection, automated road speed enforcement, collision avoidance alert system (Sharma et al., 2020), traffic planning (Ren et al., 2019) (Ahmed et al., 2023), and management.

The role of blockchain technology in smart energy grids is gaining attention across the world. The researchers are seeking the way energy is generated, distributed, and consumed. Blockchain can reduce the wastage of energy and efficient consumption with application of smart grids (Tahir et al., 2022). The other application of blockchain is for P2P energy trading where energy consumers can trade energy with their neighbours. Blockchain data is recorded through smart contracts and verified by a distributed network of nodes, so consequently, intermediaries can be eliminated (Ul Hassan et al., 2019).

Another application of blockchain is for the verification of green energy where consumer can verify the renewable energy through the use of blockchain technology (WePower, 2023)

Blockchain-based solution for education are mainly used to keep the process of degrees (Sutikno & Aisyahrani, 2023), credit management, and certificates (Sathya et al., 2021). Besides, blockchain can be used to facilitate online testing and learning, education data mining and analytics (Chen et al., 2022). Also, the process of research article publication can be the area where blockchain can play a major role (Mackey et al., 2019).

The city ecosystem can benefit from the use of blockchain due to maximising efficiency in various domains, like improving the management of energy resources and transportation making a "smart" educational and health system (Alnahari & Ariaratnam, 2022), etc.

The ability of a city to perform its operations and uphold the balance of the ecosystem in all the aforementioned departments is known as sustainability. Through recent literature, sustainability is interpreted as the need to respond to the needs of citizens through sustainable solutions.

Sustainability in the smart city ecosystem can be achieved through the main usage of blockchain technology as a means of exchanging economic assets over the underlying cryptocurrency and digital wallets (Mora et al., 2021).

As previously stated, there are a lot of benefits offered by smart cities. Besides that, as any new technology concept, it leaves behind challenges to overcome. Private and public sectors should be accompanied in contributing to management of a smart city.

3. Smart city business model based on blockchain

The development of an appropriate business model is one of the key elements for successful planning and design of smart cities based on blockchain. The Business Model Canvas is a basis for creating new and documenting current business models as well as an effective management tool (Au et al., 2011). The Business Model Canvas for smart city based on blockchain is presented in the Table 1.

Table 1. Smart city business model based on blockchain

<table>
<tr>
<td>KEY PARTNERS
• Service providers for smart cities
• Providers of blockchain technology
• IoT device manufacturers
• Governmental organizations and regulators
• Urban planner
• Research institutions and academy</td>
<td>KEY ACTIVITIES
• Development of blockchain-enabled smart city solutions
• IoT devices
• Managing and maintaining the infrastructure of the blockchain network
• Facilitating transactions and data exchange on the blockchain network
• Collaboration with key partners
• Smart contracts development</td>
<td>VALUE PROPOSITIONS
• Transparent and safe data sharing
• Improved efficiency through automatization and decentralization
• Cost savings through optimization of city resources
• Real-time information for decision-making</td>
<td>CUSTOMER RELATIONSHIP
• Education and awareness
• Cooperative relationships
• Continuous support and maintenance
• Feedback and co-creation</td>
<td>CUSTOMER SEGMENT
• Residents and citizens of smart cities
• City governments and government entities
• Businesses involved in smart city operations (infrastructure providers and solution integrators)</td>
</tr>
<tr>
<td></td>
<td>KEY RESOURCES
• Technology and blockchain expertise
• Smart city expertise and data
• Digital infrastructure
• Financial capital</td>
<td></td>
<td>CHANNELS
• Digital channels
• Partner channels
• Direct sales
• Industry events and conferences</td>
<td></td>
</tr>
<tr>
<td colspan="3">COST STRUCTURE
• Blockchain infrastructure development
• Research and development
• Talent acquisition
• Marketing and sales
• Operational costs</td>
<td colspan="2">REVENUE STREAMS
• Licensing and subscription fees
• Data monetization
• Value-added services
• Transaction-based revenue</td>
</tr>
</table>

Key partners. In order to supply the necessary infrastructure and services for the ecosystem of the smart city, such as power and transportation, the suggested smart city business model calls for partnerships with service providers. Utilizing the resources and experience of blockchain technology providers is essential for building and maintaining the blockchain platform. Collaborations with IoT device manufacturers also make it possible for those products to be seamlessly integrated into the blockchain network. Working closely with regulatory bodies and governmental organizations ensures that laws and regulations are in line with the goals of the blockchain-enabled smart city and makes it easier to access local data and infrastructure. By bringing knowledge of creating sustainable and effective urban environments, urban planners play a significant part in a smart city business model based on blockchain. In order to incorporate smart city technologies and assure the best possible resource usage for improved urban planning and development, they work with blockchain solution providers. Through experience of research and academic institutions in conducting research, analysis, and invention, they contribute to the smart city business model based on blockchain. To investigate novel applications, confirm the efficacy of blockchain technology, and create best practices for implementing blockchain-enabled solutions in smart cities, they collaborate closely with blockchain developers and stakeholders in smart cities. Their academic cooperation and research-driven innovations fuel the development of the smart city.

Key activities. Blockchain technology is used in the development of the smart city solutions to improve the efficiency and security of services and transactions within the smart city. This advancement enables the capture and exchange of real-time data by connecting IoT devices into the blockchain network. To guarantee its dependability and security, the blockchain network's infrastructure is controlled and maintained. The blockchain network enables safe data exchange and transactions, maximizing efficiency within the ecosystem for smart cities. Working together with important partners is crucial for fostering the development and promotion of blockchain-enabled smart city solutions, building connections and accelerating adoption. The development of smart contracts is essential for automating and streamlining numerous procedures in the smart city, improving operational effectiveness.

Key resources. The technical know-how and assets required to build and manage the blockchain network, including blockchain expertise. Access to pertinent data and knowledge of smart city systems are required to successfully integrate blockchain-enabled solutions. The hardware and software needed to build and maintain the network's digital infrastructure, which supports the blockchain. The financial capital required for investing in research and development projects and for the continued maintenance of the blockchain network.

Value proposition. A blockchain-based business model for smart cities provides improved security and transparency in data sharing, reducing the possibility of fraud and ensuring responsibility. It makes it possible for smart city processes to be automated and decentralized, enhancing their effectiveness and maximizing the use of available resources. Blockchain technology enables

cost reductions through resource optimization and creates new revenue-generating options. Additionally, blockchain-based data analytics give decision-makers reliable insights for efficient resource management within the ecosystem of smart cities through real-time information.

Customer segments. The benefits of blockchain-based smart city solutions are mostly enjoyed by the citizens and residents of those cities, since they have better access to the necessities of everyday life like basic services and transactions. The openness, effectiveness, and possible cost savings that blockchain technology provides to their operations are advantageous to city governments and other governmental bodies. Businesses involved in operating smart cities, such as infrastructure providers and solution integrators, can take advantage of blockchain's greater efficiency and transparency to explore new business opportunities and save money.

Customer relationships. As the technology is still in its infancy, it is essential to educate and raise customer knowledge of the advantages and worth of smart city solutions powered by blockchain. For the successful implementation of blockchain-enabled smart city solutions, it is essential to forge cooperative partnerships with key partners and stakeholders, including governmental organizations, infrastructure suppliers, and solution integrators. For long-term profitability and customer happiness, it is crucial to offer continuing support and maintenance to resolve consumer questions and issues.

Channels. To effectively reach and inform customers about blockchain-enabled smart city solutions, digital channels like social media platforms, internet advertising, and email marketing can be utilized. Establishing partnerships with key stakeholders, such as service providers for smart cities and governmental organizations, can be facilitated through partner channels. Direct sales channels, including sales teams and customer service, can provide direct engagement with customers, offering ongoing support and maintenance. Participating in industry events and conferences specifically focused on smart cities allows for showcasing blockchain technology and creating valuable networking opportunities with potential customers and partners.

Cost structure. Setting aside funds for the creation and upkeep of the blockchain network, including costs for hardware, software, and security measures. Investing in research and development efforts to advance blockchain technology regularly and adjust to changing demands in the field of smart cities. Obtaining and keeping hold of qualified personnel with experience in the fields of data analytics, blockchain development, and smart cities. Implementing marketing and sales techniques enable selling blockchain-powered smart city solutions such as advertising campaigns, sales teams, and industry events. Covering operating expenses like office rent, utilities, and overhead expenditures necessary for the blockchain-based smart city business model to operate smoothly.

Revenue stream. Revenue can be generated in a smart city business model based on blockchain by charging customers licensing and subscription fees in return for utilizing the blockchain platform and receiving ongoing support

and maintenance. Another source of revenue is through the sale of valuable data derived from blockchain to interested parties, including researchers, city planners, and businesses. Additionally, offering value-added services such as consultation, smart contract development, and personalized analytics reports creates additional streams of revenue. Leveraging business models that generate revenue based on the volume of transactions facilitated by the blockchain network can also contribute to the financial success of the smart city business model.

4. An ecosystem for smart cities based on blockchain

Smart city application domains and key stakeholders for an ecosystem for smart cities based on blockchain are shown in Figure 1.

Many different domains can make use of IoT devices and their implementation. Domains that proved to provide the most benefits are:

- **Smart transportation.** The main goal is to improve safety and efficiency in urban traffic conditions. The solution can be found in equipping vehicles and road infrastructure with smart sensors that are able to detect changes in traffic conditions and behaviour of pedestrians. Gathered data can then be combined with real-time communication (Guerrero-Ibáñez et al., 2018).
- **Smart environments.** In this domain, smart devices can be used to collect data from the environment, mostly related to everyday tasks. The data can be used in real-time to track any changes and enable quick reaction in case problems arise.
- **Smart healthcare.** The focus of this domain is to improve traditional medical system by adding efficiency and personalization. For example, significant aspects of patient's health can be collected at any given moment. Then the doctor can revise all the data, providing better treatment plan (Tian et al., 2019).
- **Smart education.** Implementing smart education allows teachers and students to move away from traditional teaching methods. It allows them to embrace their creativity when learning, by providing flexibility regarding different methods of interaction and sharing learning materials.
- **Smart grids.** One of the main goals of smart grids is to help in saving up the energy. Using advanced metering infrastructure and smart distribution boards, improves optimization and provides a way for efficient consumption of energy (Mohd Shari & Malip, 2022).
- **Public safety.** Domain of public safety is mainly mentioned as a part of smart city environment. This aspect is especially important and solutions include video analytics and face recognition software, smart street lighting, etc.

- **Smart waste management.** Focus of this domain is mainly related to recycling used products and their packaging. Implementation of smart sensors can improve efficiency of recycling by notifying waste management services if containers are full and tracking the condition of materials inside.

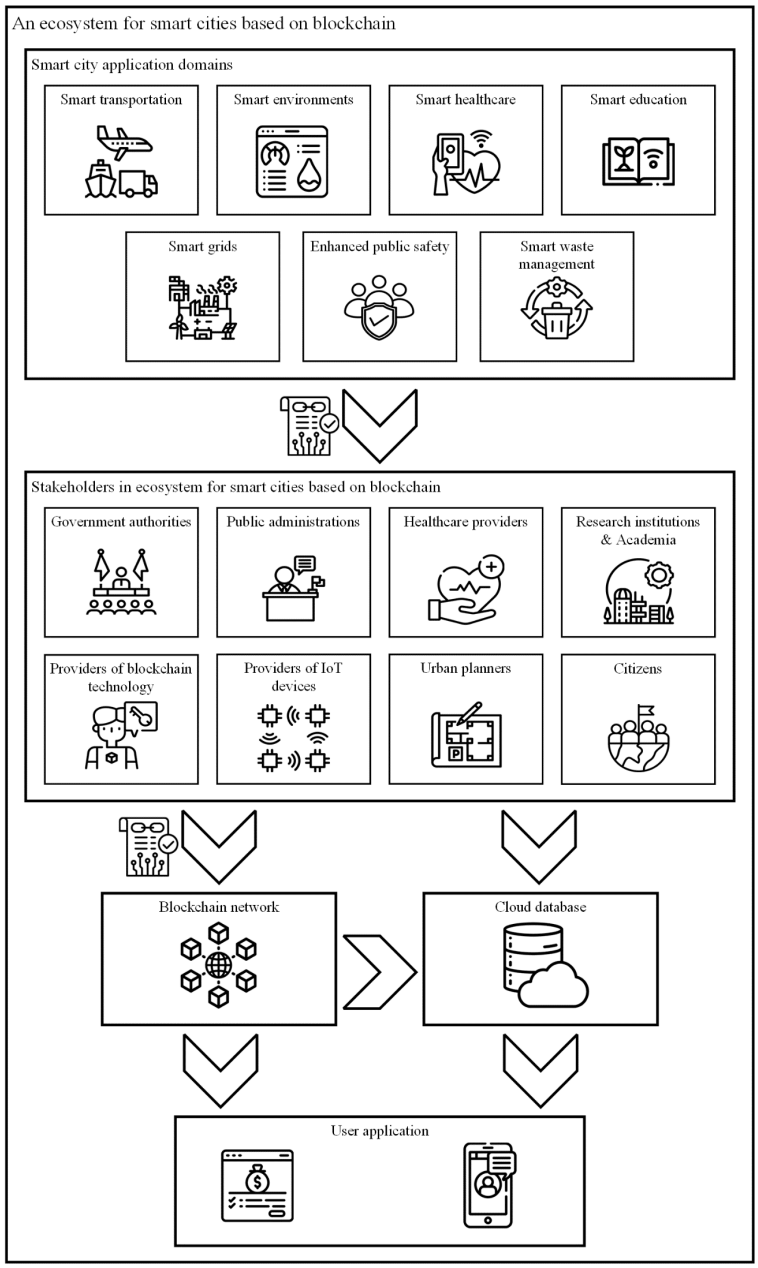


Figure 1. An ecosystem for smart cities based on blockchain

Stakeholders are essential part in ideation and implementation of smart city services. All end solutions should benefit the life of every citizen. Need for legal support and funding implies cooperation with government institutions and public administration office. Providers of products and services are essential part in implementation of smart city services. Firstly, there are domain specific stakeholders, for example Healthcare providers which are essential for smart healthcare or Research institutions & Academy, whose support is needed for implementation of smart education. Secondly, there are technology providers that include Providers of IoT devices and Providers of blockchain technologies.

Smart sensors and IoT devices are essential part of physical implementation of smart services. They gather information from our surroundings and enable real-time exchange of messages between components in every smart city service. On the other hand, usage of blockchain technology is proposed with the idea to enable transparent communication between stakeholders and build trust. Communication between stakeholders is implemented using smart contracts on blockchain network. Advantage of this approach is that all agreed upon statements of the contract are implemented using programming code. This enables quick fact checking without space for human errors, but also fast payments without bank provisions using cryptocurrency. On the other hand, using blockchain technologies enables access to data for all stakeholders, which improves communication when building any of the smart city service. Since the data that is passed to the blockchain network cannot be altered, and hierarchy of information is recorded, there is no option for deception.

Data is collected using smart devices from every stakeholder. All collected data is uploaded to the cloud database, while only essential data is recorded on the blockchain network. This combination allows for affordable yet secure data storing. Since big part of proposed smart city solutions is to make life better and easier for every citizen, user application is essential to enable simple way to view data and interact with smart services from any device.

There are many services that can make use of blockchain technologies. In the context of smart grids, users are able to generate their own power using solar panels for example. They also have the opportunity to transfer residual power to main energy grid and sell it on the market. Blockchain technology could be used to track if produced energy is from renewable sources. Also, the process of buying and selling energy could be implemented efficiently using smart contracts transactions on blockchain network (Gao et al., 2012).

Smart transportation can also benefit greatly from blockchain technology. Smart sensors can be used to improve efficiency in transportation and track transported goods throughout the supply chain. Smart sensors can aid driver by providing information about possible traffic congestion or inform driver about free parking spaces near the destination (Jan et al., 2019). On the other hand, every step of product journey is recorded, including transportation start time, transportation end time, temperature, humidity, stakeholders that are a part of the chain and other important parameters depending on the product. In this case, blockchain network can be used to store essential data that cannot

be altered. Smart contract could also be implemented to check if all conditions were fulfilled during transportation and provide hierarchy of possession between stakeholders.

As mentioned before, smart healthcare services can be used to provide a detailed record of patient's condition. Role of blockchain could be to make this information from medical chart more secure by providing availability only to the patient. A doctor could gain the access to medical chart only when needed and approved by the patient.

5. Conclusion

This paper presents the integration of blockchain technology in the proposed business model for the smart cities ecosystem. Smart cities may improve trust, accountability, and efficiency by utilizing blockchain, laying the groundwork for a more sustainable and connected future. The scientific contribution of this paper is the development of an innovative smart city business model based on blockchain and an ecosystem for smart cities based on blockchain. Smart cities could provide a basis for a more adaptable, open, and highly technological urban environment by adopting blockchain technology.

Future research directions will refer to the development of services for smart cities based on IoT and blockchain technologies. It is planned to implement transactions in the proposed smart cities ecosystem using smart contracts. Algorand blockchain platform and PyTeal programming language will be used for the development of smart contracts and conducting transactions in the proposed smart cities ecosystem.

Reference

1. Ahmed, M., Ahmed, A., & Ahmed, M. (2023). *Implementation of IoT and Blockchain in Traffic Control by using Matrix Algorithm*. 0–9.
2. Albino, V., Berardi, U., & Dangelico, R. M. (2015). Smart cities: Definitions, dimensions, performance, and initiatives. *Journal of Urban Technology*, *22*(1), 3–21. https://doi.org/10.1080/10630732.2014.942092
3. Alnahari, M. S., & Ariaratnam, S. T. (2022). The Application of Blockchain Technology to Smart City Infrastructure. *Smart Cities*, *5*(3), 979–993. https://doi.org/10.3390/smartcities5030049
4. Attaran, H., Kheibari, N., & Bahrepour, D. (2022). Toward integrated smart city: a new model for implementation and design challenges. *GeoJournal*, *87*(s4), 511–526. https://doi.org/10.1007/s10708-021-10560-w
5. Au, M., Oliveira, Y., José, J., & Ferreira, P. (2011). Business Model Generation: A handbook for visionaries, game changers and challengers. *African Journal of Business Management*, *5*(7).

6. Bellini, P., Nesi, P., & Pantaleo, G. (2022). IoT-Enabled Smart Cities: A Review of Concepts, Frameworks and Key Technologies. *Applied Sciences (Switzerland)*, *12*(3). https://doi.org/10.3390/app12031607

7. Bhushan, B., Khamparia, A., Sagayam, K. M., Sharma, S. K., Ahad, M. A., & Debnath, N. C. (2020). Blockchain for smart cities: A review of architectures, integration trends and future research directions. *Sustainable Cities and Society*, *61*, 102360. https://doi.org/10.1016/J.SCS.2020.102360

8. Caragliu, A., Bo, C. Del, & Nijkamp, P. (2011). Smart Cities in Europe. *Journal of Urban Technology*, *18*(2), 65–82. https://doi.org/10.1080/10630732.2011.601117

9. Chang, S., & Smith, M. K. (2023). Residents’ Quality of Life in Smart Cities: A Systematic Literature Review. *Land*, *12*(4). https://doi.org/10.3390/land12040876

10. Chen, X., Zou, D., Cheng, G., Xie, H., & Jong, M. (2022). Blockchain in smart education: Contributors, collaborations, applications and research topics. *Education and Information Technologies*, *28*(4), 4597–4627. https://doi.org/10.1007/S10639-022-11399-5/METRICS

11. Daramola, O., & Thebus, D. (2020). Architecture-Centric Evaluation of Blockchain-Based Smart Contract E-Voting for National Elections. *Informatics 2020, Vol. 7, Page 16*, *7*(2), 16. https://doi.org/10.3390/INFORMATICS7020016

12. Dimitrov, D. V. (2019). Blockchain applications for healthcare data management. *Healthcare Informatics Research*, *25*(1), 51–56. https://doi.org/10.4258/hir.2019.25.1.51

13. Gao, J., Xiao, Y., Liu, J., Liang, W., & Chen, C. L. P. (2012). A survey of communication/networking in Smart Grids. *Future Generation Computer Systems*, *28*, 391–404. https://doi.org/10.1016/j.future.2011.04.014

14. Griggs, K. N., Ossipova, O., Kohlios, C. P., Baccarini, A. N., Howson, E. A., & Hayajneh, T. (2018). Healthcare Blockchain System Using Smart Contracts for Secure Automated Remote Patient Monitoring. *Journal of Medical Systems*, *42*(7), 1–7. https://doi.org/10.1007/s10916-018-0982-x

15. Guerrero-Ibáñez, J., Zeadally, S., & Contreras-Castillo, J. (2018). Sensor technologies for intelligent transportation systems. *Sensors (Switzerland)*, *18*(4), 1–24. https://doi.org/10.3390/s18041212

16. Huh, K. Y., Moon, S. J., Jeong, S. un, Kim, M. J., Yang, W., Jeong, M., Kim, M. G., & Lee, S. H. (2022). Evaluation of a blockchain-based dynamic consent platform (METORY) in a decentralized and multicenter clinical trial using virtual drugs. *Clinical and Translational Science*, *15*(5), 1257–1268. https://doi.org/10.1111/cts.13246

17. Jan, B., Farman, H., Khan, M., Talha, M., & Din, I. U. (2019). Designing a Smart Transportation System: An Internet of Things and Big Data Approach. *IEEE Wireless Communications*, *26*(4), 73–79. https://doi.org/10.1109/MWC.2019.1800512

18. Jezdović, I., Popović, S., Radenković, M., Labus, A., & Bogdanović, Z. (2021). A crowdsensing platform for real-time monitoring and analysis of noise pollution in smart cities. *Sustainable Computing: Informatics and Systems*, *31*. https://doi.org/10.1016/J.SUSCOM.2021.100588

19. Kamel Boulos, M. N., Wilson, J. T., & Clauson, K. A. (2018). Geospatial blockchain: Promises, challenges, and scenarios in health and healthcare. *International Journal of Health Geographics*, *17*(1), 1–10. https://doi.org/10.1186/s12942-018-0144-x

20. Labaran, M. J., & Hamma-Adama, M. (2021). The Nigerian Pharmaceutical Supply Chain: Blockchain Adoption, Counterfeit Drugs and Successful Deployment of COVID-19 Vaccine in Nigeria. *Journal of Scientific Research and Reports*, *27*(2), 20–36. https://doi.org/10.9734/jsrr/2021/v27i230356

21. Labus, A., Radenković, M., Bogdanović, Z., Bjelica, D., & Despotović, V. (2022). A blockchain system for healthcare. *5th INTERNATIONAL SCIENTIFIC CONFERENCE ON DIGITAL ECONOMY DIEC 2022*, 23–32.

22. Laufs, J., Borrion, H., & Bradford, B. (2020). Security and the smart city: A systematic review. *Sustainable Cities and Society*, *55*, 102023. https://doi.org/10.1016/J.SCS.2020.102023

23. Mackey, T. K., Shah, N., Miyachi, K., Short, J., & Clauson, K. (2019). A Framework Proposal for Blockchain-Based Scientific Publishing Using Shared Governance. *Frontiers in Blockchain*, *2*, 486144. https://doi.org/10.3389/FBLOC.2019.00019

24. Mars, R., Youssouf, J., Cheikhrouhou, S., & Turki, M. (2021). Towards a Blockchain-based approach to fight drugs counterfeit. *CEUR Workshop Proceedings*, *3067*, 197–208.

25. Mohd Shari, N. F., & Malip, A. (2022). State-of-the-art solutions of blockchain technology for data dissemination in smart cities: A comprehensive review. *Computer Communications*, *189*, 120–147. https://doi.org/10.1016/J.COMCOM.2022.03.013

26. Mollah, M. B., Zhao, J., Niyato, D., Guan, Y. L., Yuen, C., Sun, S., Lam, K. Y., & Koh, L. H. (2021). Blockchain for the Internet of Vehicles towards Intelligent Transportation Systems: A Survey. *IEEE Internet of Things Journal*, *8*(6), 4157–4185. https://doi.org/10.1109/JIOT.2020.3028368

27. Mora, H., Mendoza-Tello, J. C., Varela-Guzmán, E. G., & Szymanski, J. (2021). Blockchain technologies to address smart city and society challenges. *Computers in Human Behavior*, *122*(April). https://doi.org/10.1016/j.chb.2021.106854

28. Nam, T., & Pardo, T. A. (2011). Conceptualizing smart city with dimensions of technology, people, and institutions. *ACM International Conference Proceeding Series*, 282–291. https://doi.org/10.1145/2037556.2037602

29. Parenti, C., Noori, N., & Janssen, M. (2022). A Smart Governance diffusion model for blockchain as an anti-corruption tool in Smart Cities. *Journal of Smart Cities and Society*, *1*(1), 71–92. https://doi.org/10.3233/scs-210122

30. Ren, Q., Man, K. L., Li, M., & Gao, B. (2019). Using Blockchain to Enhance and Optimize IoT-based Intelligent Traffic System. *2019 International Conference on Platform Technology and Service, PlatCon 2019 - Proceedings*, 1–4. https://doi.org/10.1109/PlatCon.2019.8669412

31. Sathya, A. R., Panda, S. K., & Hanumanthakari, S. (2021). Enabling smart education system using blockchain technology. *Intelligent Systems Reference Library*, *203*(May), 169–177. https://doi.org/10.1007/978-3-030-69395-4_10

32. Sharma, A., Awasthi, Y., & Kumar, S. (2020). The Role of Blockchain, AI and IoT for Smart Road Traffic Management System. *Proceedings - 2020 IEEE India Council International Subsections Conference, INDISCON 2020*, 289–296. https://doi.org/10.1109/INDISCON50162.2020.00065

33. Siddiquee, S. M. S., Khan, M. M. H., Al-Ismail, F. S., Ullah, A., Alam, M. S., & Ahmed, H. (2022). Blockchain applications in smart sustainable city context—A systematic mapping study. *Energy Reports*, *8*, 162–169. https://doi.org/10.1016/j.egyr.2022.10.102

34. Simic, K., Despotovic-Zrakic, M., Bojovic, Z., Jovanic, B., & Knezevic, D. (2016). A platform for a smart learning environment. *Facta Universitatis - Series: Electronics and Energetics*, *29*(3), 407–417. https://doi.org/10.2298/fuee1603407s

35. Sladić, G., Milosavljević, B., Nikolić, S., Sladić, D., & Radulović, A. (2021). A blockchain solution for securing real property transactions: A case study for serbia. *ISPRS International Journal of Geo-Information*, *10*(1). https://doi.org/10.3390/ijgi10010035

36. Sun, J., Yan, J., & Zhang, K. Z. K. (2016). Blockchain-based sharing services: What blockchain technology can contribute to smart cities. *Financial Innovation*, *2*(1). https://doi.org/10.1186/s40854-016-0040-y

37. Sutikno, T., & Aisyahrani, A. I. B. (2023). Non-fungible tokens, decentralized autonomous organizations, Web 3.0, and the metaverse in education: From university to metaversity. *Journal of Education and Learning (EduLearn)*, *17*(1), 1–15. https://doi.org/10.11591/edulearn.v17i1.20657

38. Tabane, E., Ngwira, S. M., & Zuva, T. (2017). Survey of smart city initiatives towards urbanization. *Proceedings - 2016 3rd International Conference on Advances in Computing, Communication and Engineering, ICACCE 2016*, 437–440. https://doi.org/10.1109/ICACCE.2016.8073788

39. Tahir, M., Ismat, N., Rizvi, H. H., Zaffar, A., Nabeel Mustafa, S. M., & Khan, A. A. (2022). Implementation of a smart energy meter using blockchain and Internet of Things: A step toward energy conservation. *Frontiers in Energy Research*, *10*(December), 1–14. https://doi.org/10.3389/fenrg.2022.1029113

40. Tian, S., Yang, W., Grange, J. M. Le, Wang, P., Huang, W., & Ye, Z. (2019). Smart healthcare: making medical care more intelligent. *Journal of Global Health*, *3*(3), 62–65. https://doi.org/10.1016/j.glohj.2019.07.001

41. Ul Hassan, N., Yuen, C., & Niyato, D. (2019). Blockchain Technologies for Smart Energy Systems: Fundamentals, Challenges, and Solutions. *IEEE Industrial Electronics Magazine*, *13*(4), 106–118. https://doi.org/10.1109/MIE.2019.2940335

42. Ullah, Z., Naeem, M., Coronato, A., Ribino, P., & De Pietro, G. (2023). Blockchain Applications in Sustainable Smart Cities. *Sustainable Cities and Society*, *97*(September 2022), 104697. https://doi.org/10.1016/j.scs.2023.104697

43. United Nations. (2018a). *The 2018 Revision of World Urbanization Prospects*.

44. United Nations, D. of E. and S. A. (2018b). *68% of the world population projected to live in urban areas by 2050*.

45. WePower. (2023). *Blockdata | WePower*.

46. Zheng, Z., Xie, S., Dai, H. N., Chen, W., Chen, X., Weng, J., & Imran, M. (2020). An overview on smart contracts: Challenges, advances and platforms. *Future Generation Computer Systems*, *105*, 475–491. https://doi.org/10.1016/j.future.2019.12.019

Antun Biloš, PhD[1]
Bruno Budimir, MSc[2]

Keynote paper

HOW MUCH DO WE TRUST IN AI? EXPLORING THE IMPACT OF ARTIFICIAL INTELLIGENCE ON USER TRUST LEVELS

Abstract

Artificial intelligence is a broad branch of computer science that deals with the development and study of smart machines and programs, which are increasingly used in private and business environments. Considering that artificial intelligence is in a relatively early stage of wide-range application, it is necessary to investigate the readiness of users to accept it. Given that no more extensive research has been conducted in Croatia on the level of readiness to accept artificial intelligence technologies, nor on the potential implications of its increase, this research provides answers to related questions to a certain extent. Internet users were chosen as the target audience because they are considered to be potential users or users of artificial intelligence. The survey was conducted on 1036 respondents. The research compares respondents' trust in humans, artificial intelligence and humans with the assistance of artificial intelligence, depending on whether they perform on low or high level stakes and risks in different areas of personal and professional life. The assumptions predicting greater trust in humans compared to artificial intelligence were confirmed, but also the assumption that trust in humans with the assistance of artificial intelligence will be greater than in humans alone. The results show that the respondents are aware that artificial intelligence is entering their private and business lives, but they are still very cautious and ready to trust it more significantly only when artificial intelligence has a role of supporting tool.

***Key words**: Artificial Intelligence, Trust, Willingness to Accept Technology, AI.*

1 Full professor, Josip Juraj Strossmayer University of Osijek, Croatia, antun.bilos@efos.hr
2 Teaching and research assistant, Josip Juraj Strossmayer University of Osijek, Croatia, budimir@efos.hr

1. Introduction

The father of artificial intelligence, John McCarthy (2004), defines artificial intelligence as a scientific discipline that deals with the creation of machines and programs whose behavior can be interpreted as intelligent. Weber and Schutte (2019) state that artificial intelligence was actually born from thinking about how and to what extent machines can replace people in performing certaing actions. Artificial intelligence is the field of numerous scientific and professional studies, and in practice it is applied using computers to perfrom tasks that are usually achieved using human intelligence, and such tasks may include understading images or sounds, recognizing the enivornment and making independent decisions (Nath et al., 2020). Artificial intelligence – based systems can be software-based and operate in the virtual world, such as voice assistants, facial or voice recognition software, but they can also be hardware-based, such as robots, autonomous cars, drones, and the Internet of Things (European Commission, 2018).

The fact that artificial intelligence can both learn and make decisions is of particular importance, as it will be able to replace humans in many areas that were previously the exclusive domain of humans. Technologies based on artificial intelligence are already being widely used to facilitate and improve people's daily lives, both at home and at work. As artificial intelligence advances, it is changing the way people live and perform many tasks in almost every field. Certain difficult, boring, or dangerous tasks have already been or will soon be replaced by artificial intelligence, and people who do not want to do these tasks will no longer have to (Rouhiainen, 2018).

Despite all the benefits that technological progress brings, there is always a flip side to the coin, namely the fact that artificial intelligence can also cause harm, whether tangible (e.g., human health and life or property damage) or intangible (loss of privacy, restriction of fundamental human freedoms, or discrimination), and it is precisely for this reason that it is necessary to define legal regulations to reduce these risks. Some of the fundamental values at risk from the negative influence of AI are the right to freedom of expression and assembly, the right to non-discrimination on the grounds of gender, race, religion and ethnic origin, the protection of personal data and privacy, and the right to a fair trial (European Commission, 2020). Moral dilemmas related to AI are visible in most AI application areas, and the high-risk areas are particularly sensitive. One of the high-risk areas is the application of artificial intelligence in the justice system, and there is scientific evidence that certain artificial intelligence algorithms based primarily on machine learning exhibit gender and racial biases. Trusted relationships are those between trusted parties, whereas artificial intelligence is a systematic set of techniques that enable machines to perform specific data processing tasks, and AI should not be trusted (Ryan, 2020). Trust in artificial intelligence should go hand in hand with trust in the companies that manage the production of such technologies. To build that trust, however, companies need to be transparent about how they use customer data and the decisions they make when developing new products. It is

critical that the person providing the data knows how their data will be handled, where it will be stored, and how it will be used when data is needed to help AI make decisions. It is good news that not only governments but also companies are providing solutions to increase transparency in the industry (Rossi, 2019). Nevertheless, Schmidt et al. (2020) note that higher levels of transparency do not necessarily mean higher levels of trust in AI. Building trust is a dynamic process that involves moving from initial trust to continuous trust growth. Continuous trust will depend on how well AI performs its tasks and fulfills its purpose. Continuous trust growth will be facilitated by AI applications that are easy to use, reliable, and can collaborate and interact well with humans. These AI applications should also be social, foster human engagement, provide good security and privacy protection, and provide an explanation of why decisions or actions were made. Uncertainty about how AI will replace and displace human workers, as well as its potential to endanger humanity, fuels distrust and hinders the growth of trust over time. Like any other trust, trust in AI takes time to build (Siau & Wang, 2018).

2. Literature review

Frank's (2020) dissertation consists of three papers, of which paper 3 examines the adoption of artificial intelligence as a function of the scope of the decision. In the conceptual design of the study, Frank (2020) highlights the differences between decisions where the stakes are high and those where the stakes are low, and presents the scenario where the activity can be performed by a human, an artificial intelligence, or a human using an artificial intelligence. The conceptual research model presented (Frank, 2020) served as the model for this paper's research model because it compares the three options (human / artificial intelligence / human + artificial intelligence) and observes the differences in trust when high stakes options and low stakes options are offered. Frank (2020) examines respondents' willingness to trust humans, artificial intelligence, or humans using artificial intelligence and asks respondents to indicate the perceived level of risk as a function of the entity performing the action and compares them in three application domains – healthcare, justice, and retail. Frank (2020) states that when it comes to trust, respondents are most willing to trust a human in all three sectors, regardless of whether the stakes are high or not, but in the judiciary and retail the differences are not significant, they are only visible in heathcare. Wang et al. (2016) point out that the perception of trust in humans is irrational because humans outperform humans using artificial intelligence. Lockey et al. (2021) also found that humans trust human advice more than AI advice, but they trust most when there is an option where AI gives advice but humans have final authority. The human-in-the-loop approach, where AI supports the human provider's decision, is the option most users prefer. Nevertheless, Frank (2020) notes that confidence in AI adoption depends not only on the superiority of AI, i.e., its competence, but also on consumers' perceptions of what is at stake in a decision involving the use of AI. In the discussion, Frank (2020) notes that perceived trust in humans

or competent experts for a given activity area is greater than trust in artificial intelligence, but he notes that in his research, trust in humans with the support of artificial intelligence is not greater than trust in humans alone, especially for activities with higher stakes and risks, which he considers irrational given that the aforementioned combination has been shown to be the most effective. In the past, reliability was considered the most important factor in the adoption of new technologies. However, according to Glickson & Williams Woolley (2020), the relationship between reliability and trust in AI could be complex, as low reliability may not always be associated with lack of use or low trust. Their study of embedded AI found that AI was a decision-making tool that was disregarded due to low reliability, indicating that reliability is important. On the other hand, in robotic AI, high machine intelligence and immediacy behaviour moderated the effect of reliability on trust, with immediacy behaviour increasing it despite the low reliability that was evident in erroneous actions. Frank (2020) also suggests conducting research in countries that are technologically weaker or more developed than the United States, which is one of the main elements affecting trust in AI, along with timing, cultural differences, and popular media events related to the aforementioned topic.

Another important concept for the design of the research instrument within this paper is the document 'Trust and excellence for artificial intelligence' publiced by European Commussion (n.d.) which lists the risk levels in the implementation of artificial intelligence and explains exactly what a high level of risk would be and what is application is:

- In infrastructure that can threaten the health and safety of citizens (e.g. traffic and transportation), in vocational education that can direct a person's further life (e.g. scoring an exam or cocluding an assessment)
- In the safety parts of the product (e.g. artificial intelligence in robot-assisted surgical operations)
- In recruitment and staffing (e.g. an algorithm for classifying resumes during recruitment)
- In basic private and public services (e.g. credit assessment or financial management)
- In the enforcement of laws that may conflict with fundamental human rights (e.g. judicial process, evaluation of the reliability of evidence)
- In the management of migration, asylum and borders (e.g. checking the authenticity of travel documents)
- In the judiciary and democratic processes (e.g. application of the law to a specific set of facts)

According to the examples given by the European Commission (n.d.), it can be interpreted how the application of high stakes and risks is divided into applications in education (judgement conclusion), medicine / healthcare (robotic-assisted surgical operations), human resources management (algorithm for sorting resumes), finance (credit rating / financial management), justice and

law enforcement (court processes / evaluation of the reliability of evidence / passport verification).

Based on the above and the work of Mazurek (2019) and Castelo (2019), a set of questions was created that divided the activity areas into private daily life, medicine and healthcare, education, finance, traffic and transportation, marketing, and justice. Some of the particles and their associated answers were deliberately adapted during the research to the specifics of the population studied and the planned research objectives, in order to minimize the risk of misunderstanding the question. For example, in the financial sector, a low stakes activity is an investment of HRK 2,000.00 (EUR 265.44), which is approximately one third of the median net salary in Croatia, and a high stakes activity is an investment of HRK 20,000 (EUR 2,654.45), which is approximately three times the median net salary in Croatia.

In its study, Capgemini (2018) presents respondents with a dilemma when it comes to the use of artificial intelligence in providing purchase advice for products that are high-consideration and low-consideration products and services. For the two aforementioned groups, respondents can choose whether they prefer the help of humans, artificial intelligence, or the combined interaction of human and artificial intelligence. The results show that for products and services that require a higher level of consideration (e.g., buying a car or an engagement ring), respondents are most likely to prefer an interaction that combines human and artificial intelligence recommendations (47%), but a slightly lower percentage of respondents (45%) prefer human interaction, and only 8% of respondents prefer artificial intelligence interaction only. In contrast, for products and services that require a lower level of consideration before purchase, 54% of respondents said they prefer an interaction that combines the recommendation of human and artificial intelligence, significantly fewer respondents (30%) prefer interaction exclusively with a human, and 17% of them opted for artificial intelligence, which is more than double the rate for products and services that require a high-consideration products and services. Capgemini (2018) also finds that respondents are more willing to trust a human for activities where the stakes are high than for activities where the stakes are low. Kaplan et al. (2023) found that shared risk, i.e., a situation in which there is collaboration between the human and AI system and both are working toward the same goals, is the only significant predictor of trust in artificial intelligence.

According to Araujo et al. (2020), assessments of the societal impact of automated decision making reveal mixed views about its fairness, usefulness, and concerns about risks. As a result, respondents often rated automated decision making as good as or better than human experts when evaluating the potential fairness, usefulness, and risks of high-impact decisions made automatically by AI. Gillath et al. (2020) suggest that safety improvement can serve as an intervention to increase trust in AI by starting from trust models among humans. As their study suggests, humans are similar in their treatment of one another and the way they interact with or think about artificial intelligence.

To assess trust, risks must first be evaluated. In deciding whether or not an AI requires trust, the user's susceptibility to the AI's actions must be verified by confirming that users believe that some of the AI's actions are unfavorable to them, or that users believe that both the favorable and unfavorable outcomes are realistic (Jacovi et al., 2021). The rational cognitions, affective thoughts and attitudes, and behavioral interactions that are relevant to users' trust in AI can be distinguished based on their orientation. In addition, the concept of users' trust in AI should consider their specific applications (Yang & Wibowo, 2022). Considering the importance of showing different application areas of AI and different levels of risks and stakes, Table 1 was created.

Table 1. The seven application domains and activities with high and low stakes and risks

AREAS OF ACTIVITIES	ACTIVITIES WITH LOW STAKES AND RISKS	ACTIVITIES WITH HIGH STAKES AND RISKS
Private life	Movie recommendation	Partner recommendation for a romantic relationship
Medicine	Simple laser operation of a mole on the hand	Cardiac surgery
Education	Predicting success for students	Decision-making for a student to repeat a grade due to insufficient academic performance
Finance	Purchasing stocks worth 2,000 HRK	Purchasing stocks worth 20,000 HRK
Transportation	Driving a tractor in the field	Operating a commercial passenger aircraft
Marketing	Company slogan recommendation	Managing a marketing campaign
Justice	Court judgment for a person who hasn't paid parking fines for months	Court judgment for a person accused of rape

Source: Modified and adapted from Castelo (2019), Mazurek (2019), Frank (2020)

3. Methodology and research results

The aim of this research is to explore the willingness of Internet users to accept artificial intelligence (AI) technologies. The research focus is on the perceived level of trust in three possible options: 1) in artificial intelligence (AI),

2) in humans (H), and 3) in humans assisted by artificial intelligence (HAI). The research concept predominantly builds upon prior studies (Frank, 2020; Mazurek, 2019, and Castelo, 2019). The level of trust expressed is further differentiated based on whether the activities involve significant stakes and risks or whether the stakes and risks are somewhat lower. This differentiation is also examined across various domains such as medicine, education, human resources, finance, transportation, marketing, justice, as well as activities related to private life. Consequently, it is essential to observe the level of trust in humans concerning these same activities and how this level of trust compares to the trust in humans assisted by artificial intelligence.

According to Eurostat (2021), the EU countries with the highest average percentage of Internet users are Iceland, Norway, Denmark, Ireland, Luxembourg, Finland, and Sweden, where more than 97% of the adult population uses the Internet. Interestingly, most of these countries are in Northern Europe. Among the European Union member states, Croatia ranks among the lowest with 82% Internet users. Only in Bulgaria (78%) and Greece (79%) is the percentage of the adult population using the Internet even lower. However, countries with similar Internet usage rates to Croatia include Serbia with 84%, Montenegro with 83%, Albania with 80% and Bosnia and Herzegovina with 77% of the adult population using the Internet.

Given that the focus of interest is on Internet users, data for this study were collected exclusively through an online survey using the Computed Assisted Web Interviewing (CAWI) data collection technique. Based on testing, the estimated completion time for this survey was between 9 and 12 minutes. A highly structured research instrument was used for the survey, consisting of 55 questions, with a maximum of 49 questions for each respondent to answer, taking into account the branching structure while completing the survey. For the purposes of this study, a 7-point Likert scale was predominantly used.

The total number of participants who accessed the survey was 1,238, of which 334 did not complete the questionnaire. Some participants abandoned the survey during the process, leaving 904 respondents who answered the final question. The data analysis also included a subset of participants who partially completed the questionnaire, specifically those who answered at least 28 questions or completed by the end of the third set of questions. The total number of these participants was 1,036. Participants were recruited using the snowball method, a sampling technique based on purposively selecting a small group of individuals who then expand the sample by sharing the survey with their friends, family, students, and colleagues. Data collection took place from April 27, 2022 to June 24, 2022, with more than 90% of the data collected within the first month of the initial survey distribution. A total of 904 participants completed the survey in full, while 132 participants partially completed the survey, the results will be analyzed in the following sections of the study.

Both descriptive and parametric statistical techniques were used in the data analysis. The parametric tests used included independent samples t-test, paired samples t-test, one-way analysis of variance (ANOVA), repeated meas-

ures analysis of variance (ANOVA Repeated Measures), and Pearson's correlation coefficient. The statistical software tools used for data analysis were IBM SPSS Statistics 25, JASP version 0.16.2, and Microsoft Excel, which were utilized for data processing and graph plotting.

3. 1. Sample description

The participants in this study are from the Republic of Croatia representing a segment of Internet users. As shown in Table 2, females are slightly more represented among the total number of respondents (62.1%) compared to males, who constitute 37.3% of the participants. The majority of respondents have secondary vocational education (38.1%), followed by those with high levels of education, who make up 27.5% in total. In addition, 20.1% of the respondents have completed higher professional education or undergraduate studies, while 5.3% have completed postgraduate studies. Only 1.5% of the respondents have completed primary education. It is interesting to note that 73.3% of the respondents earn up to HRK 8,500.00 per month. Furthermore, in Table 2 it is noteworthy that the majority of highly educated respondents have graduated in social sciences (59.7%), while the smallest proportion of highly educated participants have completed studies in natural sciences comprising only 3% of the sample).

Table 2. Respondents demographic characteristics.

Demographic characteristics		Boomers	Gen X	Gen Y	Gen Z	All
		N = 53	N = 216	N = 360	N= 405	N=1036
		(%)	(%)	(%)	(%)	(%)
	Respondents	5,1%	20,8%	34,7%	39,1%	100%
Sex	Male	34,0	31,0	45,8	34,2	37,3
	Female	66,0	69,0	54,2	65,8	62,1
Place of residence	Rural environment	22,6	29,6	17,5	33,3	26,5
	Small town	15,1	14,4	13,1	17,0	15,0
	Medium-sized town	24,5	26,9	20,8	22,2	22,8
	Large town	37,7	29,2	48,6	27,4	35,7

Education level	Primary school	7,5	3,2	0,3	0,7	1,5
	Secondary school	41,5	48,6	23,1	45,4	38,1
	Higher vocational / Professional study	13,2	10,2	6,4	6,4	7,5
	Undergraduate study	1,9	2,3	13,9	37,5	20,1
	Graduate study	30,2	27,3	47,5	9,4	27,5
	Postgraduate study	5,7	8,3	8,9	0,5	5,3
Monthly income	Up to 4.000 HRK	25,0	13,5	10,2	47,2	24,4
	4.001 – 6.000 HRK	25,0	22,4	21,7	24,3	23,0
	6.001 – 8.500 HRK	19,2	28,1	35,1	15,3	25,9
	8.501 – 11.000 HRK	21,2	25,0	17,4	6,9	15,8
	11.001 – 14.000 HRK	7,7	4,2	9,0	3,1	5,9
	More than 14.000 HRK	1,9	6,8	6,5	3,1	5,2
Employment status	Employed (full-time)	60,4	78,2	83,3	28,2	59,1
	Seasonal / part-time	0,0	3,2	3,6	4,0	3,5
	Student job	0,0	1,4	5,0	33,3	15,1
	Unemployed	3,8	12,0	8,1	34,6	19,1
	Retired	35,8	5,1	0,0	0,0	3,3
Field of education	Technical sciences	22,2	14,4	19,6	14,2	17,0
	Social sciences	59,6	60,6	58,0	61,5	59,7
	Humanities	7,4	5,8	10,5	10,6	9,6
	Natural sciences	3,7	2,9	3,3	2,8	3,0
	Biomedicine	3,7	10,6	5,8	5,0	6,2
	Biotechnical sciences	3,7	5,8	2,9	6,0	4,5

3. 2. Hypothesis testing

During hypothesis testing, seven domains of activities within private and professional life were compared, specifically examining the perceived level of trust in artificial intelligence, humans, and humans assisted by artificial intelligence for activities with high stakes and risks, as well as for activities with low stakes and risks across all seven application domains.

H1: The perceived trust in humans assisted by artificial intelligence (HAI) is higher than the perceived trust in humans (H) or in artificial intelligence (AI).

During the testing of Hypothesis 1 (H1), each application area is initially tested separately, and subsequently through a composite variable. As evident from Table 3, the assumption that humans assisted by artificial intelligence are preferred has been confirmed in 12 out of 14 possible activities. Particularly interestingly, this assumption holds true for all activities with low stakes and risks. However, there is one activity where the assumption is not confirmed, and that is "partner recommendation for a romantic relationship" (which is a private life item related to high level of stakes and risk). In this case, respondents expressed the least trust in humans ($\bar{x}_{HS1}$ = 3.26), followed by humans assisted by artificial intelligence ($\bar{x}_{HS3}$ = 4.40) and finally artificial intelligence ($\bar{x}_{HS2}$ = 4.52).

Table 3. Comparison of mean values for perceived levels of trust in humans, artificial intelligence, and humans assisted by artificial intelligence

Level of stakes and risks	Artificial Intelligence	Human	Human + Artificial intelligence	H+AI is significantly the highest
Private life				
Low	4.61	5.20	5.37	✓
High	3.26	4.52	4.40	
Medicine				
Low	4.55	5.14	5.46	✓
High	4.21	5.20	5.48	✓
Education				
Low	4.39	4.35	5.11	✓
High	4.16	4.90	5.05	✓
Finance				
Low	4.28	3.79	4.74	✓
High	4.12	4.02	4.70	✓
Transportation				
Low	4.59	5.44	5.54	
High	4.33	5.32	5.59	✓

Marketing				
Low	4.48	5.26	5.43	✓
High	4.52	5.08	5.44	✓
Justice				
Low	4.56	4.85	5.11	✓
High	4.29	4.91	5.06	✓

Table 4 shows the results of the ANOVA Repeated measures test for composite variables, where all 14 observed activities are combined. The average value of the composite variable for humans with the assistance of artificial intelligence is the highest ($x^- = 5.16$), then for humans ($x^- = 4.85$), and the lowest for artificial intelligence ($x^- = 4.31$). For the above composite variables, an analysis of the variance of repeated measurements was carried out with the use of Bonferroni Post-Hoc test, which showed that there are indeed statistically significant differences ($F = 353{,}099$, $df1 = 1{,}771$, $df2 = 1682{,}371$, $p < 0{,}01$) in trust in humans, artificial intelligence and humans with the assistance of artificial intelligence when performing the same activity.

Table 4. ANOVA Repeated measures for composite variables

Composite variables	AI / H (J)	Mean Difference (I-J)	Std. Error	p value
Human + Artificial intelligence (H+AI)	H	,313*	,031	,000
	AI	,854*	,028	,000

Based on the results of compared composite variables, and additionally the analyzed data that observes all areas of application individually, regardless of the level of stakes and risks, it can be concluded that the first hypothesis is accepted, i.e. the assumption that trust in humans assisted by artificial intelligence is the highest in comparison to trust in humans or in artificial intelligence.

H2: The perceived trust in artificial intelligence is higher for activities with low stakes and risks (AI_{low}) compared to activities with high stakes and risks (AI_{high}).

When analyzing the data related to testing H2, it is essential to emphasize that respondents expressed their perceived level of trust in artificial intelligence on a Likert scale ranging from 1 to 7. This was done based on whether the activities involved high stakes and risks or low stakes and risks. To compare the mentioned variables, a dependent samples t-test was employed.

The following presents the testing of the perception of trust in artificial intelligence across various analyzed activity domains, while the final decision on the auxiliary hypothesis will be made based on composite variables. In conducting the dependent samples t-test for six out of seven activity domains, a statistically significant difference in the perception of trust in artificial intelligence was confirmed based on whether it is applied in activities with high stakes and risks or in activities with low stakes and risks. As evident from Table 5, the differences in perceived trust in the application of artificial intelligence, depending on the level of stakes and risks, are noticeable in the use of artificial intelligence in private life ($t= 21.370$, $df = 946$, $p < 0.001$), medicine ($t= 5.811$, $df = 943$, $p < 0.001$), education ($t= 4.130$, $df = 940$, $p < 0.001$), finance ($t= 3.376$, $df = 937$, $p = 0.001$), transportation ($t= 4.877$, $df = 934$, $p < 0.001$), and justice ($t= 4.570$, $df= 939$, $p < 0.001$). However, this difference was not observed regarding the application in marketing ($t = -0.694$, $df = 938$, $p = 0.488$).

Taking into consideration that the research instrument presented this set of questions to respondents, enabling them to express their perceived trust in artificial intelligence through a Likert scale ranging from 1 to 7, where 1 signifies "not trusting at all" and 7 denotes "completely trusting", the mean value being 4.0, it is evident that only one element has a value below 4.0. Specifically, this element pertains to the application of artificial intelligence in private life during activities with high stakes and risks, which, in this particular research, refers to partner recommendation for a romantic relationship. On the other hand, the highest value is also related to the application of artificial intelligence in private life, but, in this case, for activities with low stakes and risks, which, in this context, would correspond to movie recommendations.

Furthermore, it is interesting to observe that for marketing (Element 6), the only element where no statistically significant differences were found, the perceived level of trust is higher for activities with high stakes and risks than for activities with low stakes and risks ($\bar{x}_{LS}6 = 4.48 > \bar{x}_{HS}6 = 4.52$). This is the only instance in which the perceived level of trust in artificial intelligence for activities with high stakes and risks is higher than for activities with low stakes and risks. However, in the subsequent sections of the study, it is evident that this perceived trust in artificial intelligence differs from the perceived level of trust in humans or in humans assisted by artificial intelligence. Moreover, it is worth noting that for the perceived level of trust in artificial intelligence, none of the elements have an average value higher than 5.0 on the scale ranging from 1 to 7.

Table 5. Independent samples t-tests for the perceived level of trust in artificial intelligence across different application domains

Level of stakes and risks	Mean (x^-)	Standard deviation	Standard error of the mean	T-test
Private life				
Low	4,61	1,690	0,055	t = 21,370 df = 946 p < 0,01
High	3,26	1,570	0,051	
Medicine				
Low	4,55	1,779	0,058	t = 5,811 df = 943 p < 0,01
High	4,21	1,643	0,053	
Education				
Low	4,39	1,586	0,052	t = 4,130 df = 940 p < 0,01
High	4,16	1,634	0,053	
Finance				
Low	4,28	1,683	0,055	t = 3,376 df = 937 p < 0,01
High	4,12	1,610	0,053	
Transportation				
Low	4,59	1,737	0,057	t = 4,877 df = 934 p < 0,01
High	4,33	1,693	0,055	
Marketing				
Low	4,48	1,567	0,051	t = -0,694 df = 938 p > 0,05
High	4,52	1,512	0,049	
Justice				
Low	4,56	1,760	0,057	t = 4,570 df = 939 p < 0,01
High	4,29	1,758	0,057	

For hypothesis testing, composite variables were formed by averaging the responses for all tested activity domains based on the level of stakes and risks, separately for humans, artificial intelligence, and humans assisted by artificial intelligence. The composite variable encompassing all 7 activities with low stakes and risks performed by artificial intelligence has an average value of $x^- = 4.50$, while the composite variable for all 7 activities with high stakes and risks performed by artificial intelligence has an average value of $x^- = 4.15$. To

compare the mentioned composite variables, a dependent samples t-test was employed, indicating statistically significant differences ($t = 15.855$, $df = 949$, $p < 0.001$).

Based on the analysis of the composite variables, it can be concluded that Hypothesis 2 is accepted, confirming the assumption that perceived trust in artificial intelligence will be higher for activities with low stakes and risks compared to activities with high stakes and risks. This hypothesis was further elaborated based on the presented results of data analysis for individual activity domains, where the assumption was confirmed in 6 out of 7 activity domains.

H3: The perceived trust in humans assisted by artificial intelligence is higher for activities with low stakes and risks (HAI_{low}) compared to activities with high stakes and risks (HAI_{high}).

This hypothesis focuses on the perceived level of trust in humans assisted by artificial intelligence, depending on whether the activity involves high or low stakes and risks. First, the tests are presented for individual activity domains, and then a final decision is made based on the composite variables. It is particularly interesting to observe that the assumption of significant differences in trust between activities with low stakes and risks compared to activities with high stakes and risks is confirmed only for activities related to private life ($t = 17.741$, $df = 938$, $p < 0.001$). However, for other domains, no statistically significant differences were observed. Specifically, for activities related to medicine ($t = -0.482$, $df = 938$, $p = 0.630$), education ($t = 1.222$, $df = 939$, $p = 0.222$), finance ($t = 0.767$, $df = 937$, $p = 0.443$), transportation ($t = -1.171$, $df = 940$, $p = 0.242$), marketing ($t = -0.189$, $df = 935$, $p = 0.850$), and justice ($t = 1.117$, $df = 939$, $p = 0.264$), no statistically significant differences were found.

Table 6. Independent samples t-tests for the perceived level of trust in humans assisted by artificial intelligence across different application domains

Level of stakes and risks	Mean ($\bar{x}$)	Standard deviation	Standard error of the mean	T-test
Private life				
Low	5,37	1,539	0,050	t = 17,741 df = 938 p < 0,01
High	4,40	1,700	0,055	
Medicine				
Low	5,46	1,635	0,053	t = -0,482 df = 941 p > 0,05
High	5,48	1,567	0,051	

Level of stakes and risks	Mean ($\bar{x}$)	Standard deviation	Standard error of the mean	T-test
Education				
Low	5,11	1,532	0,050	t = 1,222 df = 939 p > 0,05
High	5,05	1,546	0,050	
Finance				
Low	4,74	1,672	0,055	t = 0,767 df = 937 p > 0,05
High	4,70	1,635	0,053	
Transportation				
Low	5,54	1,585	0,052	t = -1,171 df = 940 p > 0,05
High	5,59	1,527	0,050	
Marketing				
Low	5,43	1,496	0,049	t = -0,189 df = 935 p > 0,05
High	5,44	1,507	0,049	
Justice				
Low	5,11	1,586	0,052	t = 1,117 df = 939 p > 0,05
High	5,06	1,618	0,053	

As with the previous hypotheses, a comparison of composite variables was also performed here, where the average value of the composite variable for humans assisted by artificial intelligence in activities with low stakes and risks was $\bar{x} = 5.24$, and for activities with high stakes and risks, it was $\bar{x} = 5.09$. The results of the dependent samples t-test confirmed that there are statistically significant differences between the observed variables ($t = 7.872$; $df = 952$; $p < 0.001$).

However, it is necessary to comment that in 6 out of 7 activity domains, statistically significant differences were not found, as evident from Table 6, with only one domain showing such a difference. The domain where a statistically significant difference was found is private life, specifically in the application of artificial intelligence for activities with low stakes and risks, having an average value of $\bar{x} = 5.37$, while for activities with high stakes and risks, it was $\bar{x} = 4.40$. Considering that no other activity domain has a difference greater than 0.06 in average values for low and high levels of stakes and risks, it can be concluded that the significant difference in perception for activities with high stakes and risks compared to activities with low stakes and risks in the domain of private life has contributed to the dependent samples t-test showing a statistically significant difference in the composite variables.

Therefore, based on the compared composite variables, it can be concluded that Hypothesis 3 is accepted, meaning that there are statistically significant differences in trust in humans assisted by artificial intelligence depending on

different levels of stakes and risks. However, considering all other elements related to this assumption, Hypothesis 3 should be interpreted conditionally. If composite variables were created without the domain of private life, the results would show that the average value of perceived trust in humans assisted by artificial intelligence for activities with low stakes and risks is $\bar{x} = 5.22$, and for activities with high stakes and risks, it is $\bar{x} = 5.21$, which is almost identical. In this case, the dependent samples t-test did not find statistically significant differences between the observed composite variables ($t = 0.772$, $df = 952$, $p = 0.441$).

3. 3. Research limitations and guidelines for future research efforts

A significant limitation of this study arises from the fact that respondents come from only one country, which may affect the potential generalization of research results. Another limitation of this study is the highly comprehensive and not clearly defined concept of artificial intelligence, which leads to the conclusion that not all respondents perceive the term in the same way, despite the provided definition and explanation of artificial intelligence and algorithms. Even for those who understand the functioning of artificial intelligence, there is a high probability that they are not adequately informed about all branches of application for which they are asked, ranging from medicine, traffic, human resources to education, finance, marketing, and judiciary. Additionally, a limitation of this work is partly due to the fact that the obtained data are not fully comparable to the studies upon which the conceptual design of this research was based, as certain items have been modified compared to the original works. Different measurement scales were used, some variables were excluded to simplify the study, while others were expanded to cover a broader area of research interest for the authors of this paper.

Given the specificity of this topic and the rapid pace of technological advancements related to artificial intelligence discussed in this study, conducting similar research periodically would be beneficial to track the progress in the acceptance of artificial intelligence and the understanding of this technology. Furthermore, it would be valuable to replicate the research in other countries, especially in regions where the use of smart home technologies, virtual voice assistants, and other modern technologies is more widespread, and where people exhibit higher levels of trust in governmental institutions compared to the respondents in Croatia. Trust in the system is crucial for the results of this research, as if the respondents do not trust human authorities (such as judges or doctors), it becomes challenging to draw a parallel to their trust in artificial intelligence and to determine the current state of confidence in this technology.

Researchers in the field of AI and human-computer interaction should further investigate the factors that influence trust in AI, taking into account cultural and societal differences. Cross-cultural studies could shed light on how trust perceptions differ across regions and populations. Future research should explore the role of explainable AI models and user interfaces in enhancing trust.

Understanding how explaining AI decisions positively impacts user trust could lead to the development of more user-friendly and trustworthy AI systems.

4. Discussion and conclusion

A full comparison with the work of Mazurek (2019), Castelo (2019), and Frank (2020) is not fully possible due to modifications in the research instrument and the different measurement scale. Nevertheless, the results of this research show that trust in humans is greater than trust in algorithms and artificial intelligence. Castelo (2019) states that there is a gap between trust in humans and trust in artificial intelligence. It can be seen that for all elements in this work, trust in humans was higher than trust in artificial intelligence, but humans using artificial intelligence receive the most trust from respondents. According to Capgemini (2018), trust in humans using artificial intelligence is highest regardless of whether the activities are low or high stakes and risks, while Frank's (2020) data does not give such a clear answer, trust is highest for humans with assistance of artificial intelligence for certain activities,and for others for humans. The results of this work show that trust in humans with assistance is actually greater than trust in humans or artificial intelligence in 12 of 14 possible activities. However, no statistically significant differences were found in 6 out of 7 activity domains, but in one area the difference is so large that it alone dominates the t-test results. The explanation is probably that the differences in stakes and risks are to big. In particular, a low level of stakes and risks is about recommending a movie, and a high level is about recommending a partner for a romantic relationship. At this point, it is important to note that the average value of perceived trust in a person for recommending a relationship is convincingly the lowest of all activities. There are two possible reasons for this: First, people simple refuse to have so much intrusion into their intimate lives, whether they are humans or algorithms, and second, it can be assumed that a large number of respondents are in a relationship or married and find the idea of someone recommending a partner to them inappropriate or repulsive.

Our research findings provide valuable insights into the factors influencing AI adoption, particularly the role of trust in human-assisted AI technologies. This contributes to a deeper understanding of the psychological mechanisms driving user adoption of AI and sheds light on the importance of perceived trust in shaping attitudes toward AI adoption. For researchers, this opens new avenues to study the dynamic relationship between trust, human engagement, and AI technologies, and promotes a more comprehensive understanding of the adoption process. The relevance of our findings to practice lies in their potential to help companies and organizations effectively integrate AI technologies into their operations. By recognizing the importance of human-powered AI and its impact on trust, practitioners can develop AI systems that complement, rather than completely replace, human decision making. This approach fosters a sense of collaboration and empowerment among users, improving the overall user experience and adoption of AI solutions.

In summary, our research has practical implications for businesses, policymakers, and the wider community by highlighting the central role of trust in the adoption of human-powered AI. By recognizing the impact of trust on user attitudes toward AI technologies and promoting the responsible use of AI, we are paving the way for a more inclusive and ethical AI landscape in which humans and AI work together to improve societal well-being. In addition, our findings contribute to the evolving body of knowledge on the use of AI and encourage further research to explore the complex dynamics between trust, human engagement, and AI technologies.

Literature

1. Araujo, T., Helberger, N., Kruikemeier, S., & De Vreese, C. H. (2020). In AI we trust? Perceptions about automated decision-making by artificial intelligence. *AI & society*, 35, 611-623.
2. Capgemini (2018). *The Secret to Winning Costumers' Hearts With Artificial Intelligence – Add Human Intelligence*. Capgemini Digital Transformation Institute. Available at: https://www.capgemini.com/wp-content/uploads/2018/07/AI-in-CX-Report_Digital.pdf [Accessed on July 20th, 2023]
3. Castelo, N. (2019). *Blurring the line between human and machine: marketing artificial intelligence*. Columbia University in the City of New York. PhD thesis
4. European Commission (2018). Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions. Artificial Iintelligence for Europe. Eur-Lex. Avaiable at: https://eur-lex.europa.eu/legal-content/en/TXT/?uri=COM:2018:237:FIN [Accessed on: July 20th, 2023]
5. European Commission (2020). White Paper on Artificial Intelligence: a European Approach to excellence and trust. European Commission. Avaiable at: https://commission.europa.eu/publications/white-paper-artificial-intelligence-european-approach-excellence-and-trust_en [Accessed on: July 20th, 2023]
6. European Commission (n.d.). Excellence and trust in artificial intelligence. European Commission. Available at: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/excellence-and-trust-artificial-intelligence_en [Accessed on July 24th, 2023]
7. Eurostat (2021). *Digital economy and society*. Eurostat. Avaiable at: https://ec.europa.eu/eurostat/databrowser/view/ISOC_CI_IFP_IU__custom_3119405/default/table?lang=en [Accessed on July 18th, 2023]
8. Frank, D.A. (2020). *Consumer Adoption of Artificial Intelligence Technology: The Role of Ethics and Trust*. Aarhus BSS, Denmark, PhD thesis
9. Gillath, O., Ai, T., Branicky, M. S., Keshmiri, S., Davison, R. B., & Spaulding, R. (2021). Attachment and trust in artificial intelligence. *Computers in Human Behavior*, 115, 106607.
10. Glikson, E., & Woolley, A. W. (2020). Human trust in artificial intelligence: Review of empirical research. *Academy of Management Annals*, 14(2), 627-660.
11. Jacovi, A., Marasović, A., Miller, T., & Goldberg, Y. (2021). Formalizing trust in artificial intelligence: Prerequisites, causes and goals of human trust in AI. In *Proceedings of the 2021 ACM conference on fairness, accountability, and transparency* (pp. 624-635).

12. Kaplan, A. D., Kessler, T. T., Brill, J. C., & Hancock, P. A. (2023). Trust in artificial intelligence: Meta-analytic findings. *Human factors*, 65(2), 337-359.

13. Lockey, S., Gillespie, N., Holm, D., & Someh, I. A. (2021). A review of trust in artificial intelligence: Challenges, vulnerabilities and future directions. *Proceedings of the Annual Hawaii International Conference on System Sciences*. 2021, 5463–5472.

14. Mazurek, K. (2019). Human vs. Artificial Intelligence. A consumer behavioral study on advice taking among Gen Y. Barcelona School of Management. Master thesis

15. McCarthy, J. (2004). *What is artificial intelligence*. Dostupno na: http://www-formal. stanford. edu/jmc/whatisai. [Accessed on: July 20th, 2023]

16. Nath, S. V., Dunkin, A., Chowdhary, M., & Patel, N. (2020). *Industrial Digital Transformation: Accelerate digital transformation with business optimization, AI, and Industry 4.0*. Packt Publishing Ltd.

17. Rossi, F. (2018). Building trust in artificial intelligence. *Journal of international affairs*, 72(1), 127-134.

18. Rouhiainen, L. (2018). *Artificial Intelligence: 101 things you must know today about our future*. Lasse Rouhiainen.

19. Ryan, M. (2020). In AI we trust: ethics, artificial intelligence, and reliability. *Science and Engineering Ethics*, 26(5), 2749-2767.

20. Schmidt, P., Biessmann, F., & Teubner, T. (2020). Transparency and trust in artificial intelligence systems. *Journal of Decision Systems*, 29(4), 260-278.

21. Siau, K., & Wang, W. (2018). Building trust in artificial intelligence, machine learning, and robotics. *Cutter business technology journal*, 31(2), 47-53.

22. Wang, D., Khosla, A., Gargeya, R., Irshad, H., & Beck, A. H. (2016). Deep learning for identifying metastatic breast cancer. arhiv preprint arhiv:1606.05718.

23. Weber, F., & Schütte, R. (2019). A domain-oriented analysis of the impact of machine learning the case of retailing. *Big Data and Cognitive Computing*, 3(1), 11.

24. Yang, R., & Wibowo, S. (2022). User trust in artificial intelligence: A comprehensive conceptual framework. *Electronic Markets*, 32(4), 2053-2077.

Danijela Stojanović [1]
Božidar Radenković [2]
Zorica Bogdanović [3]
Ana Miličević [4]
Dušan Barać [5]

Keynote paper

CROWD-BASED OPEN INNOVATION: MODELS, CHALLENGES, AND TRENDS

Abstract

This article considers concepts, models, achieved results and emerging trends of the open innovation approach to organizing and conducting research and development activities in companies. The goal is to perform a comprehensive systematic analysis of literature that considers the open innovation models that focus on the collaboration of various stakeholders, including companies, academia, government, startups, individuals, and others, in the context of design and development of innovative digital services, through integration of crowdsourcing and DevOps. As a result, we propose a new framework for organizing open innovation activities using DevOps practices for digitals service development. Finally, we present examples of implementing crowd-based open innovation models in various contexts.

Key words: *Open Innovation, Crowdsourcing, DevOps, Digital Services.*

1. Introduction

Austrian economist Joseph Schumpeter (1883-1950) in the first half of the twentieth century was the first to recognize and define the concept of innovation theory. Throughout history, innovations have had a special contribution not only through the development of new products, services, and technologies but also through the progress of the entire society as a whole. As a result of the general social digital transformation, a digital economy was created, which is precisely based on innovation processes. In the conditions of market competition and the digital economy, the continuous implementation of innovation projects is necessary for the successful operation of a company. Constant

1 Research Associate, Institute of economic sciences, Serbia, danijela.stojanovic@ien.bg.ac.rs
2 Full professor, University of Belgrade Faculty of Organizational Sciences, Serbia, boza@elab.rs
3 Full professor, University of Belgrade Faculty of Organizational Sciences, Serbia, zorica@elab.rs
4 PhD student, University of Belgrade Faculty of Organizational Sciences, Serbia, ana.milicevic@fon.bg.ac.rs
5 Full professor, University of Belgrade Faculty of Organizational Sciences, Serbia, dusan@elab.rs

innovative activities are necessary for a company to be competitive in the market. The main function of innovations is to introduce changes in the company that can increase its economy, effectiveness, and profitability, thus influencing the development and growth of the company (Curley & Salmelin, 2013). Digital transformation, which is innovative by its nature, brings radical changes in the organization and operations of a company. The development of various Industry 4.0 technologies, such as Internet of Things (hereinafter: IoT), big data, virtual reality and others, enabled the wider social community to define problems and offer solutions in many areas of social action (Bogdanović, et al., 2021).

According to the chronological classification of different models of innovation management (Trott, 2017), the sixth generation is represented by the open innovation model, which appeared in 2000 and continues today. Open innovation represents a model of combining internal and external ideas, intending to improve the development of new technologies.

The purpose of this article is to analyze and present an overview of the open innovation concepts and models in the context of digital transformation, with the focus on software development aspects, and propose a research and innovation platform that leverages DevOps concepts to support open innovation. In section 2 we present the main theoretical concepts of open innovation approach. Section 3 gives an overview of crowd-based open innovation models, with the focus on hackathons, startups and the role of DevOps. In section 4 we discuss the possibilities of creating a general model of crowd-based open innovation, based on the approaches in literature. Finally, section 5 presents examples of open innovation projects, followed by concluding remarks.

2. Open innovation - term and concept

The term Open Innovation was used for the first time in 2003 by Chesbrough (Chesbrough, 2003), in the paper "Open Innovation: A New Imperative for Creating and Profiting from Technology." He defined open innovation as the use of knowledge from the company and its environment, to speed up internal innovation processes with external knowledge and thus increase the market for existing internal innovations for their external placement (Chesbrough, 2012). Until the end of the 20th century, innovative activities in companies were limited by their borders. This means that those companies implemented innovative development projects exclusively under controlled conditions, with internal knowledge and resources, without any competition (Stanisavljević et al., 2023).

The closed innovation business model, due to the rising costs of technological development and the ever-shortening lifespan of new products, has faced declining efficiency (Dodgson et al., 2008). The previously closed and traditional innovation processes no longer gave the expected results (Dhal et al., 2018). This was influenced by the increased number of experts in various fields, then opportunities for capital inflow, as well as opportunities to reach innovative and high-quality solutions outside the company (Cruz & Astudillo, 2020).

The way out of the closed circle of ever-increasing costs and decreasing revenues was provided by a model of open innovation. The development of modern technologies, especially the IoT, has enabled companies to use knowledge from the immediate and wider social environment, from other companies, research organizations, educational institutions, local governments, and even directly from the citizens themselves (Santoro et al., 2018; Wang et al., 2021). Accordingly, open innovation represents a "distributed innovation process based on the management of knowledge flows beyond the boundaries of the organization" (Chesbrough & Bogers, 2014; Bogers et al., 2018). Transparency, cooperation, clear goals, finding the right channels, commitment, and rewarding participants are key factors for the success of open innovation (Durst & Ståhle, 2013; Subtil de Oliveira et al., 2018).

In the past two decades, few studies have addressed the difficulties in implementing open innovation, intending to provide managers with guidelines for managing and managing these processes, to successfully implement open innovation. The European Commission promoted the Open Innovation 2.0 approach, which was based on innovation ecosystems, cooperation, and joint value creation, to integrate and synergize innovation processes (Curley & Salmelin, 2013; Lopes et al., 2021). The emergence of the "Industry 4.0" paradigm and the development of information technologies and IoT have created the conditions for today's innovation processes to represent the integration of knowledge from the fields of education, business, public and state administration, the civil sector, and individuals themselves. These activities aim to offer new, innovative services, as well as to open new markets (Hizam-Hanafiah & Soomro, 2021; Stojanović et al., 2021). The Industrial Technology Research Institute is just one of the international R&D organizations working on a platform-based open innovation model and its generation from idea to commercialization, to create social and economic value (Wang et al., 2021).

3. Analysis of the crowd-based business model of open innovation

Models of open innovation can be generally categorized in three groups: a) Outside-In; b) Inside-Out; c) Coupled. The Outside-in model includes the use of external knowledge and the taking over of other people's discoveries and their inclusion in internal innovation processes, while the Inside-out model is aimed at the placement of internally generated knowledge to other companies (Inauen et al., 2011). The integration of Outside-In and Inside-Out models represents the combined Coupled model (Chesbrough & Bogers, 2014; Bogers, 2012; Enkel et al., 2009; Gassmann et al., 2010), which includes two or more partners who, through joint activities, manage the development of an innovation from an idea to its commercialization outside of their organizational units (Bogers et al., 2012). The focus of further analysis is on the coupled models, which include multiple stakeholders, and span across the industry, academia, government, and society participation, through crowdsourcing.

The concept of open innovation in theory and practice is based on the crowdsourcing model, in which the source of knowledge is the "mass of individuals" (crowd), which leads to better, faster and more innovative solutions (Estellés-Arolas & González-Ladrón-de-Guevara, 2012). Crowdsourcing is most often used at the beginning of the innovation process, which is crucial for its successful implementation (Sarić et al., 2022; Stanisavljević et al., 2022). According to the definition of author Jeff Howe (Howe, 2008), crowdsourcing is a process by which a certain task in the form of an open call is transferred from specialized individuals to an undefined, large group of people outside the company. With the necessary conditions met, a community will almost always perform better than employees within a single company.

Digital transformation creates conditions for unifying the processes of creating innovations, developing and exploiting software for digital products and services, as well as processes related to market research and customer relations. In digital transformation, innovative processes are more diverse and it is not possible to realize them with a single model of innovation management. The crowdsourcing platform is just one of the digital platforms for open innovation, and includes crowdsourcing, crowdfunding, microwork, social product development and the sharing economy (Abhari et al., 2022). In theory, that model is known as the Crowd-based business model of open innovation. The application of this model of open innovation enables companies to find, in addition to resources within the company itself, sources of innovation and actors of the innovation process in the business environment, as well as among citizens. Digital platforms enable all actors in the innovation process to perform all their tasks remotely and efficiently (Aggeri & Segrestin, 2007). All citizens have the opportunity to get involved in the innovative process, whether for financial or other reasons (Saebi & Foss, 2015).

Numerous digital platforms have been developed for the crowd-based business model of open innovation. They provide digital services for the creation of innovations, most often in the form of a virtual environment. According to Hallerstede (Hallerstede, 2013), digital platforms for open innovation can be divided into:

- Innovation contests and competitions (Innovation Contest)
- Innovation Community
- Innovation Marketplaces
- Innovation Toolkits
- Technologies to support innovation (Innovation Technologies)

3. 1. Hackathons and student competitions

Student competitions and *hackathon*s represent one approach to implementing the concept of open innovation in non-formal education. They were originally organized with the aim of participants developing prototype software solutions through intensive programming in a short period, over time they developed

into different models of student competitions (Briscoe & Mulligan, 2014). Companies have already recognized the value of *hackathons* as an open model of innovation, where ideas and prototypes can be created by students and other participants. Numerous *hackathons* have recently been organized as virtual events, based on the cooperation and synergy of various international and cultural teams. The shortcoming of this model of open innovation is that the focus is only on the innovation capacities of educational institutions or technology transfer, and educational goals and learning outcomes are missing.

The improvement of engineering education can be achieved through open innovation and the implementation of project-based learning in formal education. Research conducted at the Department of e-business, Faculty of Organizational Sciences, University of Belgrade showed that both of these approaches to improving engineering education yield good results and have a positive effect on learning outcomes and students. Both approaches have been implemented for teaching and learning IT education subjects, namely Blockchain technologies and IoT (Ćirković et al., 2023).

Project-based learning is already widespread and recognized as a method for developing innovative competencies in engineers. However, the disadvantage of project-based learning for open innovation is that the results obtained from the classroom often do not reach potential investors, consumers, or the market (Awuor et al., 2022).

3. 2. Startups

Startup companies are a powerful engine of open innovation. Startup companies are essentially open organizations, necessarily involved in innovation processes (Spender et al., 2017). In stimulating the growth and success of startup companies, open innovation plays a key role, as a unique challenge and opportunity. Thanks to external knowledge, resources, and networks, startup companies can accelerate their innovation processes, reduce risks and gain a competitive advantage in dynamic markets. They can use a variety of open innovation strategies, including collaboration with industry leaders and research institutions. Startups can use open innovation to fuel their growth and achieve long-term success (Budiyono, 2023). In the literature, the application of open innovation in startup companies is a relatively unexplored field, and research dealing with collaborative innovation between startups and large companies is practically non-existent. Open innovation for startups has advantages, and startup managers with experience working in or with large companies can skillfully deal with a larger partner in the innovation network (Usman & Vanhaverbeke, 2017).

3. 3. DevOps model for development management

Open innovation platforms have emerged as software solutions to facilitate collaboration between different participants in an open innovation initiative (Cruz & Astudillo, 2020). The *DevOps* model for software development management combined with the Crowd-based open innovation management model represents an integrated model for open innovation. The crowd-based business model of open innovation includes research of potential markets, new ideas, creation of innovations, services, and implementation of prototypes. In a situation where companies are in the process of digital transformation, and their products and services are digital, the DevOps software development management model is necessary for conceptual design, testing, commercialization, and exploitation of digital products and services.

A wide set of stakeholders is involved in the functioning of open innovation platforms. Platform providers are companies that implement and maintain it, and provide technical support, innovative services, legal security, and monetary compensation for the services provided. The users of the platform, on the other hand, are other companies, entrepreneurs, freelancers, public administration, the academic community, the civil sector, and citizens (Bogdanović et al., 2023).

4. Open innovation using DevOps and Crowdsourcing

Thanks to the development of IoT and social networks, instead of traditional open innovation we increasingly have Internet-based innovation. Online environments create opportunities for different ideas, products, and services. Through public sharing, open innovation and knowledge management can be linked. In this way, companies speed up their work, reduce risk and, thanks to open innovation platforms, reach innovative resources.

For a long time, triple helix was the dominant model of innovation, as an approach that focuses on the interactions between industry, academia and government (Leydesdorff, 2000). Lately, the focus is shifting to quadruple and quintuple innovation models, which add knowledge society and natural environment (Carayannis & Campbell, 2010). An illustration of the quintuple helix model of innovation is presented in Figure 1.

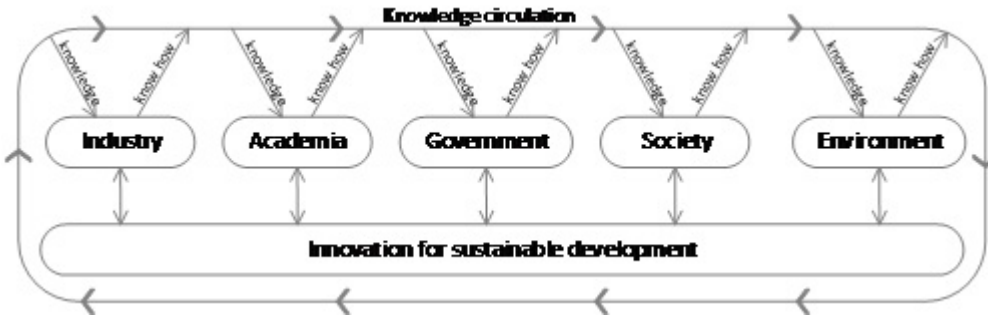


Figure 1. Quintuple helix model of innovation, based on (Carayannis et al. 2012)

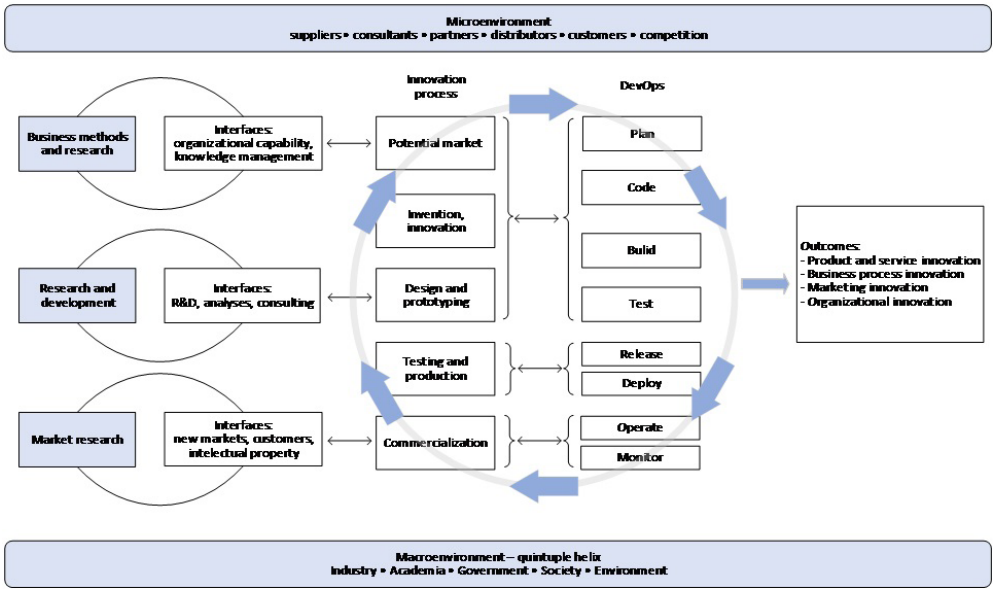


Figure 2. An integrated model for managing crowd-based open innovation with DevOps, based on (Caraça et al., 2007) (Carayannis et al. 2012) (Bogdanović et al., 2023)

However, the development of modern digital products and services is based on integration of new approaches to innovation with modern product development and software development concepts and models, such as DevOps (Bogdanović et al., 2023). Open innovation models in this context are various, and hard to be presented with one comprehensive model of innovation management. As one attempt to integrate open innovation models with modern software development approaches based on DevOps, we present an integrated model that includes a crowd-based model of open innovation management based on the chain-interactive model from the literature, DevOps approach to software development, and quintuple helix elements (Figure 2). The proposed approach is founded on crowd-based models, which rely on the participation of a large number of stakeholders, including stakeholders from macroenvironment, such as industry, academia, government, citizens and environment, as well as stakeholders from microenvironment, such as suppliers, consultants, consumers, distributors, competitors, to jointly develop sustainable solutions. In all phases, the company relies not only on internal resources and knowledge, but communications with the relevant stakeholders through a set of interfaces and communication shannels. The DevOps phases of software development correspond to phases of innovation process, as shown in the figure. Many of the innovations require some kind of software development, and thus the lifecycle of the innovative product or service has to be in line with the lifecycle of the software that serves it. Innovation outcomes may come in various areas or forms, including new products or services, new business models, new marketing strategies or techniques, or any kind of organizational innovation.

5. Examples of crowd-based open innovations

Open innovations are applied in a wide variety of fields, and the best results are achieved precisely in cases of intersectoral cooperation. Thus, for example, railways and the railway industry, as complex and multidisciplinary systems, are particularly suitable for the application of the open innovation model. In European and global railway companies, the application of the open innovation model was "an original, efficient, and high-quality response to existing problems" (Dodgson et al., 2015; Thurner & Gershman, 2014; Hanley et al., 2022).

Only in the past few years have there been numerous examples of this. "Alstom", an international company for the production of high-speed trains, has solved the problem of fallen and withered leaves, which caused adhesion between the rails and the wheels of the train, by applying open innovation ("Open Innovation in Railway: Example of AlstomTM | ideXlab"). As many as 38 companies from Great Britain and France applied to the open call of the Eurotunnel, which connects these two countries under the English Channel, with innovative proposals for improving the maintenance of railway rolling stock ("CPC and Eurotunnel Invite SMEs to Provide Railway Innovation Solutions"). Indian Railways received online over 100 thousand innovative proposals on the topic of future innovations in business ("Improving Indian Railways with Open Innovation"). The Rail Activation project, which was funded by the European Union's Horizon 2020 research and innovation program, was implemented by the Spanish railway industry association Mafex, which brings together 90 companies. The main goal of this project was to motivate and direct small and medium-sized enterprises from the railway industry to undertake workplace innovations, as part of the open innovation ecosystem. It is the first project of its kind in the railway sector (RailActivation project website http://railactivation.eu/).

When it comes to Serbian railways, an open innovation project was organized with students of the Faculty of Organizational Sciences of the University of Belgrade, to propose solutions for increasing the safety of railway traffic, based on IoT, through DevOps and crowdsourcing (Stanisavljević et al., 2023). The project included around 50 students working on solving real problems identified within the Serbian railways, both by developing new digital products and software.

Open innovation models are also increasingly present in the field of telecommunications, as telecommunications companies face market demands and find new opportunities to attract new subscribers with innovative products and services. In the period from 1985 to 2002, the mobile phone manufacturer Nokia combined various concepts related to cooperation strategies in research and development, applying the concept of open innovation in mobile telephony (Dittrich & Duysters, 2007). Such is the situation with telecom operators in Serbia, who have recognized the need to move from traditional to the concept of open innovation. These innovations are usually oriented towards smart city services based on the development of IoT technologies, cloud computing, software-defined networks, and blockchain. The development of the

crowdsourcing model enabled telco companies in Serbia to include customers in the open innovation system, to better design and develop services adapted to their needs (Sarić et al., 2022).

Governments are increasingly focusing their efforts on encouraging innovation within small and medium-sized enterprises. Thanks to this, cooperation between the Government, industry, and universities is gaining importance in the agenda of policy makers, to enable open innovation in small and medium-sized enterprises (Bertello et al., 2022). Open innovation had a particularly significant role in fostering the business model of small and medium-sized enterprises during the Covid-19 pandemic (Jabeen et al., 2023). The implementation of a digital *hackathon* in Sweden, in response to the Covid-19 pandemic by applying the model of open innovation through crowdsourcing, has led to a significant growth of the digital health community in this country (Temiz, 2021).

And while many studies dealt with open innovation in large organizations, some authors analyzed eleven open innovation projects in SMEs in four European regions and found a wide range of primary and secondary stakeholders, with different levels of power and dependence, used in these projects (Albats et al., 2020). A typical example is IBM, which, despite promising assumptions, failed to make a significant profit from Watson Health, as a general-purpose technology, because, given its characteristics, the approach to its market entry was too closed. The authors of the study that analyzed this example suggest that the very concept of open innovation would improve the appropriation of value from general-purpose technology (Yang et al., 2022).

The authors also studied open innovation at Sri Lankan universities and their cooperation with industry, to improve innovation through knowledge and technology transfer (Weerasinghe & Dedunu, 2021). Open innovation platforms are applied in tourism, where stakeholders communicate with each other, reach agreements and jointly solve problems through the platform, using predominantly constructive styles of interaction (Lalicic, 2018). Open innovations also play a significant role in social enterprises, bearing in mind that they simultaneously realize their planned social mission, but also profit, which is proven by the example of four leading social enterprises in the field of education in Indonesia (Harsanto et al., 2022). Also, open innovation contributes to a sustainable, circular economy (Jesus & Jugend, 2023), and Procter & Gamble, with its "Connect and Grow" strategy, implemented organizational and technological changes based on the model of open innovation (Dodgson et al., 2006). and open innovation is also applied in the pharmaceutical industry (Schuhmacher et al., 2013). The authors also deal with the risks that open innovation within companies entails, primarily due to aligned managerial motives and asymmetry among different stakeholders (Shaikh & Randhawa, 2022).

Innovations are crucial for the growth and development of a company's business and its competitiveness in the market. Open innovation is expressed through three different processes: acquisition of external technology; external exploitation of technology (outbound innovation); and merged innovation (Bigliardi et al., 2020). Acceptance and implementation of the open innova-

tion model depend to a large extent on the organizational culture, knowledge, attitudes, and rewards of employees, which was confirmed by research that included 528 employees from 28 different industries in 37, mostly European countries (Alassaf et al., 2020).

6. Conclusion

The increasing adoption of the open innovation model has brought with it the need to adapt the business strategies of companies to new business conditions. To make strategic sense of innovation communities, ecosystems, networks, and their implications for competitive advantage, a new approach to strategy is needed - open strategy (Chesbrough & Appleyard, 2007). An increasing number of European companies are adopting the open innovation model as a way to innovate and make better use of their business environment. Based on the experiences of 31 large European companies that are considered innovation leaders according to the annual "SEP Europes Corporate Startup Stars" ranking, corporate cooperation models and approaches are continuously developing, and companies and innovation drivers jointly open and develop their innovation projects for mutual benefit (Onetti, 2021).

From the experiences in practice, it is clear that companies that wish to ensure sustainable development need to expand their innovation capabilities in line with the quintuple helix model, include a large number of internal and external stakeholders, and create an environment for continuous improvement and innovation. When the innovation is based on IT services or includes digital transformation, DevOps principles can be of use, and support continuous innovation with continuous software development.

Future research will be organized in several directions: 1) more details about the readiness of software companies to embrace open innovation concepts beyond open source software need to be obtained; in this context, they can take the role of organizers of open innovation projects, but can also take a more proactive role in participating in crowd-based open innovation projects organized by other companies; 2) further analyses of alignment of open innovation models with DevOps is needed; although their lifecycles are compatible, more experiences from practice are needed, especially when coordination between a large number of participants is required; 3) empowering companies to embrace open innovation model is needed; although internal stakeholders frequently recognize the potential, top-management support is not always present, nor is this innovation model recognized as a strategic priority; 4) finally, is in needed to study in more details the relationships and models to integrate all the identified components of quintuple helix in an effective and productive way, and support crowd-based innovations for sustainable development through organizational models and technological infrastructures.

Reference

1. Abhari, K., Davidson, E., & Xiao, B. (2022). Inventing together: The role of actor goals and platform affordances in open innovation. *Journal of the Association for Information Systems*, *23*(1), 264–302.
2. Aggeri, F., & Segrestin, B. (2007). Innovation and project development: an impossible equation? Lessons from an innovative automobile project development. *R&d Management*, *37*(1), 37–47. https://doi.org/10.1111/j.1467-9310.2007.00457.x
3. Alassaf, D., Dabić, M., Shifrer, D., & Daim, T. (2020). The impact of open-border organization culture and employees' knowledge, attitudes, and rewards with regards to open innovation: an empirical study. *Journal of Knowledge Management*, *24*(9), 2273–2297.
4. Albats, E., Alexander, A., Mahdad, M., Miller, K., & Post, G. (2020). Stakeholder management in SME open innovation: interdependences and strategic actions. *Journal of Business Research*, *119*, 291–301.
5. Awuor, N. O., Weng, C., Piedad, E. J., & Militar, R. (2022). Teamwork competency and satisfaction in online group project-based engineering course: The cross-level moderating effect of collective efficacy and flipped instruction. *Computers & Education*, *176*, 104357. https://doi.org/10.1016/J.COMPEDU.2021.104357
6. Bertello, A., Ferraris, A., De Bernardi, P., & Bertoldi, B. (2022). Challenges to open innovation in traditional SMEs: an analysis of pre-competitive projects in university-industry-government collaboration. *International Entrepreneurship and Management Journal*, *18*(1), 89–104. https://doi.org/10.1007/S11365-020-00727-1
7. Bigliardi, B., Ferraro, G., Filippelli, S., & Galati, F. (2020). The influence of open innovation on firm performance. *International Journal of Engineering Business Management*, *12*.
8. Bogdanović, Z., Despotović-Zrakić, M., Barać, D., Labus, A., & Radenković, M. (2023). The Role of DevOps in Sustainable Enterprise Development. *International Series in Operations Research and Management Science*, *333*, 217–237. https://doi.org/10.1007/978-3-031-16620-4_12/COVER
9. Bogdanović, Z., Stojanović, M., Radenković, M., Labus, A., & Despotović-Zrakić, M. (2021). Mobile Operator as the Aggregator in a Demand Response Model for Smart Residential Communities. *Lecture Notes on Data Engineering and Communications Technologies*, *79*, 58–67. https://doi.org/10.1007/978-3-030-79206-0_5
10. Bogers, M., Bekkers, R., & Granstrand, O. (2012). Intellectual property and licensing strategies in open collaborative innovation. In *Open innovation in firms and public administrations: Technologies for value creation* (pp. 37–58). https://doi.org/10.4018/978-1-61350-341-6.ch003
11. Bogers, M. (2012). Knowledge sharing in open innovation: An overview of theoretical perspectives on collaborative innovation. *Open Innovation in Firms and Public Administrations: Technologies for Value Creation*, 1–14.
12. Bogers, Marcel, Chesbrough, H., & Moedas, C. (2018). Open Innovation: ReseaRch, PRactices, and Policies. *California Management Review*, *60*(2), 5–16. https://doi.org/10.1177/0008125617745086
13. Briscoe, G., & Mulligan, C. (2014). *Digital innovation: The hackathon phenomenon*.
14. Budiyono, A. (2023). Startups and Open Innovation: Leveraging Collaboration for Success. *Progress and Communication in Sciences*, *5*(1).
15. Caraça, J., Ferreira, J. L., & Mendonça, S. (2007). A chain-interactive innovation model for the learning economy: Prelude for a proposal.

16. Carayannis, E. G., Barth, T. D., & Campbell, D. F. (2012). The Quintuple Helix innovation model: global warming as a challenge and driver for innovation. *Journal of innovation and entrepreneurship*, 1, 1-12.

17. Carayannis, E. G., & Campbell, D. F. (2010). Triple Helix, Quadruple Helix and Quintuple Helix and how do knowledge, innovation and the environment relate to each other?: a proposed framework for a trans-disciplinary analysis of sustainable development and social ecology. *International Journal of Social Ecology and Sustainable Development* (IJSESD), 1(1), 41-69.

18. Chesbrough, H., & Bogers, M. (2014). Explicating Open Innovation: Clarifying an Emerging Paradigm for Understanding Innovation. In *New Frontiers in Open Innovation* (pp. 3–28). Oxford: Oxford University Press, Forthcoming.

19. Chesbrough, H. W. (2003). *Open Innovation The New Imperative for Creating and Profiting from Technology*. Boston, Massachusetts: Harvard Business Press.

20. Chesbrough, H. W., & Appleyard, M. M. (2007). Open innovation and strategy. *California Management Review*, *50*(1), 57–76.

21. Chesbrough, Henry. (2012). Open innovation: Where we've been and where we're going. *Research Technology Management*, *55*(4), 20–27. https://doi.org/10.5437/08956308X5504085

22. Ćirković, A., Bogdanović, Z., & Radenković, B. (2023). Project-based Learning with Mattermost in Higher Education. *E-Business Technologies Conference Proceedings*, *3*(1), 260–264.

23. Cruz, P., & Astudillo, H. (2020). Towards a Maturity Model for Assessment of Organization Readiness in Implementing and Deploying an Open Innovation Platform. *Proceedings of the 16th International Symposium on Open Collaboration*, 1–4. https://doi.org/10.1145/3412569.3412868

24. Curley, M., & Salmelin, B. (2013). Open Innovation 2.O: A New Paradigm. *OISPG White Paper*, 1–12.

25. Dhal, S. P., Chowdhury, P., & Shaw, S. K. (2018). IOT: Making Things Better. *International Journal of Computer Science and Mobile Applications*, 85–104.

26. Dittrich, K., & Duysters, G. (2007). Networking as a means to strategy change: The case of open innovation in mobile telephony. *Journal of Product Innovation Management*, *24*(6), 510–521. https://doi.org/10.1111/j.1540-5885.2007.00268.x

27. Dodgson, M., Gann, D., MacAulay, S., & Davies, A. (2015). Innovation strategy in new transportation systems: The case of Crossrail. *Transportation Research Part A: Policy and Practice*, *77*, 261–275.

28. Dodgson, M., Gann, D. M., & Salter, A. (2008). *The management of technological innovation: strategy and practice*.

29. Dodgson, Mark, Gann, D., & Salter, A. (2006). The role of technology in the shift towards open innovation: The case of Procter & Gamble. *R and D Management*, *36*(3), 333–346. https://doi.org/10.1111/j.1467-9310.2006.00429.x

30. Durst, S., & Ståhle, P. (2013). Success Factors of Open Innovation-A Literature Review. *International Journal of Business Research and Management (IJBRM)*, *4*(4), 111.

31. Enkel, E., Gassmann, O., Management, H. C.-R., & 2009, undefined. (2009). Open R&D and open innovation: exploring the phenomenon. *Wiley Online Library*, *39*(4), 311–316. https://doi.org/10.1111/j.1467-9310.2009.00570.x

32. Estellés-Arolas, E., & González-Ladrón-de-Guevara, F. (2012). Towards an integrated crowdsourcing definition. *Journal of Information Science*, *38*(2), 189–200. https://doi.org/10.1177/0165551512437638

33. Gassmann, O., Enkel, E., & Chesbrough, H. (2010). The future of open innovation. *R and D Management*, *40*(3), 213–221. https://doi.org/10.1111/J.1467-9310.2010.00605.X

34. Hallerstede, S. (2013). Open innovation platforms. In *Managing the Lifecycle of Open Innovation Platforms*. https://doi.org/10.1007/978-3-658-02508-3_5

35. Hanley, D., Li, J., & Wu, M. (2022). High-speed railways and collaborative innovation. *Regional Science and Urban Economics*, *93*, 103717.

36. Harsanto, B., Mulyana, A., Faisal, Y. A., & Shandy, V. M. (2022). Open innovation for sustainability in the social enterprises: An empirical evidence. *Journal of Open Innovation: Technology, Market, and Complexity*, *8*(3), 160. Retrieved from https://www.sciencedirect.com/science/article/pii/S2199853122007612

37. Hizam-Hanafiah, M., & Soomro, M. A. (2021). The situation of technology companies in industry 4.0 and the open innovation. *Journal of Open Innovation: Technology, Market, and Complexity*, *7*(1), 1–20. https://doi.org/10.3390/joitmc7010034

38. Howe, J. (2008). Why the Power of the Crowd is Driving the Future of Business. *Crown Publishing Group New York, NY*, 320. Retrieved from http://www.amazon.com/Crowdsourcing-Power-Driving-Future-Business/dp/0307396207

39. Inauen, M., & Schenker-Wicki, A. (2011). The impact of outside-in open innovation on innovation performance. *European Journal of Innovation Management*, *14*(4), 496–520. https://doi.org/10.1108/14601061111174934

40. Jabeen, F., Belas, J., Santoro, G., & Alam, G. M. (2023). The role of open innovation in fostering SMEs' business model innovation during the COVID-19 pandemic. *Journal of Knowledge Management*, *27*(6), 1562–158. https://doi.org/10.1108/JKM-05-2022-0347/FULL/HTML

41. Jesus, G. M. K., & Jugend, D. (2023). How can open innovation contribute to circular economy adoption? Insights from a literature review. *European Journal of Innovation Management*, *26*(1), 65–98. https://doi.org/10.1108/EJIM-01-2021-0022/FULL/HTML

42. Lalicic, L. (2018). Open innovation platforms in tourism: how do stakeholders engage and reach consensus? *International Journal of Contemporary Hospitality Management*, *30*(6), 2517–2536. https://doi.org/10.1108/IJCHM-04-2016-0233

43. Leydesdorff, L. (2000). The triple helix: an evolutionary model of innovations. *Research policy*, 29(2), 243-255.

44. Lopes, J. M., Gomes, S., Oliveira, J., & Oliveira, M. (2021). The role of open innovation, and the performance of european union regions. *Journal of Open Innovation: Technology, Market, and Complexity*, *7*(2). https://doi.org/10.3390/joitmc7020120

45. Onetti, A. (2021). Turning open innovation into practice: trends in European corporates. *Journal of Business Strategy*, *42*(1), 51–58. https://doi.org/10.1108/JBS-07-2019-0138

46. Saebi, T., & Foss, N. J. (2015). Business models for open innovation: Matching heterogeneous open innovation strategies with business model dimensions. *European Management Journal*, *33*(3), 201–213.

47. Santoro, G., Vrontis, D., Thrassou, A., & Dezi, L. (2018). The Internet of Things: Building a knowledge management system for open innovation and knowledge management capacity. *Technological Forecasting and Social Change*, *136*, 347–354.

48. Sarić, Ž., Obradović, V., Bogdanović, Z., Labus, A., & Mitrović, S. (2022). Crowd-based open innovation in telco operators: Readiness assessment for smart city service development. *Serbian Journal of Management*, *17*(1), 179–196. https://doi.org/10.5937/sjm17-36913

49. Schuhmacher, A., Germann, P. G., Trill, H., & Gassmann, O. (2013). Models for open innovation in the pharmaceutical industry. *Drug Discovery Today*, *18*(23–24), 1133–1137.

50. Shaikh, I., & Randhawa, K. (2022). Managing the risks and motivations of technology managers in open innovation: Bringing stakeholder-centric corporate governance into focus. *Technovation*, *114*, 102437.

51. Spender, J. C., Corvello, V., Grimaldi, M., & Rippa, P. (2017). Startups and open innovation: a review of the literature. *European Journal of Innovation Management*, *20*(1), 4–30.

52. Stanisavljević, N., Stojanović, D., & Petrović, L. (2022). Open Innovation and Crowdsourcing: Challenges and Opportunities for Serbian Railways. *E-Business Technologies Conference Proceedings*, *2*(1), 36–41. Retrieved from https://ebt.rs/journals/index.php/conf-proc/article/view/137

53. Stanisavljević, N., Stojanović, D., & Bogdanović, Z. (2023). Fostering Crowd-Based Open Innovations in Serbian Railways - Preliminary Readiness Assessment. In *Mihić, M., Jednak, S., Savić, G. (eds) Sustainable Business Management and Digital Transformation: Challenges and Opportunities in the Post-COVID Era* (pp. 278–297).

54. Stojanović, D., Stanisavljević, N., & Jovičić, E. (2021). Digital marketing techniques for promotion of "Infrastructure of Serbian Railways." *E-Business Technologies*, 44–46.

55. Subtil de Oliveira, L., Echeveste, M.E. and Cortimiglia, M. N. (2018). Critical success factors for open innovation implementation. *Journal of Organizational Change Management*, *31*(6), 1283–1294.

56. Temiz, S. (2021). Open innovation via crowdsourcing: A digital only hackathon case study from Sweden. *Journal of Open Innovation: Technology, Market, and Complexity*, *7*(1), 1–14.

57. Thurner, T., & Gershman, M. (2014). Catching the runaway train innovation management in Russian railways. *Journal of Technology Management & Innovation*, *9*(3), 158–168.

58. Trott, P. (2017). Innovation Management and New Product Development. In *6th ed.* Pearson Education Limited.

59. Usman, M., & Vanhaverbeke, W. (2017). How start-ups successfully organize and manage open innovation with large companies. *European Journal of Innovation Management*, *20*(1), 171–186. https://doi.org/10.1108/EJIM-07-2016-0066/FULL/HTML

60. Wang, Y. chu, Phillips, F., & Yang, C. (2021). Bridging innovation and commercialization to create value: An open innovation study. *Journal of Business Research*, *123*, 255–266. https://doi.org/10.1016/j.jbusres.2020.09.052

61. Wang, Y. M., Wang, Y. S., & Wang, Y. Y. (2021). Exploring the determinants of university students' contribution intention on crowdsourcing platforms: a value maximization perspective. *Interactive Learning Environments*, 1–23. https://doi.org/10.1080/10494820.2021.1890619

62. Weerasinghe, I. M. S., & Dedunu, H. H. (2021). Contribution of academics to university–industry knowledge exchange: A study of open innovation in Sri Lankan universities. *Industry and Higher Education*, *35*(3), 233–243. https://doi.org/10.1177/0950422220964363

63. Yang, J., Chesbrough, H., & Hurmelinna-Laukkanen, P. (2022). How to Appropriate Value from General-Purpose Technology by Applying Open Innovation. *California Management Review*, *64*(3), 24–48. https://doi.org/10.1177/00081256211041787

Nuša Erman, PhD[1]
Katarina Rojko, PhD[2]

Original scientific paper

COVID-19 IMPACTS ON INDUSTRY ROBOTIZATION

Abstract

The advancement in technological developments and recent Covid-19 impacts lead to continuous robotization in industries, especially in the manufacturing sector. As we were interested in impacts on the economy (and society), we analysed some economic indicators in comparison with data on industrial robots installations to present recent developments in the industry. We focused on changes due to Covid-19 as we expected that the pandemic had positive impacts on the manufacturing sector in terms of accelerating progress to the next level of industry development - to Industry 4.0 and even to some extent to Industry 5.0 stage. After the strong robotization of industry in the pre-Covid-19 period, a hindered demand was observed during the pandemic, as also a decline in manufacturing output and employment. Nonetheless, trends quickly regained growth, while the vector autoregression model forecast shows, that the manufacturing sector has a bright future ahead since robotization will be able to increase employment and output of workers, which is also a goal of Industry 4.0 and 5.0. This implies that investments in industrial robots proved to be beneficial also during the pandemic periods and that the Covid-19 pandemic did not have negative impacts on the ongoing transformation of industry. Robotization thus led to recent positive developments in the manufacturing sector, despite some negative impacts were observed in the pre-Covid-19 period.

Key words: *Covid-19, Robotization, Industrial output, Industry 4.0, Industry 5.0.*

1. Introduction

The progress in technological advancement leads to continuous robotization in industries, especially in the manufacturing sector. Specifically, based on data processing we noted that robotization has been accelerating during the recent years, while the increased number of robots within the industry has been having positive and negative impacts on the economic indicators. For this reason, our research goal was to analyze relations between robotization data and some of the economic indicators to investigate the recent Covid-19

1 Asst. Prof. Nuša Erman, PhD, Faculty of Information Studies in Novo mesto, Slovenia, nusa.erman@fis.unm.si
2 Assoc. Prof. Katarina Rojko, PhD, Faculty of Information Studies in Novo mesto, Slovenia, katarina.rojko@fis.unm.si

pandemic impacts. Specially, we focused on this to find out how the manufacturing sector proceeds to Industry 4.0 and further to Industry 5.0.

Besides, this research aims to provide further (e.g. from Rojko et al., 2020) insight into the current developments within industry transformation, due to the great disruption caused by the Covid-19 pandemic, to observe changes and based on to prepare new projections. We also wanted to determine if this transition has positive or negative effects. Namely, some reports (e.g., in World Economic Forum, 2018) put to front only positive consequences of recent industry transformation, while some authors (e.g., Johannessen, 2018; Compagnucci et al., 2019) also reveal negative effects. Moreover, the fear of artificial intelligence and robots replacing humans in the industry (and even elsewhere) causes also a subconscious rejection of the use of robots by employees.

In contrast, during the Covid-19 pandemic robots were put to the front, enabling job execution with more limited possibility for people to get sick. For example, robots were promoted in different industries, especially in healthcare (Kaiser et al., 2021). This caused people to look at robots differently, not only as an existential threat to the human role in industry but as assistants providing safe and easier workplaces for humans.

To analyze economic indicators for the manufacturing sector, we used official data on employment, the output of workers, and labour productivity, measured as output per hour worked, by the Federal Reserve Bank (FRED, 2023). Then we combined those data with data on the number of industrial robots installations provided by the Industrial Federation of Robotics (IFR, 2022a; IFR, 2023). Statistical data processing allowed us to show associations and changes during the Covid-19 period. Furthermore, we also calculated the expected trends to present future developments in the manufacturing sector.

The next chapter of the paper includes a literature review, including Industry 4.0 and Industry 5.0 definitions, and impacts on economic indicators of industry transformations. Following the presentation of our research goal and research questions, data and the research methods are explained. After data analysis, the summary includes a condensed presentation of research findings, comments on certain literature, and puts forward some proposals for further research.

2. Literature Review

The term Industry 4.0, coined in 2011, refers to advanced manufacturing or also called the *Smart Manufacturing* concept. It relies on the adoption of digital technologies to gather data in real-time and to analyze it, providing useful information to manufacturing in changing conditions (Wang et al., 2016a; Schuh et al., 2017 in Frank et al., 2019).

Frank et al. (2019) present the theoretical framework of Industry 4.0 as a combination of front-end technologies (Smart Supply Chain, Smart Working, Smart

Manufacturing, and Smart Product as well as base technologies (Internet of Things, Cloud, Big Data and Analytics) aiming to increase productivity and efficiency of the industry. This means that Industry 4.0 requires extensive investments in new technology solutions and therefore also properly upskilled employees. Namely, Industry 4.0 requires convergence between physical and digital spaces, which is revolutionizing the way that production operations are managed (Guo et al., 2021).

According to Ghobakhloo (2018), most design principles and technologies that enable Industry 4.0 have already been used in practice. He claims that Industry 4.0 is no longer a "future trend" and that organizations that have taken it at the centre of their strategic agenda, benefit from the competitive advantages. Despite known advantages, Raj et al. (2020) present the influencing barriers to wider adoption of Industry 4.0 technologies – i.e., suggesting that improvements in standards and government regulation could facilitate the adoption of Industry 4.0 technologies in developing country case, whereas technological infrastructure is needed to promote the adoption of these technologies in developed country case.

Nonetheless, there are already certain movements toward Industry 5.0 concepts since there have been emerging requirements to put human workers back at the centre of the production processes. According to Rojko et al. (2020), Industry 5.0 should focus primarily on human and robot engagement and the integration of human knowledge, creativity, intuition, skills, experience, etc. within robotized production. Moreover, within Industry 5.0 robots are supposed to transform into ideal human companions, that will know, or learn, what to do for human workers (Nahavandi, 2019).

Leng et al. (2022) write about three leading characteristics of Industry 5.0: human-centricity, sustainability, and resiliency. Therefore, they construct a tri-dimension system architecture for implementing Industry 5.0, namely, the technical dimension, reality dimension, and application dimension. According to our research focus on human centricity, i.e., the technical dimension is considered as the above-mentioned collaboration of humans and technology. Human-robot collaboration, as one of three technological trends (IFR, 2022a) including expanding product range with higher payloads and longer reach, business ecosystems and one-stop shops ease the deployment, and ease of use is a driver for the use of cobots.

According to Javaid et al. (2020), Industry 5.0, as the fifth industrial revolution, consisting of smart digital information and manufacturing technologies, generated effective processes and makes rapid improvements in industries. Especially it developed rapidly in healthcare during the COVID-19 pandemic. Nonetheless, Industry 5.0 is also considered the "Sublation" of Industry 4.0 and is still in the preliminary exploration stage (Leng et al., 2022).

As for the impacts of industry transformations on economic indicators evidence shows that the increase in the number of robots reduces employment, where the impact is conditioned on labour intensity: labour-intensive industries reveal an impact that is more than one-third larger than capital-intensive

sectors (ILO, 2018). On the other hand, according to Rojko et al. (2020) the manufacturing output, as well as the number of employees in manufacturing and labour productivity, have steadily grown in the U.S. during the pre-covid period despite massive robotization. And since the number of installed robots continued to grow immediately after 2020 due to COVID-19 disruption (IFR, 2022b), we believe that pandemics led even quicker transition to the Industry 5.0 period.

3. Research goal and research questions

As we were interested in the impacts that the most recent developments in the industry had on the economy (and society), we analyzed some economic indicators in comparison with data on industrial robots installations. We focused on changes due to Covid-19 as we expected that the pandemic had positive impacts on the manufacturing sector in terms of accelerating progress to the next level of industry development - to Industry 4.0 and even to some extent to Industry 5.0 stage. Thus, our research goal was to analyze three key economic performance indicators to explore the impacts of concurrent industry robotization. Accordingly, we derived the following research questions:

1) How did the industrial robots installations change due to the Covid-19 pandemic impacts and how did employment, output of workers, and labour productivity change in the manufacturing sector in the last ten years?
2) What were the impacts of robotization on employment, output of workers, and labor productivity in the manufacturing sector during the period of Covid-19 and earlier?
3) What are the projected forthcoming correlative occurrences in manufacturing employment, the output of workers, labour productivity, and robotization?

4. Methodology

To answer the research questions, we analyzed the time series data on the number of industrial robots installations, provided by IFR (2022a, 2023), and related them to the growths in selected economic indicators, i.e., employment, output by worker, and labour productivity in the manufacturing sector (FRED, 2023) for a 10-year period between 2013 and 2022. Here, the term *industrial robot* refers to the "automatically controlled, reprogrammable multipurpose manipulator for use in automation applications in an industrial environment" (ISO, 2021). On the other hand, data on employment measures the number of workers in manufacturing sector, and the output of workers is measured as sectoral output in manufacturing and equals the total value of goods and services produced by manufacturing sector (also known as gross output) ex-

cluding intra-industry transactions (BLS, 2023), whereas labour productivity is quantified as output per hour worked and is calculated as a ratio between index of real output and index of hours worked of all persons in the manufacturing sector (FRED, 2023).

We analyzed the data using various methods. Firstly, we presented the trends in the number of industrial robot installations as well as annual growths in employment, output by workers, and labor productivity in the manufacturing sector. The trends were discussed using average annual growth rate (AAGR) and compound annual growth rate (CAGR), where applicable. Secondly, to investigate the relations between the growths of the number of industrial robots installations and selected economic indicators, we used correlation analysis. Here, we also considered the possibility of lagged correlations (Zhang et al., 2008) and therefore used cross-correlation analysis as well (Shumway and Stoffer, 2017). For all possible pairs of time series data, we calculated the cross-correlation function (CCF), which presents a set of correlations between two time series in time t, where the values of one time series change according to the lag value h, which in our case corresponds to the number of years. When lag value $h < 0$, the calculated correlations indicate that the changes in the second time series appear h years after the changes in the first time series happen, when lag value $h > 0$, the calculated correlations indicate that the changes in the second time series appear h years before the changes in the first time series happen, and when lag value $h = 0$, the value of cross-correlation equals the value of Pearson correlation coefficient between the two time series (Shin, 2017). Finally, we examined the mutual dynamics of the observed time series using vector autoregression (VAR) analysis, which allows predicting future trends using a single model. VAR model is basically a system of multiple equations, where each equation represents a time series as a linear combination of the lagged values of other time series (Hanck et al., 2019). We used the estimated VAR model to predict and present the future trends in the growth of industrial robots installations, employment, output of workers, and labor productivity in the manufacturing sector.

5. Analysis of results

According to Essentra (2019), U.S. is the leading market in Industry 4.0 and is also known as the country in which manufacturing is one of the most important sectors for growth (Schreiber in Essentra, 2019). Therefore, in our analysis, we focus on the data for U.S. in the manufacturing sector.

Figure 1 presents the number of industrial robot installations in the U.S., as well as the growths in employment, output by workers, and labour productivity in the U.S. manufacturing sector. The number of industrial robots installations grew at a CAGR of 5.8% from 2013 to 2022 (IFR, 2022a and 2023), whereas in the same period, employment in manufacturing sector grew only at a CAGR of 0.7%. Regarding average annual growth rates (AAGR), the number of industrial

robots installations grew by 6.7%, employment by 0.8%, and output of workers by 0.2%, whereas labour productivity declined by 0.4% on average.

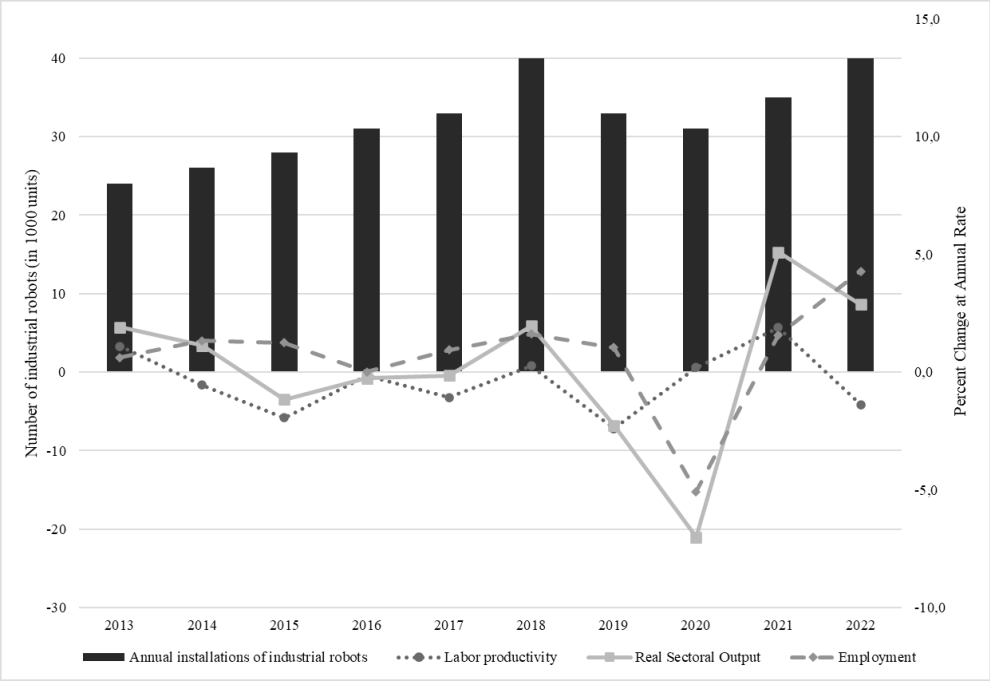


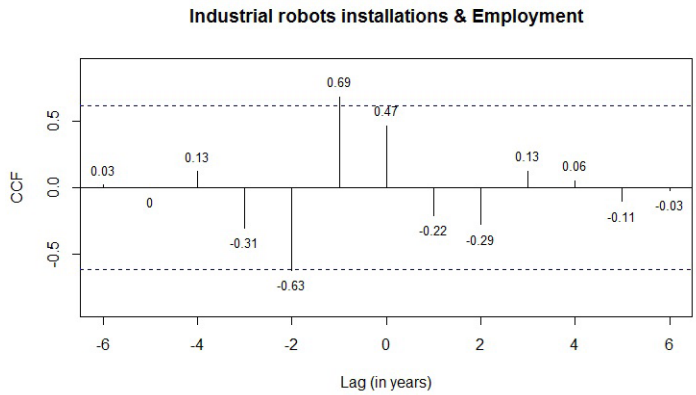
Figure 1. Number of installed industrial robots vs. annual percent changes for employment, output by workers and labor productivity in the U.S. manufacturing sector (2013-2022) (IFR, 2022a and 2023, FRED 2023)

Looking at the period from Covid-19 pandemic crisis onwards, in 2019 we observe a 17.5% decline in the number of industrial robots installations, and the decline has continued into 2020, when the data show a further 6.1% drop. However, the situation has already changed in 2021, when the number of industrial robots installations increased by 12.4%, and in 2022 by 14.1%. On the other hand, the number of employees dropped by 5.1% in 2020, and then increased only slightly in 2021 and 2022, by 1.6% and 3.8%, respectively. Due to decreased employment, output by workers decreased by 7.0% in 2020 as well, whereas labour productivity increased by 0.2%. A similar trend is observed for the entire 2013-2022 period, as the AAGR data show that when the number of industrial robots installations and employment grow, labour productivity declines which is probably due to the fact that for the same or amount of output, more employees and robots are available.

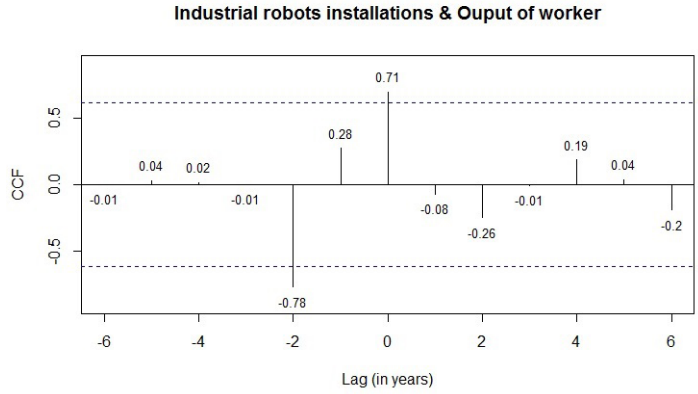
According to the observed trends, we also investigated correlations between the annual percent changes in the number of industrial robots installations and selected economic indicators. To do so, we used the cross-correlation analysis for which graphical presentations can be seen in Figure 2, in which blue dot-

ted lines represent the approximate 95% confidence intervals that serve as the threshold for identifying statistically significant cross-correlation values.

a)



b)



c)

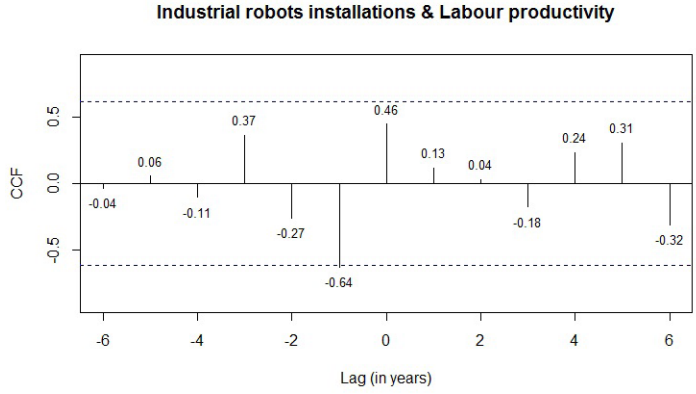


Figure 2. Cross-correlation functions (CCFs) for the number of industrial robots installations and a) employment, b) output of workers, and c) labor productivity in U.S. manufacturing sector in the observed 2013-2022 period

Figure 2 a) presents the CCF for the number of industrial robot installations and employment in manufacturing. The correlation between the observed time series data is significant at time lags -1 and -2 years. This indicates that an increase in the number of installed robots most certainly leads to an increase in manufacturing employment about one year later (r = 0.69), whereas about two years later employment in manufacturing decreases (r = -0.64). In Figure 2 b) we present the CCF for the number of industrial robots installations and output by workers. Here we observe a significant correlation at time lag = 0 (r = 0.71), indicating that at the same time when the number of installed robots increases, the output of workers in the manufacturing sector increases as well, but the results also show that an increase in the number of installed robots also leads to a decrease in output of workers about two years later (r = -0.78). Furthermore, the CCF for the number of industrial robots installations and labor productivity shown in Figure 2 c) indicates a significant correlation at time lag = -1, which means that an increase in the number of installed robots leads to a decrease in labour productivity about one year later (r = -0.64).

According to the findings presented above, we can observe a tendency toward an association between the number of industrial robots installations, and employment, output by workers, as well as labor productivity in the manufacturing sector. In this context, we finally conducted a VAR analysis to predict future trends based on the observed data for the past 10 years, which are presented in Figure 3.

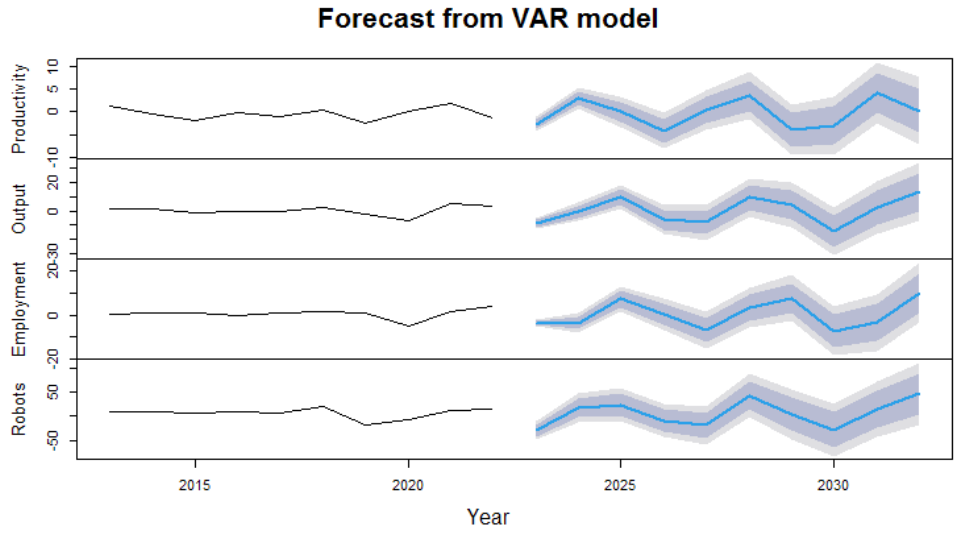


Figure 3. Values for industrial robots installations (Robots), employment (Employment), the output of workers (Output), and labour productivity (Productivity) in U.S. manufacturing sector based on the VAR model (2013-2022 historical, 2023–2032 predicted)

The left side of Figure 3 shows the actual data for the observed 2013–2022 period, and the right side represents the predictions for the next 10-year period based on each autoregression equation. The predicted values for each time series are presented as blue lines, and the shaded areas represent 80% (dark grey) and 95% (light grey) confidence intervals thereof.

The results show that in the coming 10-year period, we can still expect fluctuations in all of the observed indicators, but the mutual interdependence between the growth of the number of industrial robots installations and economic indicators for the manufacturing sector will be maintained. This means that a change in the number of industrial robot installations will positively affect the changes in employment and output of workers in the manufacturing sector, while labour productivity will change in the opposite direction. This means, as the number of industrial robots and employment increase at the same time, labour productivity will decline.

However, these calculations project a future in which, on the one hand, we can expect some kind of crisis to reappear, which will have an impact on the decline in the number of industrial robots installations and consequently in employment and output, while, on the other hand in crisis period for this reason productivity is to grow. But, considering the trends in the last 10-year period, it turns out that even if the number of industrial robots installations will increase in general, this will not have a negative impact on employment.

6. Discussion

In this paper, we have focused on the changes due to Covid-19, as we expected that the pandemic had a positive impact on the manufacturing sector in terms of accelerating progress toward robotization.

Hereinafter we provide answers and reflections related to the proposed research questions.

1) How did the industrial robots installations change due to the Covid-19 pandemic impacts and how did employment, output of workers, and labor productivity change in the manufacturing sector in the last ten years?

In the period of the most severe Covid-19 pandemic crisis impacts (2019 and 2020), we observe a decline in the number of industrial robots installations, whereas in 2021 and 2022 the number of industrial robots installations increased.

Data for the observed 10-year period between 2013 and 2022 show that on average (AAGR) the number of industrial robots installations grew, whereas the changes in employment, output of workers, and labor productivity in the manufacturing sector are almost negligible, but show minor increases in employment and output of workers, and minor decrease in labor productivity.

According to the trends presented in Figure 1, we can also indicate mutual changes in the observed data. Namely, when the number of industrial robots installations and employment grow, labor productivity declines. But labour productivity decline is not in line with the observations of Rojko et al. (2020) which is probably due to the fact that for the same amount of output, more employees and robots are available.

2) What were the impacts of robotization on employment, output of workers, and labor productivity in the manufacturing sector during the period of Covid-19 and earlier?

Thus, the identified impacts of robotization on selected economic indicators support the relationships identified on the basis of trend analysis. But cross-correlation analysis also enabled us to see how this impact is expressed when time lags are considered as well. On this basis, cross-correlation analysis showed that an increase in the number of installed robots most certainly leads to an increase in manufacturing employment about one year later, whereas about two years later employment in manufacturing decreases. Furthermore, the results also showed that immediately after the number of installed robots increases, the output of workers in the manufacturing sector increases as well, although an increase in the number of installed robots leads to a decrease in the output of workers about two years later. Finally, an increase in the number of installed robots leads to a decrease in labour productivity about one year later.

3) What are the projected forthcoming correlative occurrences in manufacturing employment, output of workers, labour productivity, and robotization?

Using VAR analysis, we were also able to project forthcoming correlative occurrences in manufacturing employment, output of workers, labour productivity, and robotization. The 10-year forecasts show that we can still expect fluctuations in all of the observed indicators, but the mutual interdependence between the growth of the number of industrial robots installations and economic indicators for the manufacturing sector will be maintained. The forecast projects another crisis to occur, which will have an impact on the decline in the number of industrial robots installations and consequently on the employment and output of workers. In the crisis period, this should lead to an increase or minor decline in productivity, which is both reasonable and expected. Nonetheless projecting another crisis impacts is problematic, but predicted due to the use of only data for 10 years including the period of the recent Covid-19 crisis. Despite this fact, this prediction shows that in general employment would not be decreased as a consequence of the increase in the number of industrial robots installations, which means that there is a bright future for human workers in the industry (according to the directions for transition to Industry 5.0 by e.g. Nahavandi (2019)) in any case.

7. Conclusion

Our results show, that when the number of industrial robots installations and employment grow, labour productivity declines which is probably due to the fact that for the same or lower amount of output, more employees and robots are available. For this reason in future research, we should include also data on manufacturing demand, because the data over the last 10 years show that productivity has contracted when the number of employees and the number of robots installed increases. A combination of used data and manufacturing demand would thus show if there really exists a negative effect on productivity as now indicated. Or this is indicated because demand has not risen (is not rising) enough to allow productivity to rise, despite the potential, and therefore we see an absence of considering also manufacturing demand data as an opportunity for improvement of our research.

Looking at the trends before the Covid-19 pandemic, the number of industrial robots installations steadily increased, however, a pandemic starting in 2019 and continuing into 2020 has led to a decline in their number. For this reason, we also should include a wider historic time period in our future research to exclude the distraction of the Covid-19 period and thus provide a more realistic picture of past developments and forecasts for the manufacturing sector.

To conclude, analysts expect (IFR, 2022a) that in the near future manufacturing sector will face a lack of skilled staff, while also our projections show continued demand for employees in the manufacturing sector despite robotization, and for this reason, the policy implication of our research is that education offer and interest in this area should increase. This is also important since technology advances rapidly and AI is opening up new use cases and improves performance in existing ones. Lastly, due to demographic changes an inevitable lack of employees will lead to decreased number of workers also in manufacturing, and for this reason, robotization is necessary. And is not necessary not only in manufacturing but also in other sectors, to enable the development of new business models. Therefore human workers should not be afraid of competition by robots, but get educated to exploit robots' potential, as was the case of good practice in healthcare during the Covid-19 pandemic.

References

1. BLS (2023). *Handbook of Methods*. U.S. Bureau of Labor Statistics: Washington. https://www.bls.gov/opub/hom/about.htm.
2. Compagnucci, F., Gentili, A., Valentini, E., Gallegati, M. (2019). Robotization and labour dislocation in the manufacturing sectors of OECD countries: a panel VAR approach, *Applied Economics*, 51 (57), 6127-6138. https://doi.org/10.1080/00036846.2019.1659499
3. Essentra (2019). *A guide to Industry 4.0 in the US*. (23. Jan.). https://www.essentracomponents.com/en-us/news/trends/industry-40/a-guide-to-industry-4-0-in-the-us

4. FRED (2023). *Manufacturing Sector: Employment for All Workers, Labor Productivity (Output per Hour) for All Workers, Real Sectoral Output for All Workers.* https://fred.stlouisfed.org/graph/?g=4qpY

5. Germán Frank, A., Santos Dalenogare, L., Fabián Ayala, N. (2019). Industry 4.0 technologies: Implementation patterns in manufacturing companies. *International Journal of Production Economics*, 210, 15-26. https://doi.org/10.1016/j.ijpe.2019.01.004

6. Ghobakhloo, M. (2018). The future of manufacturing industry: a strategic roadmap toward Industry 4.0. *Journal of Manufacturing Technology Management*, 29 (6), 910-936. https://doi.org/10.1108/JMTM-02-2018-0057

7. Guo, D., Li, M., Lyu, Z., Kang, K., Wu, W., Zhong, R. Y., Huang, G. Q. (2021). Synchroperation in industry 4.0 manufacturing. *International Journal of Production Economics*, 238, 108171. https://doi.org/10.1016/j.ijpe.2021.108171

8. Hanck, C., Arnold, M., Gerber, A., Schmelzer, M. (2019). *Introduction to Econometrics with R*. Department of Business Administration and Economics, University of Duisburg-Essen, Essen, Germany. https://www.econometrics-with-r.org/

9. IFR (2022a). *World Robotics 2022.* International Federation of Robotics. October 2022. https://ifr.org/downloads/press2018/2022_WR_extended_version.pdf

10. IFR (2022b). *China overtakes USA in robot density.* International Federation of Robotics. December 2022. https://ifr.org/ifr-press-releases/news/china-overtakes-usa-in-robot-density

11. IFR (2023). *Building Resilience for Europe through Automation*. International Federation of Robotics. June 2023. https://ifr.org/downloads/press2018/2023_06_28_IFR_Executive_Roundtable.pdf

12. ILO (2018). *Robots worldwide: The impact of automation on employment and trade*. International Labour Office. Research Department. Working paper No. 36. https://www.ilo.org/wcmsp5/groups/public/---dgreports/---inst/documents/publication/wcms_648063.pdf

13. ISO (2021). *Robotics — Vocabulary*. ISO 8373:2021. https://www.iso.org/standard/75539.html.

14. Javaid, M., Haleem, A., Pratap Singh, R., Ul Haq, M. I., Raina A., Suman R. (2020). Industry 5.0: Potential Applications in COVID-19. *Journal of Industrial Integration and Management*, 5 (4), 507-530. https://doi.org/10.1142/S2424862220500220

15. Johannessen, J. A. (2018). *Automation, Innovation and Economic Crisis, Surviving the Fourth Industrial Revolution*. Routledge, London.

16. Kaiser, M.S., Al Mamun, S., Mahmud, M., Tania, M. H. (2021). Healthcare Robots to Combat COVID-19. In: Santosh, K., Joshi, A. (eds). *COVID-19: Prediction, Decision-Making, and its Impacts.* Lecture Notes on Data Engineering and Communications Technologies, vol 60. Springer, Singapore. https://doi.org/10.1007/978-981-15-9682-7_10

17. Leng, J., Sha, W., Wang, B., Zheng, P., Zhuang, C., Liu, Q., Wuest, T., Mourtzis, D., Wang, L. (2022). Industry 5.0: Prospect and retrospect. *Journal of Manufacturing Systems*, 65, 279-295, https://doi.org/10.1016/j.jmsy.2022.09.017

18. Nahavandi, S. (2019). Industry 5.0—A Human-Centric Solution. *Sustainability*, 11 (16), 4371. https://doi.org/10.3390/su11164371

19. Raj, A., Dwivedi, G., Sharma, A., Lopes de Sousa Jabbour, A. B., Rajak, S. (2020). Barriers to the adoption of industry 4.0 technologies in the manufacturing sector: An inter-country comparative perspective. *International Journal of Production Economics*, 224, 107546. https://doi.org/10.1016/j.ijpe.2019.107546

20. Rojko, K., Erman, N., Jelovac, D. (2020). Impacts of the Transformation to Industry 4.0 in the Manufacturing Sector: The Case of the U.S. *Organizacija*, 53 (4), 3920, 287-305. https://doi.org/10.2478/orga-2020-0019

21. Shin Y. (2017). *Time Series Analysis in the Social Sciences: The Fundamentals*. Oakland: University of California Press.

22. Shumway RH, Stoffer DS. (2017). *Time Series Analysis and Its Applications: With R Examples. 4th ed.* Cham (CH): Springer.

23. World Economic Forum (2018). *Europe, Asia Lead the Way to the Factories of the Future*. https://www.weforum.org/press/2018/09/europe-asia-lead-the-way-to-the-factories-of-the-future/

24. Zhang P., Aikman S.N., Sun H. (2008). Two types of attitudes in ICT acceptance and use. *International Journal of Human-Computer Interaction*, 24 (7), 628–648. https://doi.org/10.1080/10447310802335482

dr.sc. Haris Hamidović, dipl.ing.el.[1]
dr.sc. Jasmina Kabil-Hamidović, dipl. defektolog logoped[2]
Amina Buljubašić, BA ing. el.[3]
Edina Šehić, dipl. ing. inf. teh.[4]

Preliminary communication

POSSIBLE USE OF THE NIST CYBER SECURITY FRAMEWORK IN HEALTHCARE INSTITUTIONS IN BOSNIA AND HERZEGOVINA

Abstract

In all business sectors, choosing the right security framework is critical to help define an organization's security posture, identify gaps, and develop strategies for improvement. The increasing reliance of healthcare organizations brings numerous benefits, but also exposes them to a greater number of malicious attacks from cyberspace. In this paper, we present the NIST Cybersecurity Framework, which can be of help to healthcare institutions in Bosnia and Herzegovina in determining priorities in solving cyber security challenges. While the NIST Cybersecurity Framework will not protect digital assets and data by itself, it can provide a guide for healthcare organizations to manage their own assets, gaining a complete view of their organization and its vulnerabilities. Using the NIST Cybersecurity Framework as a framework can also be helpful in protecting personal data that is processed in healthcare systems.

Key words: *NIST CSF, NIST Cybersecurity Framework, Health Data, Personal Data, Information Security, Risk Assessment.*

1. Introduction

According to the Law on Personal Data Protection of Bosnia and Herzegovina ("Official Gazette of BiH", no. 49/06, 76/11), a special category of personal data is considered to be all personal data that reveals, among other things, the health status of the data subject.

The obligation is enumerated that the data controller and, within the scope of its competence, the processor take care of data security, and take all technical and organizational measures and establish the rules of procedure that are

1 doc.dr., Visoka škola „Internacionalna poslovno-informaciona akademija" Tuzla, mr.haris.hamidovic@ieee.org
2 Klinika za bolesti uha, grla i nosa, Univerzitetski Klinički Centar Tuzla, jasminakabil@gmail.com
3 Visoka škola „Internacionalna poslovno-informaciona akademija" Tuzla, amina@ipi-akademija.ba
4 Visoka škola „Internacionalna poslovno-informaciona akademija" Tuzla, edina.salkanovic@gmail.com

necessary for the implementation of data protection law and other regulations related to data protection and secrecy. The controller and the data processor are obliged to take measures against unauthorized or accidental access to personal data, alteration, destruction or loss of data, unauthorized transfer, other forms of unlawful data processing, as well as measures against the misuse of personal data. This obligation remains in force even after the data processing is completed.

Regulation on the Manner of Storage and Special Measures of Technical Protection of Personal Data ("Official Gazette of BiH" No. 67/09) stipulates, among other things, that the Personal Data Security Plan must contains organizational and technical measures that must ensure:

a) that only authorized persons can know personal data - confidentiality;

b) data to remain unchanged, complete and up-to-date - integrity during the processing;

c) that the data are constantly available and can be processed correctly - availability;

d) that the origin of the personal data can be determined at any time - authenticity;

e) it can be determined who, when, what personal data and how it was processed - the possibility of revision;

f) the procedure for the processing of personal data is complete, up-to-date and appropriately recorded-transparency.

Failure to adopt a formal security plan, and not to take the necessary measures and procedures against unauthorized or accidental access, alteration, destruction or loss, unauthorized transfer, other forms of illegal processing, as well as measures against misuse of personal data, constitutes an offence for which penalties of up to 50,000 EUR are attributed in Bosnia and Herzegovina.

The development of an information security program that enables the protection of information assets and active compliance with legal data protection obligations can be a challenging task. In addressing these challenges, good information security practices presented in international standards and frameworks can be helpful to organizations.

In this paper, we present the NIST Cybersecurity Framework, which can be of help to healthcare institutions in Bosnia and Herzegovina in determining priorities in solving cyber security challenges.

2. Information security governance frameworks

Information security practitioners state that while every organization may have its unique missions, objectives, business models, tolerance for risk, and so on, organizations need not invent information security governance frameworks from scratch to manage their information security objectives. In the context of strategy development, some organizations may already have a suitable control framework in place, while others might not. While it is not always necessary for an organization to select an industry control framework, it is advantageous to do so. Industry-standard control frameworks have been in use in many organizations, and they are regularly updated to reflect changing business practices, emerging threats, and new technologies. (Gregory, 2022)

In addition, it is pointed out that it is often considered a mistake to select a control framework because of the presence or absence of a small number of specific controls. Usually, such selection is made on the assumption that control frameworks are rigid and inflexible. Instead, the strategist should take a different approach: select a control framework based on industry alignment and then institute a process for developing additional controls based on the results of risk assessments. Indeed, this is exactly the approach described in BAS ISO/IEC 27001, as well as in the NIST Cybersecurity Framework. Organizations should start with a well-known control framework and then create additional controls, if needed, to address risks specific to the organization. (Gregory, 2022)

When it comes to the series of ISO 27000 standards and the specifics of their application in healthcare providers, the International Organization for Standardization (ISO) released ISO 27799 to define guidelines to support the interpretation and implementation in health informatics of ISO/IEC 27002, and it is a companion to that standard. ISO 27799 specifies a set of detailed controls for managing health information security and provides health information security best practice guidelines. (Hamidovic, Kabil, 2011) In this paper, we will focus more on the second of the previously mentioned information security control frameworks, which can also be useful when developing information security programs for health service providers - NIST Cybersecurity Framework.

3. NIST Cybersecurity Framework in brief

Modern states depends on the reliable functioning of critical infrastructure. Cybersecurity threats exploit the increased complexity and connectivity of critical infrastructure systems, placing the states's security, economy, and public safety and health at risk. To better address these risks the US National Institute of Standards and Technology (NIST) developed Cybersecurity Framework also known as NIST CSF. While this document was developed to improve cybersecurity risk management in critical infrastructure, the Framework can be used by organizations in any sector or community. (NIST, 2018) NIST further states

that „the Framework Core provides a set of activities to achieve specific cybersecurity outcomes, and references examples of guidance to achieve those outcomes." The Framework Core comprises four elements: Functions, Categories, Subcategories, and Informative References, as presented on Figure 1. (NIST, 2018)

Figure 1. NIST Cybersecurity Framework Core (NIST, 2018)

NIST also points out that the component Functions "organize basic cybersecurity activities at their highest level. These Functions are Identify, Protect, Detect, Respond, and Recover. They aid an organization in expressing its management of cybersecurity risk by organizing information, enabling risk management decisions, addressing threats, and improving by learning from previous activities." (NIST, 2018)

For example, the Identify function has the role of developing an organizational understanding to manage cybersecurity risk to systems, people, assets, data, and capabilities. Within this function, the following categories - subdivisions of a function into groups of cybersecurity outcomes closely tied to programmatic needs and particular activities - are listed:

- Asset Management
- Business Environment
- Governance
- Risk Assessment
- Risk Management Strategy
- Supply Chain Risk Management

It is also important to point out that the NIST CSF Functions and Categories each have a unique alphabetical identifier, as shown in Table 1.

Table 1. Function and Category Unique Identifiers (NIST, 2018)

Unique Identifier	Function	Category Unique Identifier	Category
ID	Identify	ID.AM	Asset Management
		ID.BE	Business Environment
		ID.GV	Governance
		ID.RA	Risk Assessment
		ID.RM	Risk Management Strategy
		ID.SC	Supply Chain Risk Management
PR	Protect	PR.AC	Identity Management and Access Control
		PR.AT	Awareness and Training
		PR.DS	Data Security
		PR.IP	Information Protection Processes and Procedures
		PR.MA	Maintenance
		PR.PT	Protective Technology
DE	Detect	DE.AE	Anomalies and Events
		DE.CM	Security Continuous Monitoring
		DE.DP	Detection Processes
RS	Respond	RS.RP	Response Planning
		RS.CO	Communications
		RS.AN	Analysis
		RS.MI	Mitigation
		RS.IM	Improvements
RC	Recover	RC.RP	Recovery Planning
		RC.IM	Improvements
		RC.CO	Communications

Furthermore, each of the categories contains corresponding Subcategories. For example, previously mentioned ID.AM - Asset Management category contains the following subcategories:

- ID.AM-1: Physical devices and systems within the organization are inventoried
- ID.AM-2: Software platforms and applications within the organization are inventoried
- ID.AM-3: Organizational communication and data flows are mapped

- ID.AM-4: External information systems are catalogued
- ID.AM-5: Resources (e.g., hardware, devices, data, time, personnel, and software) are prioritized based on their classification, criticality, and business value
- ID.AM-6: Cybersecurity roles and responsibilities for the entire workforce and third-party stakeholders (e.g., suppliers, customers, partners) are established

Useful Informative References are listed for each of the subcategories. For example, the following Informative References are listed for previously mentioned the subcategory ID.AM-1:

- CIS CSC 1
- COBIT 5 BAI09.01, BAI09.02
- ISA 62443-2-1:2009 4.2.3.4
- ISA 62443-3-3:2013 SR 7.8
- ISO/IEC 27001:2013 A.8.1.1, A.8.1.2
- NIST SP 800-53 Rev. 4 CM-8, PM-5

When it comes to other categories, below is a brief explanation of each of them, and a detailed explanation with subcategories and other useful information can be found on the publicly available NIST Cybersecurity Framework (NIST, 2018):

- PR - Protect – Develop and implement appropriate safeguards to ensure delivery of critical services.
- DE - Detect – Develop and implement appropriate activities to identify the occurrence of a cybersecurity event.
- RS - Respond – Develop and implement appropriate activities to take action regarding a detected cybersecurity incident.
- RC - Recover – Develop and implement appropriate activities to maintain plans for resilience and to restore any capabilities or services that were impaired due to a cybersecurity incident.

4. Methodology for making improvements to an information security program

The NIST CSF is an outcomes-based security management and control framework that guides an organization to understand its existing maturity levels, assess risk, identify gaps, and develop action plans for strategic improvement. (Gregory, 2022)

The CSF contains a methodology for establishing or making improvements to an information security program. The steps in this methodology are (Gregory, 2022):

- Step 1: Prioritize and Scope. Here, the organization determines which business units or business processes are part of the scope of a new or improving program.
- Step 2: Orient. The organization identifies assets that are in scope for the program; the risk approach; and applicable laws, regulations, and other legal obligations.
- Step 3: Create a Current Profile. The organization identifies the category and subcategory outcomes from the Framework Core (the CSF controls) that are currently in place.
- Step 4: Conduct a Risk Assessment. Here, the organization conducts a risk assessment covering the entire scope of the program. This is an ordinary risk assessment, where threats (together with their likelihood and impact) are identified for each asset or asset group.
- Step 5: Create a Target Profile. The organization determines the desired future states for each of the framework's categories and subcategories (the controls). This includes the desired tier level for each category and subcategory.
- Step 6: Determine, Analyze, and Prioritize Gaps The organization compares the current profile (developed in step 3) and the target profile (step 5) and develops a list of gaps. These gaps are analyzed and prioritized, and the necessary resources to close gaps are identified. A cost-benefit analysis is performed, which also helps with prioritization.
- Step 7: Implement Action Plan The organization develops plans to close gaps identified and analyzed in step 6. After action plans have been completed, controls are monitored for compliance.

5. Calculation of the degree of compliance with NIST CSF

Research conducted in the USA shows that only 44 percent of healthcare organizations, including hospitals and health systems, adhere to NIST Cybersecurity Framework standards, despite a drastic increase in healthcare data breaches in recent years. (Davis, 2020) When it comes to our country, although there are no official statistical data regarding the compliance of healthcare providers with good information security practices, we can assume that the situation is significantly worse than in the USA.

The NIST Cybersecurity Framework should first of all be seen as a good tool for building and maintaining an information security program. Considering that not all information assets are equally critical for health care providers, and that organizations have limited resources that they can use for these purposes, it is important to assess where we are currently in terms of compliance with good practices, where we want to be, and create a plan for compliance.

When it comes to the numerical calculation of the degree of compliance with the NIST CSF, a practical example can be found in the work of Ibrahim et al.,

where the authors state that in their case study, the compliance for each measure was based on the responses provided by the participants. They were graded as either, Complaint, Partially Compliant, or Non-Compliant; and each was assigned scores of either 10, 5, or 0, respectively, for each core function's subcategory. Therefore, the total compliance score C for each core function's category can be defined as (Ibrahim et al., 2018):

$$C = \frac{\Sigma R}{\Sigma N' \times 10}$$

where R is the compliance score for each category of the respective Core Function. (Ibrahim et al., 2018).

Using a similar approach, an initial assessment of compliance with NIST CSF controls was performed in one of the organizations in Bosnia and Herzegovina, with the aim of obtaining a picture of the current state and creating a program of activities towards the desired state. In the specific case, the degree of compliance is scaled on a scale of 0-1. The results of the initial assessment are shown in Figure 2.

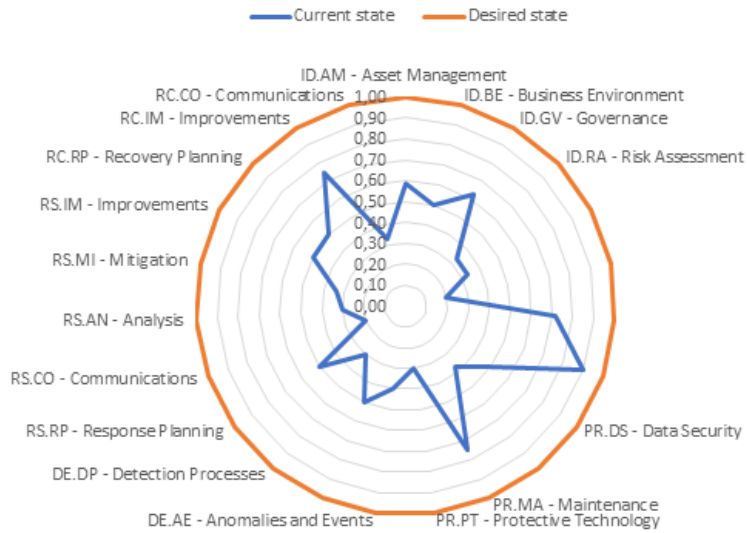


Figure 2. Example of initial assessment of compliance with NIST CSF

Based on the initial assessment, the organization in question made an action plan to increase the level of compliance with the NIST CSF in the next three years.

The ISACA Cybersecurity Audit Certificate Study Guide may also be a useful tool for evaluators of compliance with information security good practices based on the NIST CSF. (ISACA,2018)

6. Conclusion

Merely investing in information security technology solutions is not enough, as information security requires consideration of human and process components in addition to technology. Organizations must commit to implementing a robust information security program supported by frameworks that help identify and manage information security risks consistently and effectively. One such framework is the National Institute of Standards and Technology Cybersecurity Framework for Improving Critical Infrastructure, which has been adopted by many healthcare organizations in the developed countries of the world, especially in the US, to combat the challenges of maintaining high security standards in an industry facing extreme cyber risk. This article briefly discusses how the NIST Cybersecurity Framework can be applied to healthcare organizations in Bosnia and Herzegovina and how they can leverage it to achieve security posture maturity.

References

1. Davis J. (2020). Just 44% of Healthcare Providers Meet NIST Cybersecurity Standards, TechTarget URL: https://healthitsecurity.com/news/just-44-of-healthcare-providers-meet-nist-cybersecurity-standards Date of access: 29.06.2023.
2. Gregory P. H. (2022). *CISM Certified Information Security Manager All-in-One Exam Guide*, McGraw Hill
3. Hamidovic, H., Kabil, J. (2011). *An Introduction to Information Security Management in Health Care Organizations*, ISACA Journal
4. Ibrahim et al. (2018). *A security review of local government using NIST CSF: a case study*, The Journal of Supercomputing
5. ISACA. (2018). *Cybersecurity Audit Certificate Study Guide*, Information Systems Audit and Control Association
6. ISO. (2016). ISO 27799:2016, *Health informatics — Information security management in health using ISO/IEC 27002*
7. NIST. (2018). *Framework for Improving Critical Infrastructure Cybersecurity*, National Institute of Standards and Technology

Dino Arnaut, PhD[1]
Damir Bećirović, PhD[2]

Original scientific paper

ANALYSIS OF HR PLATFORMS IN BOSNIA AND HERZEGOVINA

Abstract

The human resource departments are under pressure to adjust to technological advancement, as employing new employees is an important element in the human resource management (HRM) process and significantly increases the success of the company. E-recruitment is just one of the many HR issues for which the Internet has emerged as a crucial tool. This goal of this paper is to assess the variables that influence people's attitudes and intentions for using electronic recruitment via HR platforms in Bosnia and Herzegovina. The research was conducted on a suitable sample using the CAWI method from respondents who are jobs seekers and had the opportunity to use e-recruitment. A questionnaire was created to analyze applicants' intention to use HR platforms. The findings demonstrate that most respondents frequently use internet platforms and websites for recruitment (employment). Most significantly, respondents strongly indicate that they will continue to use these sites. Respondents exhibit an incredibly favorable attitude about internet platforms and websites (HR platforms) for recruitment (employment). The variables ease of use, usefulness, and enjoyment using online platforms/websites for recruitment are all perceived positively by respondents. The results of correlation and regression analysis demonstrate that attitudes towards the platforms are the main determinant of whether a person intends to use online HR platforms or websites for recruiting (employment).

Key words: *HR Platforms, E-Recruitment, TAM, Intention to Use, Bosnia and Herzegovina.*

1. Introduction

Since hiring new personnel is a crucial step in the human resource management (HRM) process and plays a significant role in increasing the success of the firm, the human resource departments are under pressure to adapt to technological development. Technology advancements are continuously enhancing the human resource process of employee recruitment and hiring (White,

1 Professor at International Business Information Academy Tuzla, Bosnia and Herzegovina, arnaut.dino@gmail.com
2 Professor at International Business Information Academy Tuzla, Bosnia and Herzegovina, damirbeci@hotmail.com

2018). Technology has the potential to enhance the hiring process, and smart technology's accuracy will enable recruiters to work more effectively and quickly (White, 2021). It is now simpler to apply for jobs and identify suitable candidates anywhere in the world thanks to technologies like applicant tracking systems and new AI algorithms (White, 2017). According to a Pew Investigate Centre survey, 54 percent of Americans use the internet to research available jobs in 2016, up from only 26 percent in 2005, indicating a significant growth in the number of online job seekers (Smith, 2015). Nearly a third of Americans have sought for work in the past two years, and 79 percent of them used online job search tools in their most recent job search (Smith, 2015).

According to Handlogten (2009), the Internet was first used as a recruiting tool in the middle of the 1990s. The official online sourcing of employment information is described by the word's online recruitment, e-recruiting, cybercruiting, or Internet recruiting (Galanaki, 2002). The way organizations approach recruiting for human resources (HR) has been significantly altered by the use of the Internet (Chapman et al., 2005). Many organizations—both big and small ones—use e-recruitment. E-recruitment has advantages for firms because it provides recruitment management more freedom in reaching out to potential candidates using internet channels like e-mails and Short Message Services (SMS) (Kapse et al., 2012).

The development of human capital and the attraction of talent depend heavily on the recruitment of human resources (Liviens and Chapman, 2010). The impact of technological improvements on various organizational operations and functions is widespread. The expansion of internet users and technological improvements are having an impact on a lot of human resource activities, making it crucial to hire the proper personnel (Tong and Sivanand, 2005). E-recruitment, sometimes known as online recruiting, is the practice of corporations conducting their hiring processes using web-based tools and technology, such as an organization's public website or niche websites like Monster.com (Kering and Kettley, 2003). The e-recruitment system has changed the conventional hiring procedure into a collaborative, time- and space-independent one (Holm, 2012). Websites for job searching provide enterprises and job seekers convenience, cost savings, and more efficient and effective solutions (Leonard, 2000). In the current context, e-recruitment sources are becoming more and more important for attracting applications (Holm, 2012).

E-HRM or Electronic Human Resource Management improves the effectiveness and efficiency of the HR system by reducing cycle times, sharpening data, and eliminating HR staff. E-recruitment is one of the ways that e-HRM enables the HR system to add value for the firm in new ways (Lengnick-Hall & Moritz, 2003). Because of the increased expenses of advertising as well as the simplicity and speed of identifying more eligible candidates, businesses are developing their own websites for e-recruitment in ever-better ways (Cober et al., 2004).

Researchers and academics in the past have identified several elements that affect employers and job seekers' use of e-recruitment. Some have noted that

firms can reach a varied and larger pool of job seekers thanks to e-recruitment (Doherty, 2010). E-recruitment, according to Hafeez and Farooq (2017), has a beneficial effect in luring candidates. The development of e-recruitment is aided by several factors. According to Leonard (2000), one of the reasons for the expansion of e-recruitment is the cheaper cost. Additionally, studies have shown that job seekers favor excellent websites on the web over conventional job advertising (Zusman and Landis, 2002; Hafeez and Farooq, 2017). Numerous studies on the adoption of e-recruitment have been conducted, and many of these studies employed the Technology Acceptance Model (TAM) to determine the variables influencing the intention to adopt e-recruitment systems. Perceived usefulness, perceived simplicity of use, attitude, and perceived danger are among the characteristics identified as positively affecting the adoption of e-recruitment (Yoon, 2009; Kashi and Zheng, 2013). The use of e-recruitment is expanding quickly and is essential for drawing in a candidate pool.

The literature's advice on how e-recruitment benefits any business in various ways served as the inspiration for this paper. However, many organizations have not yet fully embraced this strategy. From an organizational standpoint, scholarly research on e-recruitment hasn't gotten much attention (Parry & Tyson, 2008). Despite the widespread use of the Internet by both job seekers and businesses, research on the use of Internet technology in recruitment is scarce (Cho, Lee & Liu, 2011). Both job seekers and recruiters will incur much lower costs using this strategy (Suvankulov, 2010). Because online recruitment processes have benefits for both the organization and the applicants, career portals for companies like Shell, Coca-Cola, and Nike don't even include the option to apply via email (Handlogten, 2009). Approximately 4 million job seekers launch their browsers each day to look for employment online. It is completely normal, especially among students, to utilize the Internet to learn about potential employment opportunities (Tepe, 2011). 74 percent of job seekers use companies' career websites, and 94 percent of respondents said that employers should have a special page on at least one social network in addition to the organization's career website, according to a study by Ziesing (2013) (Ziesing, 2013) that surveyed students and graduates in the US, Europe, and Asia about their attitudes toward online, social, and mobile recruitment.

2. Literature review

The primary goal of recruitment is to locate and draw in prospective employees. The fundamental purpose of recruitment is to bring valuable human capital into the company (Barber, 1998). According to estimates, hiring only from online sources will cost the company roughly one-twentieth as much as hiring through traditional channels (Cappelli, 2001). This is comparable to Maurer and Liu's (2007) estimate that web-based hiring can reduce costs by up to 87 percent for each new person employed by a firm (Maurer & Liu, 2007). E-recruitment is defined differently by several authors (Galanaki, 2002). The social networking sites are successful and valuable for recruiting, according to many

recruiters and HR staff, and they might become a significant strategy if not in the following generation (Córdoba-Pachón & Teng, 2010).

Several aspects are taken into consideration when developing theories and literature on the intention to accept or utilize technologies (Davis et al., 1989; Venkatesh et al., 2003). The most popular paradigm, the Technology Acceptance Model (TAM), comprises two components: perceived usefulness and perceived usability (Davis et al., 1989). Many scholars have utilized the TAM to forecast and comprehend the adoption of new technologies because it helps explain the intention or behavior to use them (Yoon, 2009; Wu and Chen, 2017). The Theory of Reasoned Action (TRA), which can be used to understand and predict behavior, is extended by the TAM (Ajzen and Fishbein, 1980). The TRA considers behavioral intentions, and Ajzen and Fishbein (1980) noted that a person's past intention can influence their actual behavior. Davis et al. (1989), using the TAM, emphasized that an individual's actual adoption or usage of technology is a response that may be anticipated or explained by the individual's motivation. The Unified Theory of Acceptance and Use of Technology was expanded further by Venkatesh et al. in 2003. That model comprised the TAM and TRA. It is possible to determine the likelihood of new technology adoptions and comprehend the aspects that contribute to their acceptance by using the model created by Venkatesh et al. (2003). To illustrate the purpose of using systems like e-recruitment systems, the TAM and Unified Theory of Acceptance and Use of Technology models might be used.

In 2008, Thompsons et al. conducted research on how organizations' websites affect potential job seekers. The usability of the website, the organization's web appeal, participant impressions of the organization, and willingness to pursue employment were all evaluated by 182 participants as they looked at an online job advertisement. It was discovered that while both formatting attractiveness and usability of online recruitment materials influenced participants' inclinations to pursue jobs, formatting was more significant than usability (Thompson, Braddy & Wuensch, 2008).

A few constructs related to behavioral intention to use and actual system use were supported by prior research on the intention to use new technologies and systems (Teo and Milutinovic, 2015; Joo et al., 2018). According to a study by Teo and Milutinovic (2015), attitude has a direct and beneficial impact on one's intention to use technology. Self-efficacy, perceived ease of use, and perceived usefulness all had a favorable impact on the intention to utilize new technology, according to another study by Joo et al. (2018). Wu and Chen (2017) discovered that the intention to employ new systems and technologies is favorably influenced by both attitude and perceived utility. The intention to adopt new technology can also be influenced by culture, according to studies from the past. According to a study by Tarhini et al. (2015), British respondents adopted technology at a rate that was noticeably higher than Lebanese respondents. The findings revealed that adoption in the British setting was, at 36 percent, much higher but also modest. In the study by Tarhini et al. (2015), there were variations between the British and Lebanese respondents in terms of perceived utility and convenience of use. Similar to this, earlier research discovered a favorable influence of

a number of variables on intention to employ electronic recruiting. El Ouirdi et al. (2016) study discovered a favorable relationship between effort expectation, performance expectation, and social influence on propensity to adopt new technology. According to the signaling theory, Kashi and Zheng (2013) discovered that candidates' impressions of an organization's website stimulated their interest in the company and increased their desire to employ e-recruitment. As a result, there are several things that can affect someone's decision to use or adopt an electronic recruitment system.

Using the Davis (1989) technology model as a framework, Brahmana and Brahmana (2011) conducted a study in Indonesia in 2011 to investigate the factors that affect job seekers' intentions to use e-recruitment. They proposed perceived usefulness, perceived ease of use, and perceived enjoyment as the determinants of the job seekers' intention and discovered that all three variables influenced the decision of job seekers' intention to use. Additionally, in 2012, Odumeru conducted a study for Nigeria using a modified technology acceptance model to identify candidates who intended to use electronic recruitment (Odumeru, 2012). In 2013, Kashi and Zheng used a sample of 332 job applicants to study the intentions of job applicants to utilize e-recruitment to apply for a job in Iran using a modified technology acceptance model (Kashi & Zheng, 2013). The findings revealed that applicants' behavioral intentions to utilize e-recruitment were significantly influenced by perceived utility, however these intentions were not significantly influenced by perceived simplicity of use.

One of the constructs in the TAM is perceived utility. Perceived usefulness is the *extent to which a person believes that utilizing a certain system would increase his or her job performance*, according to Davis et al. (1989). Several earlier studies revealed that perceived usefulness was a predictor of behavioral intention based on the TAM model by Davis et al. (1989) (Kashi and Zheng, 2013; Park et al., 2014). Perceived usefulness was found to be positively connected to behavioral intention to utilize technology in a study based on the TAM model by Park et al. (2014). Additional studies discovered that applicants' behavioral desire to use electronic or e-services was positively and significantly impacted by perceived usefulness (Horst et al., 2007; Kashi and Zheng, 2013). The findings of a study by Amoako-Gyampah (2007) further revealed that increasing people's perceptions of the technology's utility and relevance will encourage their use of it.

Numerous research on the intention to use e-recruitment have been conducted (Lin, 2010; Brahmana and Brahmana, 2013). According to a study by Brahmana and Brahmana (2013) that was based on the TAM model, job searchers' inclination to use an e-recruitment system was affected by their perception of its utility. Similar findings were made by Lin (2010) who discovered that attitude toward intention to use an e-recruitment system was significantly influenced by perceived utility. According to the findings of a different study by Priyadarshini et al. (2017), information quality factors positively influence perceived utility, and perceived usefulness in turn influences attitude toward a website. The following hypothesis was developed for testing in the current study based on the previous research findings mentioned above and logically expanding them.

3. Research on HR platforms

The literature summarized in Table 1, which illustrates the relevance of the selected factors that influence the intention to utilize e-recruitment for information gathering, was used to support the construction of the study model factors. The model shown in Figure 1 looks at how perceived ease of use (PEU), perceived usefulness (PU), and perceived enjoyment (PE) relate to one another. The model is built using previous research models that have been published in the literature on intention to use of e-recruitment.

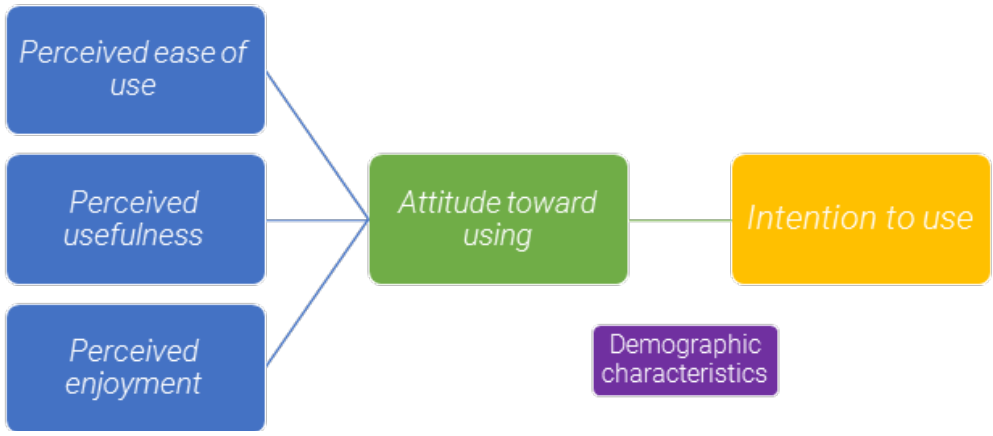


Figure 1. Research model
Source: Adapted from Alsultanny & Alotaibi (2015)

The relevance of the elements selected to influence the intention to use e-recruitment for information collection is shown in Table 1, which summarizes the associated research on e-recruitment intention to use.

Table 1. Literature related factors intention to use e-recruitment.

Factors effect intention to use	Supported literature
Perceived ease of use	Williamson et al., 2003; Davis, 1989
Perceived usefulness	Palmer, 2002
Perceived enjoyment	Sun and Zhang, 2006
Attitude toward using	Odumeru, 2012; Chen and Wells, 1999.
Intention to use	Davis, 1989; Venkatesh et al., 2003; Brahmana and Brahmana, 2013

Source: Adapted from Alsultanny & Alotaibi (2015)

4. Methodology and sample

The research was conducted and based on collected data (primary data). A survey questionnaire was used as a data collection tool. The research was conducted on a suitable sample using the CAWI method. A total of 121 respondents responded to the questionnaire, and the questionnaire was created in such a way that there were no missing answers (all answer fields were required in order to submit the survey). The research was conducted in July 2023 in the entire territory of Bosnia and Herzegovina.

Table 2 shows the structure of the respondents according to the observed socio-demographic characteristics.

Table 2. Sample characteristics

Gender	Male	Female	
	25.6%	74.4%	
Age	Mean		
	26.96		
Employment status	Student/Unemployed	Employed	
	7.4%	92.6%	
Level of education	High school	Graduate study	Master's degree
	4.1%	94.2%	1.7%

Source: Authors

A measurement instrument developed by Alsultanny & Alotaibi (2015) was used to measure the constructs in the model. A five-point Likert scale (from total disagreement to total agreement) was used. The composite variables Perceived ease of use, Perceived usefulness, Perceived enjoyment, Attitude toward using and Intention to use were calculated as the arithmetic means of the values of the corresponding items.

The reliability of the measurement scales used was measured by calculating the Cronbach's Alpha coefficient. Table 3 gives the values of the Cronbach's alpha coefficients for the model constructs.

Table 3. Cronbach's Alpha analysis of measurement scales

Construct	Number of items	Cronbach Alpha
Perceived ease of use	4	0.889
Perceived usefulness	6	0.841
Perceived enjoyment	3	0.889
Attitude toward using	3	0.796
Intention to use	3	0.701

Source: Authors

From Table 3, all measurement scales have good internal consistency, and show a good level of reliability. Cronbach's Alpha coefficient values are above 0.70.

Data analysis was performed using descriptive statistical analysis, correlation analysis and regression analysis.

5. Research results

The analysis of the research results begins with a descriptive statistical analysis, which is shown in Table 4. The mean values of the respondents' responses for all items that are part of the observed latent variables are given.

Table 4. Descriptive statistical analysis

Construct	Number of items	Mean
Perceived ease of use	4	4.61
Perceived usefulness	6	4.34
Perceived enjoyment	3	4.13
Attitude toward using	3	4.80
Intention to use	3	4.85

Source: Authors

We see that the respondents have a very high degree of agreement with the statements related to all observed constructs. The average value of respondents' answers is in all cases greater than 4. We have the highest degree of agreement for the construct *Intention to use* (4.85), and the lowest for the construct *Perceived enjoyment* (4.13).

Table 5 gives the respondents' answers to the question: How often do you visit online platforms/websites for recruitment (employment)? The results show that the largest number of respondents (65.3%) constantly visit online platforms/websites for recruitment (employment).

Table 5. Frequency of visits to online platforms/websites for recruitment (employment)

	Sometimes	I follow	Constantly
How often do you visit online platforms / websites for recruitment (employment)?	7.40%	27.3%	65.3%

Source: Authors

Figure 2 shows frequency of visits to different online platforms/websites for recruitment (employment).

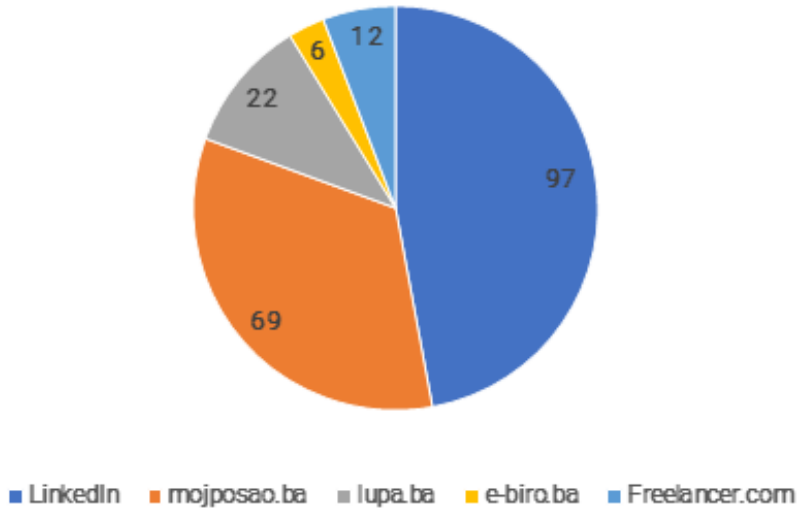


Figure 2. Frequency of visits to different online platforms/websites for recruitment (employment)
Source: Authors

From the respondents' answers (97%), we see that LinkedIn is the most popular online platform for recruitment (employment). The second site is mojposao.ba, which is visited by 69% of respondents.

Table 6 shows the correlation analysis between the observed variables from our theoretical model. The relationship between the observed variables was in-

vestigated using the Pearson correlation coefficient. Compared to Intention to use, significant correlation coefficients are shown for all variables. The values of the correlation coefficients suggest a middle level of correlation of these variables with Intention to use, except for *Attitude toward using* that have a high level of correlation (Cohen, 1988). In relation to *Attitude toward using*, *Perceived usefulness* and *Perceived enjoyment*, they have a high level of correlation.

Table 6. Correlations among variables

Variables	1	2	3	4	5
Intention to use	1				
Attitude toward using	0.474**	1			
Perceived ease of use	0.348**	0.369**	1		
Perceived usefulness	0.358**	0.586**	0.715**	1	
Perceived enjoyment	0.334**	0.520**	0.492**	0.593**	1
** p<0.01					

Source: Authors

The results of Regression analysis are presented in Table 7. *Intention to use* was taken as a dependent variable in the model. F values indicate that the model is statistically significant. The value of R-square is 0.262, which means that it explains 26.2% of the variance of the dependent variable. In this model, the only statistically significant variable was the *Attitude toward using*.

Table 7. Regression analysis (Intention to use)

Variables	Model
Perceived ease of use	0.221
Perceived usefulness	0.700
Perceived enjoyment	0.560
Attitude toward using	0.405**
R-square	0.262
Adjusted R-square	0.237
F-value	10.313**

** p<0.01; * p<0.05. Beta coefficients are standardized
Source: Authors

Table 8 presents the results of the regression analysis in which the dependent variable is *Attitude toward using*. F values indicate that the model is statistically significant. The value of R-square is 0.399, which means that it explains 39.9% of the variance of the dependent variable. In this model, statistically significant variable were *Perceived usefulness* and *Perceived enjoyment*.

Table 8. Regression analysis (Attitude toward using)

Variables	Model
Perceived ease of use	0.141
Perceived usefulness	0.521**
Perceived enjoyment	0.281**
R-square	0.399
Adjusted R-square	0.384
F-value	25.903**

** p<0.01; * p<0.05. Beta coefficients are standardized
Source: Authors

6. Discussion and Conclusion

The research results show that the largest number of respondents constantly visit and follow online platforms/websites for recruitment (employment). Most importantly, respondents show a strong intention to use these platforms in the future. When it comes to attitudes towards online platforms/websites for recruitment (employment), respondents show an extremely positive attitude. At the same time, respondents perceive very positively the variables: ease of use, usefulness and enjoyment online platforms/websites for recruitment (employment).

The results of correlation and regression analysis show that the intention to use online platforms/websites for recruitment (employment) primarily depends on the attitudes towards the mentioned platforms. Ease of use, usefulness and enjoyment have no significant impact. On the other hand, Perceived usefulness and Perceived enjoyment significantly influence attitudes about the use of online platforms/websites for recruitment (employment). The fact that the regression analysis showed that Perceived ease of use was not a statistically significant variable in either model may indicate that the use of online platforms and websites for recruitment and employment is very simple from the perspective of today's users. The usefulness of platforms is obviously the most significant factor that influences attitudes, and thus indirectly the intention to use them.

References

1. Ajzen I. & Fishbein M. (1980). *Understanding attitudes and predicting social behavior* (Pbk.). Prentice-Hall.
2. Alsultanny, Y. A., & Alotaibi, M. F. (2015). Evaluating the factors affecting on intension to use of e-recruitment. *American Journal of Information Science and Computer Engineering*, *1*(5), 324-331.
3. Barber, A. E. (1998). *Recruiting employees: Individual and organizational perspectives*. Sage Publications.
4. Brahmana R. K., & Brahmana, R. (2011). Determinants Of Jobs Seekers' Intention In Using E-Recruitments: Insight From Indonesia. In *International Conference on Information Systems For Business Competitiveness*.
5. Cappelli, P. (2001). Making the most of on-line recruiting. *Harvard business review*, *79*(3), 139-148.
6. Chapman, D. S., Uggerslev, K. L., Carroll, S. A., Piasentin, K. A., & Jones, D. A. (2005). Applicant attraction to organizations and job choice: a meta-analytic review of the correlates of recruiting outcomes. *Journal of applied psychology*, *90*(5), 928.
7. Chen, Q., & Wells, W. D. (1999). Attitude toward the site. *Journal of advertising research*, *39*(5), 27-38.
8. Cho, S., Lee, W., & Liu, J. (2011). E-Recruitment: Effects of Enjoyment and Attitudes toward Web Sites on Corporate Image and intention to apply. *International CHRIE Conference-Refereed Track. 6*.
9. Cober, R. T., Brown, D. J., Keeping, L. M., & Levy, P. E. (2004). Recruitment on the net: How do organizational web site characteristics influence applicant attraction? *Journal of management*, *30*(5), 623-646.
10. Cohen, J. W. (1988), *Statistical power analysis for the behavioral sciences*. Lawrence Erlbaum Associates, Hillsdale, NJ.
11. Córdoba-Pachón, J. R., & Teng, Y. (2010). Social Networking Sites and Graduate Recruitment: Sharing Online Activities?. *Royal Holloway, University of London, School of Management Working Paper*, (1002).
12. Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS quarterly*, 319-340.
13. Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management science*, *35*(8), 982-1003.
14. Doherty, R. (2010). Getting social with recruitment. *Strategic HR review*, *9*(6), 11-15.
15. El Ouirdi, M., El Ouirdi, A., Segers, J., & Pais, I. (2016). Technology adoption in employee recruitment: The case of social media in Central and Eastern Europe. *Computers in human behavior*, *57*, 240-249.
16. Galanaki, E. (2002). The decision to recruit online: A descriptive study. *Career development international*, *7*(4), 243-251.
17. Hafeez, M., & Farooq, U. (2017). The Role of E-Recruitment in Attracting Potential Candidates: Evidence from Fresh Graduate Job Seekers. In *International Conference on Advances in Business, Management and Law (ICABML), 1*.
18. Handlogten, C. (2009). *Implementation of e-recruitment Enablers and success indicators from the.*. (Master's thesis, University of Twente).

19. Holm, A. B. (2012). E-recruitment: towards an ubiquitous recruitment process and candidate relationship management. *German Journal of Human Resource Management*, *26*(3), 241-259.

20. Joo, Y. J., Park, S., & Lim, E. (2018). Factors influencing preservice teachers' intention to use technology: TPACK, teacher self-efficacy, and technology acceptance model. *Journal of Educational Technology & Society*, *21*(3), 48-59.

21. Kapse, A. S., Patil, V. S., & Patil, N. V. (2012). E-recruitment. *International Journal of Engineering and Advanced Technology*, *1*(4), 82-86.

22. Kashi, K., & Zheng, C. (2013). Extending Technology Acceptance Model to the E-recruitment Context in I ran. *International Journal of Selection and Assessment*, *21*(1), 121-129.

23. Kashi, K., & Zheng, C. (2013). Extending Technology Acceptance Model to the E-recruitment Context in I ran. *International Journal of Selection and Assessment*, *21*(1), 121-129.

24. Kerrin, M., & Kettley, P. (2003). *E-recruitment: Is it Delivering?*. The Institute for Employment Studies.

25. Lengnick-Hall, M. L., & Moritz, S. (2003). The impact of e-HR on the human resource management function. *Journal of labor research*, *24*(3), 365.

26. Leonard, B. (2000). Online and Overwhelmed. Use these tips to make online recruiting more effective. *HR MAGAZINE*, *45*(8), 36-43.

27. Lievens, F., & Chapman, D. (2019). Recruitment and selection. *The SAGE handbook of human resource management*, 123-150.

28. Maurer, S. D., & Liu, Y. (2007). Developing effective e-recruiting websites: Insights for managers from marketers. *Business horizons*, *50*(4), 305-314.

29. Odumeru, J. A. (2012). Diffusion of online recruiting technology in Nigeria. *Online Journal of Social Sciences Research*, *1*(4), 104-114.

30. Palmer, J. W. (2002). Web site usability, design, and performance metrics. *Information systems research*, *13*(2), 151-167.

31. Parry, E., & Tyson, S. (2008). An analysis of the use and success of online recruitment methods in the UK. *Human resource management journal*, *18*(3), 257-274.

32. Smith, A. (2015). Searching for work in the digital era. Pew Research Center: Internet. *Science & Tech., Article published on*, *19 November*.

33. Sun, H., & Zhang, P. (2006). Causal relationships between perceived enjoyment and perceived ease of use: An alternative approach. *Journal of the Association for Information Systems*, *7*(1), 24.

34. Suvankulov, F. (2010). *Job search on the internet, e-recruitment, and labor market outcomes*. The Pardee RAND Graduate School.

35. Tarhini, A., Scott, M., Sharma, S., & Abbasi, M. S. (2015). Differences in intention to use educational RSS feeds between Lebanese and British students: A multi-group analysis based on the technology acceptance model. *The Electronic Journal of e-Learning*, Volume 13, Issue 1 14-29.

36. Teo, T., & Milutinovic, V. (2015). Modelling the intention to use technology for teaching mathematics among pre-service teachers in Serbia. *Australasian Journal of Educational Technology*, *31*(4).

37. Tepe, J. (2011). *Rapport Matters in Corporate Career Websites; Personal, Supportive, Responsive–Effective!* (Master's thesis, University of Twente).

38. Thompson, L. F., Braddy, P. W., & Wuensch, K. L. (2008). E-recruitment and the benefits of organizational web appeal. *Computers in Human Behavior*, *24*(5), 2384-2398.

39. Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS quarterly*, 425-478.

40. White, G. (2021). *The impact of technology on recruitment: How to improve your hiring process*. Available from https://www.spiceworks.com/hr/recruitment-onboarding/articles/the-impact-of-technology-on-recruitment-how-to-improve-your-hiring-process/ [Accessed July 07, 2023].

41. White, S. K. (2017). *4 ways technology has changed hiring - for job seekers and recruiters*. Available from https://www.cio.com/article/228090/4-ways-technology-has-changed-hiring-for-job-seekers-and-recruiters.html [Accessed July 04, 2023].

42. Williamson, I. O., Lepak, D. P., & King, J. (2003). The effect of company recruitment web site orientation on individuals' perceptions of organizational attractiveness. *Journal of vocational behavior*, *63*(2), 242-263.

43. Wu, B., & Chen, X. (2017). Continuance intention to use MOOCs: Integrating the technology acceptance model (TAM) and task technology fit (TTF) model. *Computers in human behavior*, *67*, 221-232.

44. Yoon Kin Tong, D. (2009). A study of e-recruitment technology adoption in Malaysia. *Industrial Management & Data Systems*, *109*(2), 281-300.

45. Yoon Kin Tong, D., & Sivanand, C. N. (2005). E-recruitment service providers review: International and Malaysian. *Employee relations*, *27*(1), 103-117.

46. Ziesing, J. (2013). Online Recruitment: Match Me If You Can. *Potential Park's Online Talent Communication Study (OTaC). retrieved on June*, *11*, 2016.

47. Zusman, R. R., & Landis, R. S. (2002). Applicant preferences for web-based versus traditional job postings. *Computers in Human behavior*, *18*(3), 285-296.

Anida Zahirović Suhonjić, PhD[1]
Adnana Beganlić, MA[2]

Review paper

L&D TOOLS AND SOLUTIONS: USE IN THE POST-PANDEMIC WORKPLACE ENVIRONMENT

Abstract

Digital transformation and COVID-19 pandemic brought many changes in the business world, thus affecting learning and development (L&D) processes and activities. L&D activities are carried out within a company to ensure an environment in which employees and the company will develop, improve and grow. The aim of this paper is to examine which L&D tools and solutions can be used in the post-pandemic workplace environment. The tools and solutions presented in the paper can be a guideline for the responsible managers in terms of the available software, as well as their advantages and disadvantages.

Key words: *Learning and Development, Learning Tools, Post-Pandemic, Knowledge Management.*

1. Introduction

The rapid development of technology has brought many changes in the business world even before the COVID-19 pandemic. In the context of learning and development (L&D), "these changes have transformed the role of learning and development professionals, with a new emphasis on supporting self-managed learning through facilitation, coaching and mentoring and on developing in themselves and others the skills of working effectively in online and virtual environments" (Arney, 2017). The pandemic has caused many changes in various areas of business, thus affecting L&D processes and activities. As pointed out in the report of World Economic Forum (2021): "half of all employees around the world will need reskilling by 2025 – and that number does not include all the people who are currently not in employment."

Learning and development activities in the workplace environment can be organized on many levels, including individual level, groups or teams, organization-wide and it is often self-managed and directed (Arney, 2017). But knowledge itself is not enough for the success of a company, instead the ability to

1 Professor at International Business Information Academy Tuzla, Kulina bana 2, 75000 Tuzla, Bosnia and Herzegovina, anida@ipi-akademija.ba
2 Lecturer at International Business Information Academy Tuzla, Kulina bana 2, 75000 Tuzla, Bosnia and Herzegovina, adnana@ipi-akademija.ba

apply the gained knowledge and knowledge diffusion is the key for success (Drewniak & Posadzinska, 2020).

2. Importance of L&D

L&D activities are gaining more and more importance among knowledge management practitioners and theorists (Drewniak & Posadzinska, 2020). These activities are a foundation for building people resources and for gaining competitive advantage (Arney, 2017).

Learning and development can be seen as the cycle presented in Figure 1.

This cycle can serve as a framework for understanding employee learning and development activities. It tells us that a responsible manager should (Fee, 2011):

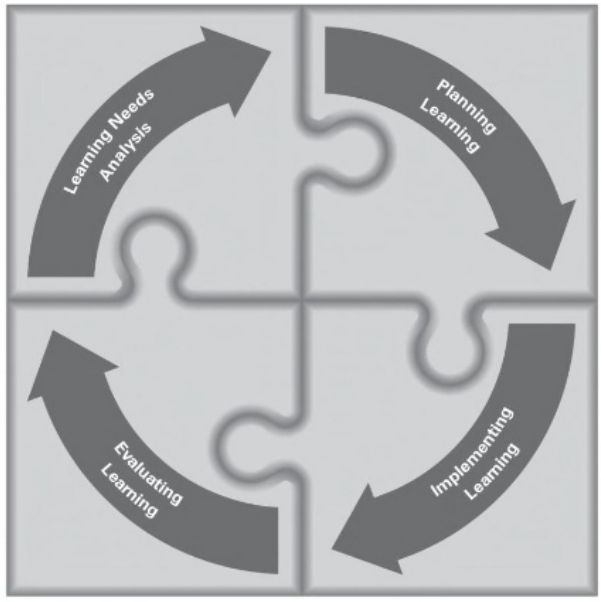


Figure 1. The learning and development cycle
Source: Fee (2011)

- identify and analyze the learning needs for the job and the required skills of employees or teams;
- use that analysis to plan, design and prepare a learning intervention;
- implement the learning intervention and
- assess and review the effectiveness of the learning intervention.

Although evaluation is usually the final stage of the L&D cycle, it should be planned from the beginning. It can be seen as the main part of the learning and

development process where organizations assess the value of L&D interventions (Arney, 2017).

Workplace learning takes many forms. Learning builds skills and knowledge but also motivates people. Learning motivates employees and provides companies with the workforce needed to follow all new trends and such companies are ready for all future challenges. Study research done by MindTools for Business from 2020 shows that the number one motivation for employees to learn at work is "To do their job faster and better", followed by "General career progression" (Mind Tools for Business, 2021).

During pandemic and post-pandemic, organizations began embracing different online learning forms as well as encouraging employees to develop skills. It is often organized as self-paced learning. Some of the steps the organizations need to take in the post-pandemic era include (Palmer, 2022):

- Let go of "command and control" - in the post-pandemic era, the top-down approach has no significant results. Instead, it is advised that the company identifies the skills and knowledge that they believe are critical to the success of individual employees as well as the company as a whole, and provide employees with guidance in acquiring those skills and knowledge. Today it often refers to communication skills, problem solving, empathy, etc.
- Track, recognize and reward - it is important for companies to find a balance between allowing employees to choose their own learning path and monitoring their progress. Responsible managers can use platforms to monitor employee progress, and it is recommended to organize face-to-face or online meetings about upskilling and reskilling goals.
- Optimize learning conditions - employees need uninterrupted time for learning, but it is necessary not to overload employees with too many tasks. Good communication within the company is crucial in order to build a strong culture of continuous learning.

Below are presented the most important tools and solutions that can be used in different phases of L&D in the post-pandemic workplace environment.

3. L&D tools and solutions

Various companies provide training and development programs to provide their employees with the improvement and advancement of their skills and knowledge. Orientation, management skills, and operational skills of employees are essential parts of a quality training program for employees (Jehanzeb & Bashir, 2013). These are the basics of any employee development program. The main task is to gain knowledge, cooperation skills, inventive thinking and resolving problems (Kottke, 1999).

According to Drewniak & Posadzinska (2020), the typical solutions to gain knowledge are:

- Training and workshops - they are considered classic tools. Workshops are suitable for smaller groups with focus on the practical part. They are usually used to gain specific knowledge or skills. Training is a broader concept and it combines workshops with theoretical parts.
- Online learning platforms - they enable implementation of various types of learning models and they are suitable for complex management of training processes.
- Knowledge bases - sometimes referred to as knowledge pills. They are a collection of documents and articles about a certain field.
- Business simulations and gamification - usually a very interesting form of learning. They rely on computer games and role-playing games to stimulate participation of employees.

Employees who follow new trends and continuously gain knowledge in their fields can respond faster to different challenges and maintain a positive company reputation (Platt, n.d.). Some of the tools that can provide companies with training that will help employees be as productive as possible are (Platt, n.d.):

- Learning Management System (LMS),
- Video conferencing tools,
- Microlearning platforms,
- Content creation tools and
- Knowledge repositories.

3. 1. Learning Management System (LMS)

A LMS framework enables organizations an access to the pre-stored training content in the form of lectures, videos, podcasts, e-books and other instructional resources accessible by all registered users from any place and at any time (Ilyas, Kadir, & Adnan, 2017). LMS is a software tool that, in addition to recognizing what training a team needs, also monitors progress achieved during training.

LMS is convenient and user friendly and supports all learning requirements of a modern organization. It supports various modules that can be shared, and has a centralized library, which can be accessed by all users. It can also contain analysis tools and reports that are programmed and customized.

Benefits of LMS are that LMS makes learning simple, provides unlimited access to e-learning materials, consolidates all training information, reduces learning costs, enables tracking and saves time. In addition to the mentioned advantages, when it comes to LMS we must also take into consideration administrative costs and setup time. It should be noted that implementation of LMS may take some time and it requires IT and programming knowledge (GoGuardian Team, 2021).

LMS in the post-pandemic workplace environment can bring (McAvoy, 2022):

- Increased learner engagement and retention - employees can assess their current level of knowledge and identify what they need to learn, set learning goals and choose different resources that will help them achieve those goals.
- Easing administrative burden and evaluation of learning - analysis of results in real time and automation of administration gives L&D staff more time to focus on higher-level tasks.
- Solving company-wide needs - all departments have fast and easy access to the latest information and training materials.

There are a lot of LMS platforms to choose from. Every of those platforms has its own strengths and weaknesses. Forbs Advisor analyzed the best LMS options and they are: Absorb, Cheaper Learning LMS, TalentLMS, iSpring, Docebo, D2L, Canvas LMS, Edmodo LMS and Moodle LMS (Henning & Main, 2023).

3. 2. Video conferencing tools

"Video conferencing software is software that allows two or more people to emulate a person-to-person meeting over the internet using real-time, multidirectional video and audio streaming." (BigCommerce, n.d.).

Video conferencing software enables online communication for all types of meetings or seminars, with the option of screen sharing or recording. It is used to improve collaboration. Employees can use video conferencing tools to host or attend virtual meetings with other employees, company partners or clients, regardless of where the participants are physically located.

Video conferencing tools must enable the following:

- Online video and audio communication,
- Giving the hosts the opportunity to invite participants to the conversation,
- Chat capability and screen sharing and
- Possibility of recording.

Benefits of video conferencing in the post-COVID era is that these communication tools are affordable and adaptable across industries. Video conferencing solutions can be used for any type of business. Video conferencing ensures the safety of workforce while improving collaboration (Bemer, 2022). Some of the issues corporate video conferencing can address, especially for large enterprises, are (Pappas, 2022):

- Low employee engagement,
- Limited peer-based support,
- No L&D team communication,
- Lack of employee feedback,
- High L&D costs etc.

Some of the most used video conferencing tools are: Microsoft Teams, Google Meet, Google Workspace, Zoom, BlueJeans Meetings, Skype, Webex Meetings, GoTo Meeting, Webex App, Slack, TeamViewer Remote, Amazon Chime etc.

3. 3. Microlearning platforms

Microlearning refers to relatively small, focused learning of units consisting of condensed learning activities (usually one to ten minutes), available on multiple devices. Microlearning lessons are designed for skill-based training, learning, and education and it is a multi-platform tool that can be applied to educate a large number of users (Shail, 2019).

Microlearning platforms must provide: content delivery and tracking, assessment and practicing, content storing and management as well as ease of administration. On the basis of these factors, the positive effects of the microlearning platforms can be measured. Some of the best microlearning platforms are: CodeofTalent, EdApp, 7apsMicrolearning, Axonify, TovutiLMS and Arist (G2, 2023).

Essence of microlearning is described across seven dimensions: requiring a short-time engagement; carrying less content; potentially being drawn from course elements; scattered form; coherent and self-contained; media-rich; and supportive of various learning approaches (Wang, Towey, Yuk-kwan & Gill, 2021). Several benefits of using microlearning have been reported, including: greater retention of concepts; better engagement for learners; improving learners motivation; engaging in collaborative learning; and improving learning ability and performance (Wang et al., 2021).

The outbreak of COVID has had a severe impact on businesses at large. Microlearning in the post-COVID period offered ways in which companies can offer services effectively for broader training initiatives and performance support. Assets used in microlearning are compact, and modalities are easily embedded with the training content, making them more interesting for the employees to assimilate information.

As regards to L&D, microlearning strategies are helpful and effective, since microlearning is flexible and it offers various learning formats and ease of delivery. Microlearning also offers the flexibility to create impactful learning pathways for employees to achieve their goals, by mixing and matching training content (Integra, 2020).

3. 4. Content creation tools

Content creation tools have emerged as something to describe digitally enabled cultural producers who create and circulate content on social media platforms, driven by an entrepreneurial spirit and desire to generate their own 'media brands' (Arriagada & Ibáñez, 2020).

Pandemic led to what we have today, over 50 million content creators, which include social media influencers, bloggers, and videographers who utilize software and financial tools that assist in their growth and monetization (Bogliari, 2021). This population is now recognized as the Creator Economy and it is one of the fastest growing economies to date (Bogliari, 2021).

L&D teams are looking for new ways to do things. They're taking a more sustainable approach to learning and development by deputizing content creation and empowering anyone from the organization to share their expertise (Markovic, 2022). Some of the steps that need to be taken in terms of content creation for more efficient L&D include (Markovic, 2022):

- Build a foundation for collaborative content creation,
- Remove barriers to access,
- Enable knowledge sharing and
- Lean into technology.

Content creator platforms that are popular today are: Grin, Creator & Co, LTK, Impact, Upfluence, Aspire, Klear and Stellar.

3. 5. Knowledge Repositories

"Knowledge repositories are online databases that continuously collect and organize a company's knowledge assets. These are also referred to as knowledge management repositories." (Capacity, 2019). These platforms allow storage, organization, collaboration and knowledge creation.

Knowledge repositories help organizations connect people with information and expertise globally via online searchable libraries, discussion forums and other elements. They provide a central location to collect, contribute and share digital learning resources for use in instructional design and content development for both traditional and non-traditional learning environments. They have become an integral part of corporate-wide knowledge management programs and a valuable stimulant of social and informal learning activities (TrainingIndustry, n.d.).

There are several key features of effective digital knowledge repositories:

- Centralization,
- Content management,
- Cost savings,
- Access control and
- Record management.

The best organizational knowledge repositories to help self-learning of employees are: EdApp, Confluence, Helpjuice, Nuclino, Guru, Trainual, Bloomfire, Document360, Knowmax and Slite.

4. Conclusion

Pandemic COVID-19 brought many profound business changes. In the post-pandemic era, many employees prefer to work online or in a hybrid model. For such employees, it is necessary to find appropriate tools for learning and development activities. This paper presents the importance of L&D, as well as the most significant tools and solutions for implementing L&D activities in today's business environment. Presented tools and solutions can be used in different stages of L&D activities. Those tools and solutions include LMS, microlearning platforms, video conferencing tools, content creation tools and knowledge repositories.

It remains questionable whether L&D will continue to develop fully online and self-paced or whether it will incorporate once again traditional forms of learning and development. The direction in which it will develop further will certainly depend on the needs of the company, its size and resources.

References

1. Arney, E. (2017). *Learning for Organizational Development : How to Design, Deliver and Evaluate Effective L&D*. Kogan Page, New York.
2. Arriagada, A., & Ibáñez, F. (2020). You Need At Least One Picture Daily, if Not, You're Dead: Content Creators and Platform Evolution in the Social Media Ecology. *Social Media + Society. 6(3).* https://doi.org/10.1177/2056305120944624.
3. Bemer, T. (2022). Benefits of Video Conferencing in the Post-COVID Era. Available at: https://www.megameeting.com/news/benefits-video-conferencing-post-covid-era/ Accessed: 12/06/2023.
4. BigCommerce (n.d.). What is video conferencing software? Available at: https://www.bigcommerce.com/ecommerce-answers/what-is-video-conferencing-software/ . Accessed: 13/06/2023.
5. Bogliari, A. (2021). Rise of the content creator economy. Available at: https://www.agilitypr.com/pr-news/public-relations/rise-of-the-content-creator-economy-and-how-it-can-promote-business/. Visited: 15/06/2023.
6. Capacity (2019). What are knowledge repositories? Available at: https://capacity.com/knowledge-management/. Accessed: 09/06/2023.
7. Drewniak, Z. & Posadzinska, I. (2020). Learning and Development Tools and the Innovative Potential of Artificial Intelligence Companies. *European Research Studies Journal*. 23(2). str. 388-404.
8. Fee, K. (2011). *101 learning and development tools: essential techniques for creating, delivering, and managing effective training*. Kogan Page Limited, Great Britain.
9. G2 (2023). Best Microlearning Platforms in 2023: Compare Reviews in 100+. Available at: https://www.g2.com/categories/microlearning-platforms. Accessed: 12/06/2023.
10. GoGuardian Team (2021). The Pros & Cons of Learning Management Systems. Available at: https://www.goguardian.com/blog/learning-management-systems-pros-cons. Accessed: 12/06/2023.

11. Henning, L. & Main, K. (2023). Best Learning Management Systems (LMS) of 2023. Available at: https://www.forbes.com/advisor/business//best-learning-managmenr-systems/. Accessed: 13/06/2023.

12. Ilyas, M., Kadir, K. A. & Adnan, Z. (2017). Demystifying the Learning Management System (LMS): Journey from e-Learning to the Strategic Role. *European Journal of Business and Management*. 9. str.12-18.

13. Integra (2020). Microlearning in post-COVID World. Available at https://integranxt.com/microlearning-in-post-covid-world/. Accessed: 14/06/2023.

14. Jehanzeb, K. & Bashir, N. A. (2013). Training and Development Program and its Benefits to Employee and Organization: A Conceptual Study. *European Journal of Business and Management*. 5. str.243-252.

15. Kottke, J. L. (1999). Corporate universities: Lessons in building a world-class work force (revised). *Personnel Psychology*. 52. str.530-533.

16. Markovic, M. (2022). Steps to open up content creator for more efficient L&D. Available at: https://www.elucidat.com/blog/steps-to-open-up-content-creation/. Accessed: 15/06/2023.

17. McAvoy, D. (2022). LMS powers small/medium business training in the post-COVID workplace. Available at: https://hireroad.com/resources/lms-powers-small-medium-business-training-in-the-post-covid-workplace. Accessed: 14/06/2023.

18. Mind Tools for Business (2021). What is Workplace Learning? Available at: https://mindtoolsbusiness.com/resources/blog/what-is-workplace-learning. Accessed: 09/06/2023.

19. Palmer, K. (2022). 3 ways to revolutionize workplace learning in the post-COVID economy. Available at: https://www.weforum.org/agenda/2022/02/revolutionize-workplace-learning-in-the-post-covid-economy/. Accessed: 12/06/2023.

20. Pappas, C. (2022). L&D pain points business video conferencing software can help you address. Available at: https://elearningindustry.com/ld-pain-points-business-video-conferencing-software-can-help-address. Accessed: 14/06/2023.

21. Platt, L. (n.d.). The best technology tools for workforce training. Available at: https://www.bairesdev.com/blog/the-best-technology-tools-for-training/. Accessed: 12/06/2023.

22. Shail, M. S. (2019). Using Micro-learning on Mobile Applications to Increase Knowledge Retention and Work Performance: A Review of Literature. *Cureus*. 11(8): e5307. doi:10.7759/cureus.5307.

23. Trainingindustry (n.d.). Knowledge repositories. Available at: https://trainingindustry.com/wiki/content-development/knowledge-repositories/. Accessed: 15/06/2023.

24. Wang, T., Towey, D., Yuk-Kwan Ng, R. & Gill, A. (2021). Case Studies of Microlearning Implementations in two Post-secondary Educational Institutions. Towards Post-pandemic Transformative Teaching and Learning: Case Studies of Microlearning Implementations in two Post-secondary Educational Institutions. *SN Comput Sci*. 2(4): 271. doi: 10.1007/s42979-021-00663-z.

25. World Economic Forum (2021). Insight Report: Upskilling for Shared Prosperity. Available at: https://www3.weforum.org/docs/WEF_Upskilling_for_Shared_Prosperity_2021.pdf. Accessed: 29/05/2023.

Mr.sc. Edin Zahirović[1]
Dr.sc. Merima Orlić[2]
Dr.sc. Almira Arnaut-Berilo[3]

Original scientific paper

ANALYSIS OF TOTAL FACTOR ENERGY EFFICIENCY OF WESTERN BALKAN COUNTRIES

Abstract

The aim of this research is to examine energy efficiency at the macroeconomic level of the Western Balkan (WB) and the EU countries from 2005 to 2019. Data envelopment analysis (DEA) with a slack-based model (SBM) was used, considering labour, capital and energy as inputs, and GDP and CO_2 as desirable and undesirable outputs, respectively. A window analysis was used to capture the changes in energy efficiency over time. The estimation of total factor energy efficiency (TFEE) reveals that the group comprising the top 5 most efficient countries consists of Malta, Montenegro, Italy, France and United Kingdom. In the WB countries, Montenegro consistently maintained high efficiency, while Serbia showed an upward trend with a slight decline between 2013 and 2016. North Macedonia demonstrated a growth trend until 2010, followed by a decline with occasional minor recoveries. In Bosnia and Herzegovina, there is a continuous decline in TFEE with values ranging from 0,66 to 0,4. Albania shows mixed efficiency levels in different years (e.g., 2009, 2012, 2019 efficient; 2005, 2014, 2017 inefficient). In order to achieve efficiency, it is necessary for the WB countries to engage 131,29 PJ less energy for the same amount of output. The TFEE is compared to the values of traditional energy efficiency, and inconsistencies can be observed. Therefore, the WB countries are encouraged to implement a set of institutional, economic, and regulatory measures, along with investing in education and training, partnering and collaborating with the private sector and establish more ambitious energy savings goals within their strategic processes.

Key words: *Total Factor Energy Efficiency, Western Balkans, SBM-DEA, Window Analysis.*

1 Master of Science, Director at Center for Development and Support, Turalibegova 36, 75000 Tuzla, Bosnia and Herzegovina, edinzahirovic@gmail.com
2 Ph.D., Associate Professor at the Faculty of Economics, University of Sarajevo, Trg oslobođenja - Alija Izetbegović 1, Sarajevo 71000, Bosnia and Herzegovina, merima.balavac@efsa.unsa.ba
3 Ph.D., Associate Professor at the Faculty of Economics, University of Sarajevo, Trg oslobođenja - Alija Izetbegović 1, Sarajevo 71000, Bosnia and Herzegovina, almira.arnaut@efsa.unsa.ba

1. Introduction

Energy production and consumption are crucial factors for every economy, both in terms of generating gross domestic product (GDP) and determining the prices of goods and services. Additionally, they have significant impacts on environmental quality and human health. The demand for energy, as a key input in the process of economic production, is constantly increasing, and this heightened demand puts pressure on the environment due to increased greenhouse gas emissions, which contribute to climate change.

According to the European Environment Agency (2018), energy efficiency and the utilization of renewable energy sources are the most significant measures in combating climate change for all European Union (EU) member states, and they are currently in the central focus of many national energy policies. Several EU directives on energy efficiency (issued in 2006, 2010, 2012, and 2018) concentrate on the obligations and targets to ensure energy efficiency (EE). The updated directive from 2018 sets new goals, with a target of at least 32,5% improvement in efficiency by 2030.

According to Kanellakis et al. (2013), energy efficiency (EE) is the fastest and most cost-effective way to increase supply security and reduce greenhouse gas emissions. While EE indicators hold an important position in EU energy policies, their treatment varies at the national level. As a result, EU member states have engaged in activities to establish a common methodology for EE indicators. For this purpose, 600 comparable descriptive and explanatory EE indicators were collected, and a database named Odyssee was defined and formed (Bosseboeuf et al., 1997). Odyssee is updated twice a year through a network of partners and national energy agencies in over 30 countries, including all EU member states, Norway, Serbia, Switzerland, and the United Kingdom. The Western Balkan countries, except for Serbia, are not included in this database.

Traditional indicators, or (partial) indices of EE, consider that one input (energy) generates an output (GDP) while disregarding other inputs such as labour and capital (Vlahinić-Dizdarević and Šegota, 2012; Vlahinić-Lenz et al., 2018). To overcome this issue, Hu and Wang (2006) developed a new EE indicator called Total Factor Energy Efficiency (TFEE). This index considers energy, labour, and capital as multiple inputs for generating output. The approach of Hu and Wang (2006) quickly gained approval, and numerous studies focus on determining the TFEE of specific regions or countries (Nikbakht et al., 2022; Bicil and Türköz, 2021; Ohene-Asare et al., 2020; egota et al., 2017; Hu and Wang, 2006).

For TFEE researches, data from various geographic areas have been used, including continents or blocs of countries. Review of the literature reveal that, thus far, there have been no studies specifically addressing the determination of TFEE in the WB countries. This study aims to determine the level of TFEE in the WB countries. It is worth emphasizing the significance of presenting the TFEE analysis for the countries within the WB, as these nations share vari-

ous similarities and specific characteristics such as transition states, post-war conditions, high levels of corruption, and outdated technologies. By examining TFEE in these countries, the scientific literature will be enriched with valuable insights into EE strategies and challenges faced by nations with such particular circumstances.

This research will provide a better understanding of the factors that lead to changes in TFEE, considering the specific context of the WB countries. The study offers new empirical evidence on the state of EE in selected countries using TFEE and applying the Data Envelopment Analysis (DEA) method in a dynamic context with a Slack-Based Model (SBM) with undesirable outputs. In addition to assessing TFEE in the WB countries, a practical contribution is made by comparing it with traditional efficiency measures based on the ratio of one input (energy) to one output (GDP) and identifying similarities and differences.

The first chapter consists of a systematic review of the literature related to TFEE. The second chapter provides an overview of the methods, including the theoretical foundations of DEA and SBM with undesirable outputs in a dynamic context. The third chapter presents the data analysis and results of TFEE in the WB and EU countries, as well as the assessment of slacks (unused resources) and a comparison of TFEE with simple EE. The final chapter includes the implications of the research findings, recommendations for improving EE at the national level, and directions for future research.

2. Literature review

In order for the WB countries to meet all the EU membership standards, they need to become part of the European approach to addressing energy issues and climate challenges. In this regard, the EU has implemented the European Climate Law. This means that a net-zero greenhouse gas emissions target needs to be achieved throughout the EU, largely through improved energy efficiency and the utilization of renewable energy sources. Considering the importance of EE in all of these processes, it is crucial to have a proper understanding of the progress made by all countries, especially those in transition. One characteristic of such transition countries, in the context of energy policy, is that there is still a prevailing belief that economic development and energy policy should be based on fossil fuels, primarily coal. This is best reflected in the strategic and planning documents related to energy development.

The concept of energy efficiency has become a central challenge for the energy policies of countries and their unions (Ang, 2006; Patterson, 1996). Improving EE represents one solution to energy problems and EE is a goal that countries need to achieve for current and future economic growth (Shi, 2007; IEA, 2014; Rajbhandari, 2017). The EU is a global leader in establishing a systematic approach to EE. Goals are set for all EU members and candidate countries to reduce energy consumption and carbon dioxide (CO_2) emissions and

more. In this regard, the EU relies on numerous studies on EE, with one of the most significant being the Odyssee project. The Odyssee project ensures the existence of a database that contains EE indicators. According to Definition of data and EE indicators in ODYSSEE data base (2020), it utilizes 200 common EE indicators. In addition to these, there is an EE index called "ODEX," which measures the progress of EE at the sectoral or national level. The ODEX index is available for EU countries, while the WB countries (except Serbia) are not included in the Odyssee project.

The term EE is often used but authors attribute different meanings to it, depending on the purpose of its use. Frequently, the term is equated with the definition used in thermodynamics. However, this concept is not applicable for economic analyses (Bhattacharyya, 2011). One of the commonly used traditional indicators in macro-level analyses is the energy-to-GDP ratio (traditional approach). A better way to present the concept and theoretical foundation of EE is to use a definition based on microeconomic production theory advocated by Evans et al. (2013) and Filippini and Hunt (2015). To understand this approach, it is necessary to recognize that energy demand is derived from the demand for products or energy services. The production of energy services and its associated efficiency can be explained using isoquants and isocosts (Chambers, 1988; Huntington, 1994).

The preferred approach to measuring EE occurs within the framework of total factors that consider other production inputs (Hu and Wang, 2006). In this sense, Hu and Wang (2006) propose the concept of *Total Factor Energy Efficiency (TFEE),* which considers labour and capital as additional inputs in the production process. Therefore, TFEE measures energy efficiency while considering the complementarity and substitutability of inputs in generating outputs (Ohene-Asare et al., 2020). The analysis of TFEE defines the production possibility curve and establishes production boundaries using relevant data on inputs and economic outputs of each production unit. There is also the possibility of analysing the relationship between each production unit and its position on the production possibility frontier to determine whether production resources are fully utilized or if there is room for improvement (Yu, 2020).

In order to overcome the limitations of partial (traditional) energy efficiency indicators, an increasing number of researchers analyse the Total Factor Energy Efficiency. Hu and Wang (2006) analysed EE of 29 administrative regions in China for the period 1995-2002 using a newly introduced index. The results showed that TFEE provided a better reflection of the actual situation, and regional TFEE generally improved during the research period. Xing-Ping et al. (2011) utilized this framework in 23 developing countries from 1980 to 2005. There is a significant number of studies on the TFEE of individual cities, regions, or provinces using DEA approach (Li and Hu, 2012; Sun and Li, 2014; Zhang et al., 2017; Li et al., 2022). TFEE has been analysed for blocs or groups of countries. Castro et al. (2016) analysed TFEE for the G7 and BRICS countries. Guo et al. (2017) examined TFEE for OECD member countries and China. Ohene-Asare and Turkson (2019) investigated TFEE for 15 member countries of the Economic Community of West African States (ECOWAS) from 1990 to

2014. Wang et al. (2019) assessed improvements in EE using DEA approach in a sample of 25 countries with the highest global CO_2 emissions. Sun et al. (2019) explored the quality of institutions, green technology innovation, and TFEE in a sample of 71 developed and developing countries for the period 1990-2014. Nikbakht et al. (2022) conducted an analysis of TFEE for the Gulf countries.

TFEE has also been explored in EU countries. Ceylan and Gunay (2010) examined EE trends in EU countries and Turkey for the period 1995-2007. Vlahinić-Dizdarević and Šegota (2012) identified changes in EE at the EU country level from 2000 to 2010 and compared the results with traditional indicators. Šegota et al. (2017) analysed environmental TFEE in EU countries for the period 2008-2014, using DEA with outputs including GDP, CO_2, and SOx emissions. Jebali et al. (2017) analysed EE in Mediterranean countries. Borozan (2018) examined the technical and TFEE of EU regions, and additionally, Borozan and Borozan (2018) investigated TFEE of regions in Croatia. Gökgöz and Erkul (2019) explored EE in 29 European countries using the DEA method to optimize an efficiency measure based on slack variables. Chang (2020) conducted an empirical analysis of 28 EU member states by dividing them into Baltic Sea region countries and non-member countries of that region. Bicil and Türköz (2021) investigated EE for 28 EU member states from 2005 to 2017.

Based on the review of previous research on the WB countries, the state of EE is primarily presented based on traditional indicators of the energy-to-GDP ratio (such as the International Energy Agency, World Bank, World Resources Institute databases, etc.), while other indicators that consider all factors are excluded from the analysis. In line with the latest scientific advancements in this field and with the aim of providing a more comprehensive overview of EE, we have decided to analyse TFEE in this paper, where the term energy efficiency will refer to total factor energy efficiency.

3. Empirical research and methodology

The concept of TFEE and its measurement have become mainstream methods of EE (Cheng, 2016). Therefore, this approach will be used to analyse countries that can be viewed as a production system and a collective process in which resources, capital, energy, and other inputs are used to create outputs. EE is measured through a composite TFEE index that includes energy, labour, and capital as multiple inputs to produce GDP as a desirable output and CO_2 emissions as an undesirable output. Additionally, one of the focus of this research is on the differences in results related to the indicators of EE in the respective countries, considering both the traditional and contemporary approaches. The contemporary approach involves TFEE, while the traditional approach involves expressing the level of EE through energy intensity and simple energy efficiency (SEE).

3. 1. Data

For the purpose of TFEE analysis, panel data at the macroeconomic level for the WB and the EU countries from 2005 to 2019 will be used. The annual data series that will be collected and processed for TFEE analysis are presented in following table.

Table 1. Description of the variables included in the analysis

Variable	Symbol	Description/Unit	Source
Public and private capital	Capital	Public and private capital in billions of constant international dollars from 2017. All series are expressed in constant international prices for 2017 (using purchasing power parity).	Investment and Capital Stock Dataset, published by the International Monetary Fund (IMF) from 1960 to 2019.
Number of employed individuals	Labour	Number of employed individuals in millions of people.	International Labour Organization.
Final energy consumption	Energy	Final energy consumption in peta-joules (PJ). This represents the total energy consumed by end-users such as households, industries, and agriculture.	International Energy Agency databases, United Kingdom: The Department for Business, Energy & Industrial Strategy of the UK Government.
Gross domestic product	GDP	Gross Domestic Product in billions of constant international dollars from 2017.	Investment and Capital Stock Dataset, published by the IMF from 1960 to 2019.
Carbon dioxide	CO_2	Carbon dioxide emissions expressed in million metric tons.	U.S. Energy Information Administration (EIA).

When selecting the inputs and outputs in the TFEE calculation method, suggestion that the number of Decision Making Units-DMU (33 countries in this study) should be at least three times larger than the sum of inputs and outputs (which is 5), i.e., 33 > 3 * 5 (Cooper et al., 2000), was considered.

3. 2. Method for calculating TFEE

Methods for calculating TFEE include Data Envelopment Analysis (DEA) for non-parametric estimation and Stochastic Frontier Analysis (SFA) for parametric estimation. In this study, DEA will be used because it does not require specific functional forms and has a broader application framework compared to SFA. Meta-analysis of DEA models in terms of EE shows that DEA is a valuable tool for evaluating EE (Mardani et al., 2017).

DEA measures the relative efficiency of units by constructing an empirical efficiency frontier or production possibility frontier based on data on the inputs used and the outputs achieved by all units. The most successful units, which determine the efficiency frontier, receive a score of "1", and the degree of technical inefficiency of other units is calculated based on the distance between their input-output ratios and the efficiency frontier. The AOP model for the linear programming problem

$$\text{Max } \Theta_0 = \sum_{i=1}^{s} w_j y_{j,k0}$$

appears as follows:

$$\sum_{i=1}^{m} v_i x_{i,k0} = 1$$

with constraints:

$$\sum_{j=1}^{s} w_j y_{jk} \leq \sum_{i=1}^{m} v_i x_{ik}, \quad k = 1,...,n; \quad w, v \geq 0$$

where n is the number of units, m is the number of inputs, s is the number of outputs, w_j represents the weight of output y_j, and v_i represents the weight of input x_i.

Several authors have proposed measuring EE while considering the presence of undesirable outputs. Wu et al. (2012), Watanabe and Tanaka (2007), and Mandal (2010) emphasize that analysing EE without considering environmental characteristics, specifically undesirable outputs such as CO_2, can lead to bias in the results. Efficiency measures related to undesirable outputs are commonly referred to as DEA models with undesirable outputs. Many authors highlight that the directional distance function approach is the most suitable solution (Mohd et al., 2015; Lee et al., 2017, Tone, 2001).

A representative of the mentioned approach is the Slack-Based Model (SBM), which disregards the assumption of proportional changes in inputs and outputs and directly focuses on slack or unused resources. This model uses slacks to calculate efficiency, meaning it measures how well the country or

Decision-Making Unit (DMU) utilizes its resources compared to the optimal use of those resources. Let's assume that there are DMUs, each associated with three factors: inputs, desirable outputs, and undesirable outputs, represented by three vectors:

$$x \in R^m, y^g \in R^{s1} \; i \; y^b \in R^{s2}$$

respectively. We define matrices

$$X, \; Y^g \; i \; Y^b$$

as follows:

$$X = [x_1, \dots, x_n] \in R^{m\,x\,n}, Y^g = \left[y_1^g, \dots, y_n^g\right] \in R^{s1\,x\,n} \; i \; Y^b = \left[y_1^b, \dots, y_n^b\right] \in R^{s2\,x\,n}$$

We assume

$$X > 0, Y^g > 0 \text{ and } Y^b > 0.$$

The production possibility set (P) is defined as:

$$P = \{(x, y^g, y^b) \big| x \geq X\,\lambda, \; y^g \leq Y^g\lambda, \; y^b \geq Y^b\lambda, \; \lambda \geq 0\},$$

where

$$\lambda \in R^n$$

represents the intensity vector. The given definition corresponds to the technology of constant returns to scale, where constant returns describe the relationship between inputs and outputs in such a way that proportional changes in inputs lead to proportional changes in outputs. DMUs, in our case the countries,

$$DMU_0(x_0, y_0^g, y_0^b)$$

is efficient in the presence of undesirable outputs if there is no vector

$$(x, y^g, y^b) \in P$$

such that

$$x_0 \geq x, y_0^g \leq y^g \; i \; y_0^b \geq y^b$$

with at least one strict inequality. In accordance with the given definition, SBM is represented as follows:

$$SBM - undesirable\ output\ p\ast = min \frac{1 - \frac{1}{m}\sum_{i=1}^{m} \frac{\bar{s_i}}{x_{i0}}}{1 + \frac{1}{s_1 + s_2}\left(\sum_{r=1}^{s_1} \frac{s_r^g}{y_{r0}} + \sum_{r=1}^{s_2} \frac{s_r^b}{y_{r0}^b}\right)}$$

subject to $x_0 = X\lambda + s^-$

$$y_0^g = Y^g\lambda - s^g$$

$$y_0^b = Y^b\lambda + s^b$$

$$s^- \geq 0, s^g \geq 0, s^b \geq 0, \lambda \geq 0$$

The vectors

$$s^- \in R^m \text{ and } s^b \in R^{s_2}$$

correspond to excesses in inputs and undesirable outputs, respectively, while

$$s^g \in R^{s_1}$$

expresses shortages in desirable outputs. The SBM function with undesirable

$$s_i^-(\forall i), s_r^g(\forall r) \text{ and } s_r^b(\forall r),$$

output strictly decreases with respect to

$$0 < p * < 1.$$

and the objective value satisfies

$$\left(\lambda^*, s^{-*}, s^{g*}, s^{b*}\right).$$

Let an optimal solution of the above program be

The above-mentioned model is presented under the assumption of constant returns. In this study, the SBM model with variable returns to scale (VRS) was used, enabling the analysis of countries' relative efficiency in simultaneously reducing inputs and increasing outputs.

Micro and macro conditions in which countries operate change over time, affecting efficiency in different functional areas. Therefore, dynamic models are employed in the analysis to examine efficiency trends over time. In this study, the window analysis approach within the framework of DEA-SBM with undesirable outputs (DEA-SBM window analysis) is utilized. For quantitative analysis and solving the TFEE calculation problem using DEA-SBM window analysis, the R programming language was employed through the deaR application.

4. Results

4. 1. Total factor energy efficiency in the Western Balkan countries and the European Union

The following table shows descriptive statistics of the data employed in the analysis. It is extended with the correlation matrix of variables included in DEA.

Table 2. Descriptive statistics and correlation matrix

Variables	Number of observations	Mean	Standard Deviation	Minimum	Maximum
Capital (in billions of constant international dollars from 2017)	495	1.634,09	2.643,40	10,71	11.567,48
Employees (in millions)	495	6,97	9,82	0,20	43,10
Energy (in PJ)	495	1.525,11	2.230,61	15,69	9.901,04
GDP (in billions of constant international dollars from 2017)	495	630,56	986,05	8,58	4.464,49
CO_2 (in millions of metric tons)	495	119,12	178,45	1,43	858,99
Correlation analysis					
	Employees	Capital	Energy	GDP	CO2
Employees	1,0000	0,9644	0,9828	0,9856	0,9714
Capital	0,9644	1,0000	0,9831	0,9922	0,9415
Energy	0,9828	0,9831	1,0000	0,9909	0,9774
GDP	0,9856	0,9922	0,9909	1,0000	0,9618
CO2	0,9714	0,9415	0,9774	0,9618	1,0000

Source: Author's calculations.

Descriptive statistics indicates huge differences among the countries with respect to considered variables. It can be observed that the standard deviations are quite high in relation to the means for both outputs and inputs, suggesting that WB and EU countries energy sectors vary in the sizes. For example, the differences between Germany and Malta, as two extremes, show that the values are several hundred times different (Employees 199, Capital 355, Energy 522, GDP 344, and CO_2 130 times). All inputs have positive correlation coefficients with the outputs, which implies that all inputs satisfy the isotonicity assumption with the outputs in the DEA model (Vlahinić-Dizdarević and Šegota, 2012). Therefore, this condition is satisfied for the DEA model and indicates that all inputs are relevant for modelling efficiency and provide credible results. The highest correlation coefficient between input and output is between GDP and

energy (0,99), while the lowest correlation coefficient is between capital and CO_2 emissions (0,94), what is still a high correlation coefficient.

The following table presents the results for TFEE by years and countries.

DMU	2005.	2006.	2007.	2008.	2009.	2010.	2011.	2012.	2013.	2014.	2015.	2016.	2017.	2018.	2019.	Mean
Albania	0,54	0,58	0,93	0,65	1,00	0,86	0,84	1,00	0,86	0,69	0,89	0,69	0,52	0,77	1,00	0,79
Austria	0,75	0,79	0,85	0,85	0,85	0,80	0,83	0,78	0,71	0,66	0,59	0,56	0,55	0,56	0,53	0,71
Belgium	0,67	0,70	0,72	0,70	0,72	0,71	0,87	0,83	0,72	0,71	0,59	0,57	0,56	0,55	0,54	0,68
Bulgaria	0,83	0,67	0,65	0,63	0,58	0,57	0,54	0,49	0,45	0,41	0,38	0,39	0,39	0,40	0,40	0,52
Bosnia and Herzegovina	0,66	0,65	0,65	0,61	0,57	0,53	0,51	0,48	0,48	0,44	0,42	0,41	0,41	0,40	0,40	0,51
Cyprus	0,51	0,51	0,52	0,49	0,48	0,49	0,49	0,50	0,48	0,46	0,45	0,45	0,43	0,45	0,45	0,48
Czech Republic	0,46	0,49	0,53	0,54	0,52	0,53	0,53	0,48	0,44	0,41	0,40	0,39	0,39	0,39	0,39	0,46
Germany	0,88	0,92	1,00	1,00	0,91	0,92	0,99	0,97	0,94	0,97	0,96	0,95	0,97	1,00	1,00	0,96
Denmark	0,80	0,79	0,82	0,83	0,80	0,79	0,81	0,78	0,71	0,66	0,62	0,60	0,62	0,62	0,63	0,72
Spain	0,85	0,90	0,89	0,92	0,91	0,91	0,91	0,87	0,89	0,87	0,92	0,90	0,91	0,93	1,00	0,91
Estonia	0,87	0,98	1,00	0,77	0,71	0,70	0,84	0,68	0,64	0,65	0,61	0,61	0,59	0,60	1,00	0,75
Finland	0,57	0,55	0,60	0,62	0,57	0,55	0,58	0,53	0,47	0,44	0,42	0,41	0,42	0,41	0,41	0,50
France	0,93	0,96	1,00	0,99	0,97	0,96	0,98	0,96	0,94	0,99	0,97	0,95	0,96	0,99	1,00	0,97
Greece	0,78	0,95	1,00	0,86	0,79	0,74	0,63	0,57	0,54	0,50	0,45	0,44	0,44	0,45	0,45	0,64
Croatia	0,62	0,64	0,67	0,65	0,60	0,59	0,59	0,54	0,52	0,48	0,45	0,45	0,45	0,45	0,45	0,54
Hungary	0,57	0,60	0,60	0,62	0,58	0,57	0,58	0,54	0,51	0,48	0,44	0,43	0,43	0,44	0,45	0,52
Ireland	1,00	0,99	1,00	0,94	0,97	0,98	0,96	0,88	0,82	0,81	1,00	0,95	0,97	1,00	1,00	0,95
Italy	0,95	0,98	1,00	0,99	0,98	0,97	1,00	0,96	0,98	0,98	0,95	0,95	0,97	0,98	1,00	0,98
Lithuania	0,91	0,96	1,00	0,97	0,76	0,76	0,86	0,82	0,78	0,75	0,58	0,61	0,66	0,76	1,00	0,81
Luxembourg	0,85	0,90	1,00	0,98	0,98	0,98	1,00	1,00	0,92	0,94	0,95	1,00	0,99	0,99	1,00	0,97
Latvia	0,77	0,87	1,00	1,00	0,61	0,55	0,62	0,61	0,58	0,54	0,52	0,52	0,53	0,53	0,52	0,65
North Macedonia	0,56	0,59	0,61	0,65	0,75	0,77	0,69	0,64	0,64	0,62	0,58	0,61	0,57	0,56	0,61	0,63
Malta	1,00	1,00	1,00	1,00	1,00	0,91	1,00	0,99	1,00	1,00	1,00	1,00	0,98	1,00	1,00	0,99
Montenegro	1,00	1,00	1,00	1,00	1,00	0,94	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	0,84	0,99
Netherlands	0,69	0,72	0,75	0,82	0,73	0,72	0,74	0,70	0,68	0,68	0,66	0,65	0,65	0,66	0,66	0,70
Poland	0,80	0,88	1,00	1,00	0,99	0,95	1,00	0,98	0,91	0,95	0,96	0,87	0,89	0,95	1,00	0,94
Portugal	0,64	0,69	0,71	0,73	0,70	0,75	0,71	0,63	0,58	0,52	0,47	0,47	0,47	0,48	0,48	0,60
Romania	0,63	0,73	0,88	1,00	0,75	0,68	0,65	0,60	0,62	0,58	0,55	0,56	0,57	0,59	0,61	0,67
Serbia	0,55	0,58	1,00	1,00	0,70	0,77	0,87	0,85	0,87	0,77	0,70	0,72	0,70	0,85	1,00	0,80
Slovakia	0,40	0,44	0,49	0,51	0,50	0,53	0,54	0,52	0,48	0,47	0,45	0,44	0,43	0,43	0,44	0,47
Slovenia	0,52	0,55	0,59	0,58	0,57	0,57	0,58	0,53	0,51	0,50	0,48	0,47	0,47	0,48	0,50	0,53
Sweden	0,88	0,93	1,00	0,97	0,94	0,90	0,95	0,88	0,83	0,84	0,88	0,75	0,75	0,82	0,64	0,86
United Kingdom	0,92	0,95	1,00	0,99	0,94	0,93	0,97	0,93	0,92	1,00	1,00	0,96	1,00	1,00	1,00	0,97

Table 3. TFEE by years and countries
Source: Author's calculations.

The top 10 most efficient countries (based on the average TFEE from 2005 to 2019) are: Malta, Montenegro, Italy, France, United Kingdom, Luxembourg, Germany, Ireland, Poland, and Spain. On the other hand, the least efficient countries include: Portugal, Croatia, Slovenia, Hungary, Bulgaria, Bosnia and Herzegovina, Finland, Cyprus, Slovakia, and Czech Republic. In the context of the Western Balkan countries, it is noticeable that Montenegro maintains a high level of efficiency throughout the entire period. Serbia also shows an upward trend in TFEE with a certain decline between 2013 and 2016. It is difficult to determine trends for Albania as there are years (e.g., 2009, 2012, or 2019) when the TFEE value is 1, indicating efficiency, while in other years, significant inefficiency is observed (2005, 2014, and 2017). North Macedonia shows a growth trend until 2010, where TFEE increases from 0,56 in 2005 to 0,77 in 2010. However, after 2010, there is a decline in efficiency with occasional slight recoveries and increases in TFEE (such as in 2016 and 2019). In Bosnia and Herzegovina, there is a continuous decline in efficiency from 2005 to 2019, with TFEE decreasing from 0,66 to 0,4.

4. 2. Unused resources (slacks) in the WB and EU countries

The Slack-Based Model (SBM), which was used to calculate TFEE, directly focuses on reserves or unused resources to measure efficiency. SBM assesses how well the countries utilize their resources compared to their optimal usage. Reserve or slack refers to the difference between the actual value of a variable in the model and its optimal or target level.

To represent the slack or unused resources for efficiency calculation, we will use data obtained through the application of DEA-SBM window analysis. The data for all countries included in this analysis (EU and WB) have been analysed using a window analysis covering the period from 2016 to 2019 as the end of the observed period. These results are compared with the window analysis results from the period 2005 to 2008 as the beginning of the observed period. Observing the initial and final periods provides insights into the improvement or deterioration of input utilization efficiency in generating outputs.

Of particular interest for this study is the analysis of energy-related slacks. When considering slacks related to energy, the slack represents the amount of energy that is not fully utilized by the analysed country, indicating that the country has more energy available than necessary to achieve its goals and outputs. Analysing energy reserves also helps identify the quantities of energy and countries that use too much energy relative to their performance. For example, in the initial period, Bosnia and Herzegovina has an energy reserve of 8,93 PJ, meaning it could reduce the amount of consumed energy by 8,93 PJ without affecting the creation of outputs (GDP and CO_2). This value indicates inefficiency in energy consumption for output creation and can be used to identify potential improvements in strategic energy processes. Albania has reserves of 8,65 PJ, North Macedonia has 12,28 PJ, and Serbia has 64,28 PJ, meaning all these WB countries could reduce their energy consumption without impacting the creation of outputs. On the other hand, Malta and Montenegro, have no reserves and are relatively efficient in output creation. The largest reserves belong to the Netherlands with 773,89 PJ, Belgium with 693,29 PJ, and Finland with 609 PJ. When considering reserves based on data from the end period (2016-2019), significant changes are noticeable. In all WB countries, there has been a deterioration. Albania has a reserve of 24,08 PJ, Bosnia and Herzegovina has a reserve of 101,57 PJ, North Macedonia has a reserve of 24,32 PJ, Montenegro 0,42 PJ, and Serbia has a reserve of 81,11 PJ. The largest decrease in reserves and an increase in EE are present in Italy with a decrease of 100%, Spain with 99%, Luxembourg with 96%, Ireland with 87%, the United Kingdom with 64%, and Germany with 54%.

In order to achieve optimal TFEE/same level of output with less inputs on average per year for WB countries, the following is needed:

- Albania: 400.000 employees, $9,09 billion in capital, and 11,46 PJ of energy;
- Bosnia and Herzegovina: 710.000 employees, $3,99 billion in capital, and 49,27 PJ of energy;

- North Macedonia: 400.000 employees, $1,28 billion in capital, and 15,47 PJ of energy;
- Montenegro: 10.000 employees, $0,08 billion in capital, and 0,11 PJ of energy;
- Serbia: 630.000 employees and 54,98 PJ of energy.

4. 3. Results of comparison of Total Factor Energy Efficiency and Simple Energy Efficiency

One of the research questions is related to the differences in results regarding energy efficiency indicators considering the traditional and contemporary approaches. The contemporary approach involves calculating the TFEE, while the traditional approach involves energy intensity and the indicator of Simple Energy Efficiency (SEE). SEE can be interpreted as the value of GDP created based on 1 PJ of final energy. The following table presents the average results of energy intensity and SEE for the period 2005-2019.

Table 4: Average Values of Energy Intensity and Simple Energy Efficiency

DMU	Energy Intensity - EI*	SEE	Rank	DMU	Energy Intensity - EI*	SEE	Rank
Albania	2,742	0,368	14.	Latvia	3,291	0,306	30.
Austria	2,546	0,394	12.	Lithuania	2,943	0,341	19.
Belgium	3,192	0,315	29.	Luxembourg	2,778	0,367	15.
Bosnia and Herzegovina	3,573	0,281	31.	Hungary	3,046	0,330	24.
Bulgaria	3,086	0,329	25.	Malta	1,552	0,651	1.
Czech Republic	3,053	0,331	23.	Germany	2,349	0,428	11.
Montenegro	2,990	0,342	18.	Poland	2,978	0,340	20.
Denmark	2,004	0,503	3.	Portugal	2,241	0,450	9.
Estonia	3,142	0,322	27.	Romania	2,260	0,453	8.
Finland	4,253	0,235	33.	North Macedonia	2,807	0,359	16.
France	2,342	0,429	10.	Slovakia	3,250	0,316	28.

DMU	Energy Intensity - EI*	SEE	Rank	DMU	Energy Intensity - EI*	SEE	Rank
Greece	2,201	0,455	6.	Slovenia	3,072	0,328	26.
Netherlands	2,838	0,355	17.	Spain	2,124	0,475	5.
Croatia	3,017	0,333	22.	Serbia	3,717	0,273	32.
Ireland	1,681	0,625	2.	Sweden	2,973	0,340	21.
Italy	2,106	0,476	4.	United Kingdom	2,218	0,454	7.
Cyprus	2,625	0,383	13.				
*PJ/billion constant 2017 international dollars.							

Source: Author's calculations.

For the WB countries, the value of energy intensity is as follows: for Albania, it is 2,742 or in the form of the SEE indicator 0,368; for North Macedonia, it requires 2,807 PJ/10^9 dollars or a SEE indicator value of 0,359; in Montenegro, it requires 2,99 PJ/10^9 dollars, resulting in a SEE indicator of 0,342; for Bosnia and Herzegovina, it requires 3,573 PJ/10^9 dollars, or a SEE indicator of 0,281; and Serbia is ranked the lowest with a SEE of 0,273 or 3,717 PJ needed to generate one billion constant international dollars in 2017.

The previously calculated TFEE is compared to the values of SEE, and several inconsistencies can be observed. If we first consider the similarity between these two approaches in terms of a difference of two ranks, we find similarity for 7 out of 33 countries (21%), namely:

- High-ranking countries: Malta (1st in both approaches), Italy (4th in SEE and 3rd in TFEE), and the United Kingdom (7th in SEE and 5th in TFEE).
- Medium-ranking countries: Albania (14th in both approaches) and the Netherlands (17th in SEE and 18th in TFEE).
- Low-ranking countries: Slovenia (26th in both approaches) and Bosnia and Herzegovina (31st in SEE and 29th in TFEE).

Of the top 10 ranked countries in SEE, 6 of them are also ranked in the top 10 in TFEE. These countries are Malta, Ireland, Italy, Spain, the United Kingdom, and France. The remaining four countries in the top 10 of SEE, namely Denmark ($SEE_3/TFEE_{16}$), Greece ($SEE_6/TFEE_{22}$), Romania ($SEE_8/TFEE_{20}$), and Portugal ($SEE_9/TFEE_{24}$), are mostly classified as low-ranking countries, indicating a significant inconsistency and overestimation in SEE. Additionally, Cyprus ($SEE_{13}/TFEE_{31}$) and the Czech Republic ($SEE_{23}/TFEE_{33}$) are also overestimated in SEE. On the other hand, the countries that are underestimated in SEE and have much higher rankings in TFEE are Luxembourg ($SEE_{15}/TFEE_6$), Montenegro ($SEE_{18}/$

$TFEE_2$), Poland (SEE_{20}/$TFEE_9$), Sweden (SEE_{21}/$TFEE_{11}$), Estonia (SEE_{27}/$TFEE_{15}$), Belgium (SEE_{29}/$TFEE_{19}$), Latvia (SEE_{30}/$TFEE_{21}$), and Serbia (SEE_{32}/$TFEE_{13}$).

5. Conclusions and recommendations

Energy efficiency is becoming an increasingly important topic due to its impact on the economy and the environment. It is considered one of the best ways to achieve energy savings and reduce greenhouse gas emissions without negative effects on the economy. This study addresses the research gap in regional energy efficiency by considering the overall factors and focusing on the Western Balkan countries and the European Union.

In the context of the Western Balkan countries, it is noticeable that Montenegro maintains a high level of efficiency throughout the observed period. The high efficiency is enabled by the fact that there are negligible unused resources (slacks) for all input and output categories. Serbia also shows an upward trend in energy efficiency. Serbia does not have unused resources in capital, while the average annual growth rate of CO_2 slacks is negative, meaning that slacks are decreasing. The growth rate of energy and employee slacks is positive but at a relatively low level below 5% annually. It is difficult to determine trends for Albania, but the annual growth rates of slacks for all variables are positive and exceed 50% annually. North Macedonia demonstrates a growth trend until 2010, but after that, there is a decline in efficiency. The increase in efficiency is the result of reducing CO_2 slacks and low growth rates of employee slacks, while the efficiency declines are caused by an increase in the annual growth rate of capital and energy slacks by over 20%. In Bosnia and Herzegovina, there is a continuous decline in energy efficiency. The annual growth rates of energy and capital slacks are over 40%, while the rates for employee and CO_2 slacks are positive but significantly lower, ranging up to 7% annually.

The model used to calculate TFEE focuses directly on reserves or unused resources for efficiency calculation. Considering energy input reserves significant changes are noticed in the period 2005-2019, i.e., there has been deterioration in all WB countries. Bosnia and Herzegovina shows the highest deterioration among the observed countries with 66,9 percentage points (p.p.). For Albania, it is 18,6 p.p., for Montenegro is 1,3 p.p., for North Macedonia it is 15,4 p.p., and for Serbia it is 4,3 p.p. When these results are presented per capita, the input energy reserves are the highest in Bosnia and Herzegovina, exceeding 25 gigajoules (GJ) per capita, while in other countries, these values do not exceed 13 GJ per capita. In the most efficient WB and the EU countries based on TFEE, the slacks are lower in the end period compared to the initial period, indicating an increase in energy efficiency during the observed period. This is the case with Ireland, Italy, Luxembourg, Germany, Spain, and the United Kingdom.

According to the latest adopted Energy Efficiency Action Plan of Bosnia and Herzegovina for the period 2016-2018 (2017), the expected energy savings in 2020 amounted to 15,24 PJ of final energy. However, to achieve optimal results

in Bosnia and Herzegovina, it would be necessary to reduce energy consumption by 49,27 PJ in average. Therefore, the low set targets, which are only at one-third of the necessary level, reflect an unambitious approach and a lack of dedication to improving energy efficiency policies in Bosnia and Herzegovina.

Based on the mentioned research and conclusions, several implications can be proposed to improve energy efficiency in the research area.

Firstly, the development of a set of institutional, economic and regulatory measures for the WB countries should consider the specifics of each individual country. According to the research results, Montenegro achieves almost top-notch results in terms of TFEE, and measures should focus on increasing labour efficiency, to some extent, reducing energy consumption, and decreasing CO_2 emissions. In Serbia, there is a need for a comprehensive set of measures to significantly improve labour efficiency, energy consumption and CO_2 emissions. In these two countries, the problem of efficiency in utilizing capital to generate GDP is not present, while in Albania, Bosnia and Herzegovina, and North Macedonia, the capital efficiency issue is relatively small.

However, it is important to highlight the challenges faced in countries like Bosnia and Herzegovina, Albania, and North Macedonia, particularly concerning labour efficiency. These nations encounter significant issues in this regard, as evidenced by the fact that, in some cases, achieving the same level of output would require over 50% fewer workers. This disparity in labour efficiency raises critical concerns and necessitates a closer examination of the underlying factors contributing to such inefficiencies. The evident problem of labour productivity in these countries should be addressed by promoting advanced technologies and innovation (Crespi and Zuniga, 2010; Criscuolo, 2009) and, on the other hand by investing in education and training (McKenzie and Woodruff, 2014; World Bank, 2010; Tan and Batra, 1996), employee engagement and efficient management (Perry et al., 2006; Frank, 2011), employee participation (Levine and Tyson, 2011), monetary incentives (Lucifora, 2015; Perry et al., 2006), working time-flexible scheduling (Golden, 2011), occupational safety and health (Rongen, 2015; ILO, 2013; Gahan et al., 2014), encouraging a positive work culture and promotion of work – private life balance (Kelly et al., 2008; Beauregard and Henry, 2009).

The serious problem in Albania, Serbia, North Macedonia, and particularly in Bosnia and Herzegovina is the inefficiency in energy consumption and CO_2 emissions. Since the energy production technologies in these countries primarily rely on use of fossil fuels, primarily coal, they result in high CO_2 emissions. As a result, significant inefficiency exists in this regard. However, it is not possible to change this situation quickly and without economic implications. It is necessary to gradually reduce the use of fossil fuels, especially coal, and to promote the use of clean renewable energy sources. The roadmap for all Western Balkan countries exists through the EU accession, membership in the Energy Community, and aligning with the EU regulations, plans, and practices. The Western Balkans, as a region, should follow the transition processes of similar regions in the EU that were dependent on fossil fuels, but significantly

reduced CO_2 emissions, such as the Scandinavian countries, Germany and the United Kingdom.

In addition, the Western Balkan countries should:

- Adopt laws and regulations that require high energy efficiency standards, especially in construction, industry and transportation;
- Actively monitor the implementation of these regulations, because experience shows that having EE laws and regulations is meaningless without competent and engaged supervision;
- Significantly increase energy savings targets in energy efficiency action plans;
- Reasonably increase energy prices within a sustainable energy pricing system that determines and regulates prices in the market, considering supply and demand, production and distribution costs, regulatory requirements, taxes and subsidies, as well as other relevant factors;
- Establish support for improving EE through subsidies, incentives for procurement of relevant equipment, incentives for building renovation, tax incentives, and financial mechanisms to enhance energy efficiency, especially in the residential sector, industry and transportation;
- Enable partnerships and collaboration with private sector to improve energy efficiency, such as cooperation within energy service companies, public-private partnerships, concessions, etc.

In future research, TFEE could consider disaggregating energy as an input into its constituent parts, such as coal energy, gas energy, biomass energy, electricity, etc., in order to identify the most and least efficient energy resources. Additionally, energy as an input could be divided into renewable energy sources and fossil fuels. Future research in this area could include the calculation of TFEE with undesirable outputs, such as other greenhouse gases, as well as emissions of pollutants like SOx, NOx, aerosols, dust, etc. This way, EE would be calculated in the context of comprehensive ecological TFEE.

Literature

1. Amowine, N., Ma, Z., Li, M., Zhou, Z., Azembila Asunka, B., Amowine, J. (2019). Energy Efficiency Improvement Assessment in Africa: An Integrated Dynamic DEA Approach. Energies 2019, 12, 3915.
2. Apergis, N., Aye, G. C., Barros, C. P., Gupta, R., Wanke, P. (2015). Energy efficiency of selected OECD countries: a slacks based model with undesirable outputs. Energy Economics 51, 45–53.
3. Beauregard, T.A., Henry, L.C. (2009). Making the link between work-life balance practices and organizational performance. Human resource management review, 19. 9-22.
4. Bhattacharyya, S.C., 2011. Energy Economics - Concepts, Issues, Markets and Governance, Springer-Verlag London, 143.

5. Bicil, I. M., Türköz, K. (2021). Are European Union countries efficient or inefficient in energy use? Eastern Journal of European Studies 12(2), 5-20.

6. Borozan, D., 2018. Technical and Total Factor Energy Efficiency of European Regions: A Two-Stage Approach, Energy (2018), 1-35.

7. Borozan, D., Borozan, L. (2018). Analysing total-factor energy efficiency in Croatian counties: evidence from a non-parametric approach. Central European Journal of Operations Research volume 26, 673–694.

8. Bosseboeuf, D., Chateau, B., Lapillonne, B. (1997). Cross-Country Comparison on Energy Efficiency Indicators: The on-going European Effort Towards a Common Methodology, Energy Policy, 25(7-9), 673-682.

9. Castro, Camioto F., Moralles HF., Mariano EB., do Nascimento Rebelatto DA. (2016). Energy efficiency analysis of G7 and BRICS considering total-factor structure. Journal of Cleaner Production 122, 67-77.

10. Ceylan, D., Gunay, E.N.O. (2010). Energy Efficiency Trends and Policies: Cross-Country Comparison in Europe. EcoMod2010 259600038, EcoMod.

11. Chang, M.C., 2020. An application of total-factor energy efficiency under the metafrontier framework, Energy Policy, Elsevier 142 (2020), 1-7.

12. Cheng, Y.D., 2016. Dynamic evolution of energy efficiency mechanism in China. Journal of Mechanichal Engineering Research and Developments 39 (2), 544-554.

13. Cooper, W.W., Seiford, L.M., Tone, K. (2000). Data envelopment analysis: A Comprehensive Text with Models, Applications, References and DEA-Solver Software. Kluwer Academic Publishers, Boston.

14. Council of Ministers of Bosnia and Herzegovina, (2017). Energy efficiency action plan of Bosnia and Herzegovina for the period 2016-2018.

15. Crespi, G., Zuniga, P. (2012). Innovation and productivity: evidence from six Latin American countries, in: World development, 40(2), 273-290.

16. Criscuolo, C. (2009). Innovation and Productivity: Estimating the Core Model Across 18 Countries, in: OECD (ed.): Innovation in Firms: A Microeconomic Perspective. Paris: Organization for Economic Cooperation and Development.

17. Definition of data and energy efficiency indicators in ODYSSEE data base, ODYSSEE project, (2020).

18. European Environment Agency (2018). National policies and measures on climate change mitigation in Europe in 2017.

19. European Environment Agency (2018). Climate change, impacts and vulnerability in Europe 2016 - An indicator-based report.

20. Feenstra, Robert C., Inklaar, R., Timmer, M.P. (2015). The Next Generation of the Penn World Table. American Economic Review, 105(10), 3150-3182.

21. Filippini, M., Hunt, L.C. (2015). Measurement of energy efficiency based on economic foundations, Energy Economics, Volume 52, Supplement 1, 5-16.

22. Frank, S.A. (2011). What Does It Take To Motivate Better Performance and Productivity in the Federal Workplace? Ask the Employees. Dissertation, Georgia State University.

23. Gahan, P., Sievewright, B., Evans, P. (2014). Workplace health and safety, business productivity and sustainability. Safe Work Australia: Melbourne.

24. Golden, L. (2012). The Effects of Working Time on Productivity and Firm Performance, Research Synthesis Paper. International Labor Organization (ILO), Conditions of Work and Employment Series, 33.

25. Gökgöz, F., Erkul, E. (2019). Investigating the energy efficiencies of European countries with super efficiency model and super SBM approaches. Energy Efficiency 12, 601–618.

26. Guo, X., Lu, C.C., Lee, J.H., Chiu, Y.H. (2017). Applying the dynamic DEA model to evaluate the energy efficiency of OECD countries and China. Energy, Volume 134, 392-399.

27. Gupta, S., Kangur, A., Papageorgiou, C., Wane, A. (2014). Efficiency-Adjusted Public Capital and Growth. World Economic Development, Vol. 57, Issue C: 164–78.

28. Han, L., Han, B., Shi, X., Su, B., Lv, X., Lei, X. (2018). Energy efficiency convergence across countries in the context of China's Belt and Road initiative. Applied Energy 213, 112–122.

29. He, P., Yulong, S., Huayu, S., Jianhui, J., Zhongfu, Y. (2019). Does Environmental Tax Affect Energy Efficiency? An Empirical Study of Energy Efficiency in OECD Countries Based on DEA and Logit Model. Sustainability 11 – 14, 3792.

30. Honma, S., Hu, J.-L. (2008). Total-factor energy efficiency of regions in Japan. Energy Policy, 36 (2), 821–833.

31. Hu, JL., Wang, SC. (2006). Total-factor energy efficiency of regions in China. Energy Policy 34 (2006), 3206–3217.

32. Hu, JL., Kao, CH. (2007). Efficient energy-saving targets for APEC economies. Energy Policy 35 (2007), 373–382.

33. Hu, JL., Lio, M.C., Kao, C.H., Lin, Y.L. (2012). Total-factor Energy Efficiency for Regions in Taiwan. Energy Sources, Part B: Economics, Planning, and Policy. 7. 292-300.

34. Huang, H., Wang, T. (2017). The Total-Factor Energy Efficiency of Regions in China: Based on Three-Stage SBM Model. Sustainability 9, 9:1664.

35. ILO (2013). Can better working conditions improve the performance of SMEs? An international literature review. Geneva: ILO.

36. Jebali, E., Essid, H., Khraief, N. (2017). The analysis of energy efficiency of the Mediterranean countries: A two-stage double bootstrap DEA approach, Energy, Volume 134, 991-1000.

37. Kanellakis, M., Martinopoulos, G., Zachariadis, T. (2013). European energy policy—A review. Energy Policy 62, 1020–1030.

38. Kelly, E.L., Kossek, E.E., Hammer, L.B., Durham, M., Bray, J., Chermack, K., Murphy, L.A., Kaskubar, D. (2008). Getting There from Here: Research on the Effects of Work-Family Initiatives on Work-Family Conflict and Business Outcomes. Acad Manag Ann. 2, 305-349.

39. Lee, B.L., Wilson, C., Jr, Pasurka., Carl, A., Fujii, H., Managi, S. (2017). Sources of airline productivity from carbon emissions: An analysis of operational performance under good and bad outputs. J. Prod. Anal. 47 (3), 223–246.

40. Levine, D.I., Tyson, L.D., (2011). Participation, Productivity and the Firm's Environment, in: Blinder, Alan S. (ed.): Paying for Productivity: A Look at the Evidence.

41. Li, G. (2019). Spatiotemporal Dynamics of Ecological Total-Factor Energy Efficiency and Their Drivers in China at the Prefecture Level. IJERPH, MDPI, vol. 16(18), 1-23.

42. Li, K., Lin, B. (2018). How to promote energy efficiency through technological progress in China? Energy, Volume 143, 812-821.

43. Li, L.B., Hu, J.L. (2012). Ecological total-factor energy efficiency of regions in China. Energy Policy 46, 216–224.

44. Li, Y., Liu, A.C., Wang, S.M., Zhan, Y., Chen, J., Hsiao, H.F. (2022). A Study of Total-Factor Energy Efficiency for Regional Sustainable Development in China: An Application of Bootstrapped DEA and Clustering Approach. Energies, 2022, 15(9), 3093.

45. Liu, C. (2017). Total-factor energy efficiency of regions in China considering natural disaster effects. Applied Ecology and Environmental Research 15, 155-169.

46. Liu, X., Liu, L., Liu, X., Liu, G. (2015). An Improved Data Envelopment Analysis (DEA) Model to Measure China's Energy Efficiency. Proceedings of the International Conference on Logistics, Engineering, Management and Computer Science, Atlantis Press, 751-758.

47. Lu, F., Lu, Y., Lei, N. (2021). Measurement and Analysis of Urban Total Factor Energy Efficiency in China. E3S Web Conf. 261 01020.

48. Lucifora, C. (2015). Performance-related pay and labor productivity. Do pay incentives and financial participation schemes have an effect on a firm's performance? IZA World of Labor, 152.

49. Mandal, S. K. (2010). Do undesirable output and environmental regulation matter in energy efficiency analysis? Evidence from Indian cement industry. Energy Policy 38, 6076–83.

50. Mardani, A., Zavadskas E.K., Streimikiene D., Jusoh A., Khoshnoudi M. (2017). A comprehensive review of data envelopment analysis (DEA) approach in energy efficiency, Renewable and Sustainable Energy Reviews, 70, 1298-1322.

51. McKenzie, D., Woodruff, C. (2014). What are we learning from business training and entrepreneurship evaluations around the developing world? in: World Bank Research Observer, 29 (1), 48-82.

52. Mohd, S.A., Khan, N., Ramli, R., Azizul Baten, M.D. (2015). Enhanced DEA model with undesirable output and interval data for rice growing farmers performance assessment. AIP Conf. Proc. 1691, 030016.

53. Nikbakht, M., Hajiani, P., Ghorbanpur, A. (2022). Assessment of the total-factor energy efficiency and environmental performance of Persian Gulf countries: a two-stage analytical approach. Environmental Science and Pollution Research.

54. Ohene-Asare, K, Turkson, C. (2019). Total-Factor Energy Efficiency and Productivity of ECOWAS States: A Slacks-Based Measure with Undesirable Outputs, Journal of African Business, vol. 20(1), 91-111.

55. Ohene-Asare, K., Tetteh, E.N., Asuah, E.L. (2020). Total factor energy efficiency and economic development in Africa. Energy Efficiency 13, 1177–1194.

56. Patterson, M. G. (1996). What is energy efficiency?: concepts, indicators and methodological issues. Energy Policy 24 (5), 377–390.

57. Perry, J. L., Mesch, D., Paarlberg, L. (2006). Motivating Employees in a New Governance Era: The Performance Paradigm Revisited. Public Administration Review, 66, 505–514.

58. Rajbhandari, A., Zhang, F. (2017). Does Energy Efficiency Promote Economic Growth? Evidence from a Multi-Country and Multi-Sector Panel Data Set. Policy Research Working Paper 8077. World Bank, Washington, DC.

59. Rongen, A. (2015). Sustainable Employability & Participation in Health Promotion Programs. Erasmus University Rotterdam.

60. Scheel, H. (2001). Undesirable outputs in efficiency evaluations. European J. Oper. Res. 132, 400–410.

61. Seiford, L.M., Zhu, J. (2001). Modeling undesirable factors in efficiency evaluation. European J. Oper. Res. 142, 16–20.

62. Shi, D. (2007). Regional differences in China's energy efficiency and conservation potentials. China & World Economy 15 (1), 96–115.

63. Sun, J., Li, S. (2014). Total Factor Energy Efficiency of Yangtze River Delta Region in China, 54th Congress of the European Regional Science Association: "Regional development &

globalisation: Best practices", 26-29 August 2014, St. Petersburg, Russia, European Regional Science Association (ERSA), Louvain-la-Neuve.

64. Sun, H., Edziah, B.K., Sun, C., Kporsu, A.K. (2019). Institutional quality, green innovation and energy efficiency. Energy Policy 135, 1-14.
65. Sueyoshi, T., Goto, M. (2013). DEA environmental assessment in a time horizon: Malmquist index on fuel mix, electricity and CO2 of industrial nations. Energy Economics, Volume 40, 370-382.
66. Šegota, A. Vlahinić Lenz, N., Maradin, D. (2017). Environmental Total-Factor Energy Efficiency in the EU countries. 6th International Scientific Symposium "Economy of Eastern Croatia - Vision and Growth. Ekonomski fakultet u Osijeku, 675-685.
67. Tan, H.W., Batra, G. (1996). Enterprise Training in Developing Countries: Overview of Incidence, Determinants, and Productivity Outcomes. World Bank, Private Sector Development Department, Occasional Paper No. 9.
68. Tone, K. (2003). Dealing with Undesirable Outputs in DEA: A Slacks-Based Measure (SBM) Approach. GRIPS Research Report Series 2003. Tokyo: National Graduate Institute for Policy Studies.
69. Vlahinić-Dizdarević, N., Šegota, A. (2012). Ukupna faktorska energijska efikasnost u zemljama Evropske unije. Zbornik radova Ekonomskog fakulteta u Rijeci 30 (2), 247-265.
70. Vlahinić-Lenz, N., Šegota, A., Maradin, D. (2018). Total-factor Energy Efficiency in EU: Do Environmental Impacts Matter? International Journal of Energy Economics and Policy 8(3), 92-96.
71. Wang, C.N., Ho, H.X., Hsueh, M.H. (2017). An Integrated Approach for Estimating the Energy Efficiency of Seventeen Countries, Energies, 10(10), 1597.
72. Wang, L.W., Le, K.D., Nguyen, T.D. (2019). Assessment of the Energy Efficiency Improvement of Twenty-Five Countries: A DEA Approach. Energies 2019, 12, 1535.
73. Watanabe, M.; Tanaka , K. (2007). Efficiency analysis of Chinese industry: a directional distance function approach. Energy Policy 35, 6323–6331.
74. World Bank, 2010. Stepping Up Skills for More Jobs and Higher Productivity, World Bank Publications - Reports 27892, The World Bank Group.
75. Wu, F., Fan, W., Zhou, P., Zhou, D.Q. (2012). Industrial energy efficiency with CO2 emissions in China: a nonparametric analysis. Energy Policy 49, 164–172.
76. Xing-Ping, Z., Xiao-Mei, C., Jia-Hai, Y., Xiao-Jun, G. (2011). Total-factor energy efficiency in developing countries. Energy Policy 39, 644–650.
77. Xu, T., You, J., Li, H., Shao, L. (2020). Energy Effiency Evaluation Based on Data Envelopment Analysis: A Literature Review. Energies 2020 (13), 35-48.
78. Yu B. (2020). Industrial structure, technological innovation, and total-factor energy efficiency in China. Environ Sci Pollut Res Int. 27(8), 8371-8385.
79. Zhang, X.P., Cheng, X.M., Yuan, J.H., Gao, X.J. (2011). Total-factor energy efficiency in developing countries. Energy Policy 39, 644–650.
80. Zhang, S., Li, D., Li, S., Jiang, H., Shen, Y. (2017). Analysis of regional total factor energy efficiency in China under environmental constraints: based on undesirable-minds and DEA window model. IOP Conference Series: Earth and Environmental Science, Volume 69.
81. Zhao, C., Zhang, H., Zeng, Y., Li, F., Liu, Y., Qin, C., Yuan, J. (2018). Total-Factor Energy Efficiency in BRI Countries: An Estimation Based on Three-Stage DEA Model. Sustainability 2018, 10, 278.

Faruk Sijerčić, BA[1]
Assist. Prof. Dr. Irfan Djedović[2]
Assoc. Prof. Dr. Dino Arnaut[3]

Original scientific paper

THE THEORY OF PLANNED BEHAVIOUR AS PREDICTOR OF ENTREPRENEURIAL INTENTIONS OF STUDENTS IN BOSNIA AND HERZEGOVINA

Abstract

This study assists in understanding the perceived influence the Theory of planned behaviour (TPB) has on entrepreneurial intention (EI) of students and further show the intricacies of this relationship. The study was conducted inside Bosnia and Herzegovina with a sample of students from different public and private universities with the aim to investigate how the model fairs within the Bosnian cultural and structural environment. The questionnaire was based on previous research and measures to preserve the reliability and validity of the results and SPSS was used to investigate our data through a series of tests. There have only been a few studies relating Theory of Planned behaviour to EI in Bosnia and Herzegovina, so our research supports and follows previous authors conclusions and is a valuable reference in support of future research of entrepreneurial intent in this country. The end goal of proving the TPB is a valuable predictor of entrepreneurial intention is important as it gives added reasoning to foster the constructs in the TPB through structural and educational support proven previously to be strong influences on personal attitudes, subjective norms, and perceived behavioural control. Entrepreneurs from Bosnia and Herzegovina oftentimes overachieve given the lack of educational and governmental support they receive during their career, showing that with a more structured approach B&H is bound to produce higher levels of entrepreneurial success across the board.

Key words: *Theory of Planned Behaviour, Entrepreneurial Intention, Personal Attitudes, Subjective Norms, Perceived Behavioural Control.*

1 BA of Management and Information Technologies, International Burch University, Francuske Revolucije bb, Sarajevo, faruk.sijercic@icloud.com)
2 International Burch University, Francuske Revolucije bb, Sarajevo, irfan_djedovic@hotmail.com
3 Assoc. Prof. Dr., University of Zenica, Fakultetska 3, Zenica, arnaut.dino@gmail.com

1. Introduction

After the era of personality traits, a big shift in explaining behaviour came about with the social psychology theories main one being Ajzen's Theory of Planned Behaviour. Personality as the main factor of entrepreneurship was set aside and new research supporting these new social models started multiplying putting the individual and their own capabilities, attitudes, and influences in the driver's seat of decision making.

Ajzen's theory of reasoned action (1985.) later expanded (Ajzen, 1991) to Theory of Planned Behaviour (TPB) stipulates that any decision a person makes is influenced by their attitudes towards the behaviour, subjective norms related to the behaviour, and perceived behavioural control they have over it. Even though entrepreneurial intention is a much more complex volitional behaviour than choosing which ice cream flavour we want or is wearing shorts to school appropriate, it fits the mould when it comes to the explanation power that PA, SN and PBC give it.

In our research we used Ajzen's classical model adapted to intention rather than behaviour as we research a pre-behaviour effect of the TPB on EI. Entrepreneurship as a behaviour is very complex to predict due to the many environmental factors that aren't considered in most models and that affect everyone differently. Things like lack of motivation, noted by Ajzen (1991) as well as Deci and Ryan (2020) can in finality lead to people not pursuing their intentions to finality. With that said intention has been proven to be the greatest predictor of behaviour, and as such an intention to pursue entrepreneurship should hold weight in predicting that same behaviour. This invites future research in Bosnia and Herzegovina to test the transition from intention to behaviour and investigate all the factors that may influence it.

2. Theory and hypotheses

Theory of planned in its core has three main factors that influence intention. Personal attitudes (PA) are shaped by an individual's beliefs about the advantages of running a business as well as the potential risks and difficulties that come with such a career. It is important to note sometimes people delve into entrepreneurship based on necessity rather than their own preference, and those businesses have higher chances of failure because of it (Block et Al, 2014).

Kautonen (2010.) talked about this as a good mechanism to fight poverty, but a negative influence on the first-time business owner to ever open a business again if it fails. Improvement in personal attitudes has been described by Lüthje C. & Frank, N. (2003) as an important level in improving EI, hence it is considered a valuable part of the TPB. Gibson and Barron (2003) and Karimi et Al. (2014) emphasise the importance of role models at universities usually found in different professors or classmates as they found that role models improve PA and coherently EI.

Subjective norms (SN) are theorised to have a significant influence on EI through social circle pressures and expectations related to entrepreneurship. It is important to note that SN are highly dependent on the cultural and social backgrounds of the sample and as such often provide contradicting results. Astuti (2012) and others proved a significant influence of SN on EI while in Krueger et Al. (2000) SN was deemed insignificant. Even in Bosnia and Herzegovina mixed results were achieved by different authors.

Katono et Al (2011) proposed that social circle should be expanded to peers and role models as they are often important in students' decisions, and we did this through adding colleagues and university support as added items of the SN construct. Through studies like Alferaih (2022), Dick and Rallis, (1991) and others we presumed a significant role of SN in predicting EI and often negative due to prejudice of a risky career choice. An important consideration we had is that Bosnia as a collectivistic country, if consistent with the patterns of others, would have stronger SN influence due to its collectivistic nature.

Behaviours not fully under our control are considered to have perceived behavioural control (PBC) as an influence. Ajzen (2002) has focused on PBC being a factor with two main subcategories, those being self-efficacy (belief in oneself) and controllability (level of control one has over a behaviour) and as such we included items for both these dimensions. Bandura (2002) confirmed this in his paper stating that competency is not only having skills, but believing we can use them and that modelling influences (like professors) should implement teaching both.

Others like Bagheri et Al (2013) stressed that PBC stems from education and that students benefit from a supportive environment. All in all, it is logical to conclude that students more exposed to entrepreneurship will have higher levels of PBC and as presumed their intention will also be stronger through the influence of PBC. Based on the previously mentioned research and our adaptation of Ajzen's (1991) model (Figure 1) we formulated below Hypotheses for testing:

H1: Personal attitudes towards entrepreneurship significantly influence students' entrepreneurial intention.

H2: Subjective norms significantly influence students' entrepreneurial intention.

H3: Perceived behavioural control significantly influences students' entrepreneurial intention.

H4: PA, PBC and SN together as parts of the TPB explain the entrepreneurial intentions of students.

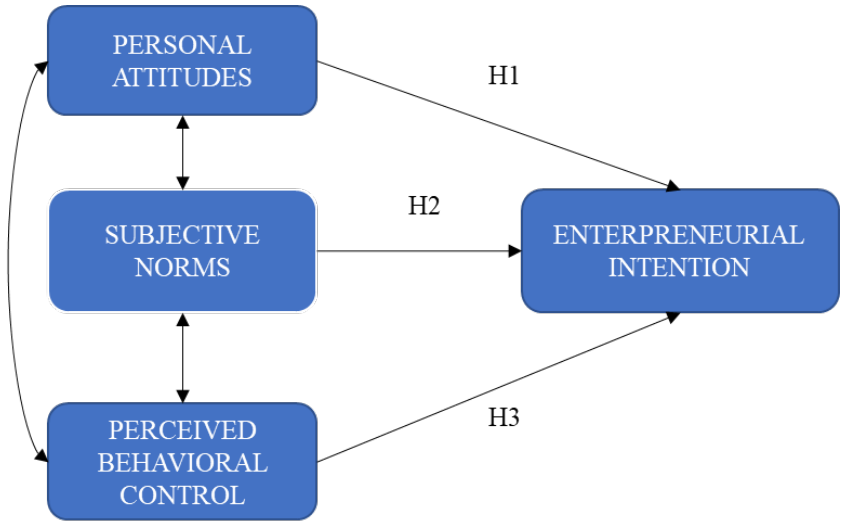


Figure 1. TPB Model adapted from Ajzen (1991)

3. Methodology and results

The methodology used is the processing of primary data acquired by administering a questionnaire. Our questionnaire was based on the original constructs of the TPB (attitude toward the behaviour, subjective norms, perceived behavioural control and entrepreneurial intention). We have also gathered respondent demographics for potential insights into what drives a student to be an entrepreneur as well as what is the potential best suited "type" of person, as a predictor of entrepreneurial intention. The questionnaire was administered through an online survey platform and the participants were provided with clear instructions on how to complete it. Our model has been tested among a convenience sample of 305 students from these public and private universities: International Burch University (IBU), University of Sarajevo (UNSA), University of Zenica (UNZE), University of Tuzla (UNTZ), University of Mostar (UNMO), International business-information academy in Tuzla (IPIA), University of Bihać (UNBI) and Sarajevo School of Science and Technology (SSST).

Table 1. Demographics of sample

VARIABLE	% OF SAMPLE
GENDER	
Male	48.2%
Female	51.8%
PROGRAMME	
Economics and Management	39%

Information Technologies	28.9%
Others	32.1%
AGE (Mean Value)	23.18
UNIVERSITY TYPE	
Private	50.5%
Public	49.5%

The sample has included students from different areas, programs, ages, and backgrounds so it serves as a good representation of the general intentions of students in B&H. The demographics measured above in Table 1. show a noticeably equal spread across groups which is confirmation for the above-mentioned conclusion. The demographics measures investigated were not only supported by other researchers (Alferaih, 2017; Arnaut et Al., 2022) but are important in showing potential differences in backgrounds of those with intentions compared to those without.

Reliability and validity of our questionnaire were kept by using previously tested variables and scales adjusted to the Bosnian language for better response rate. With that said, we aimed to further expand some of the scales from different authors and research that proved to be the most successful and reliable. For measures of PA, SN, PBC and EI we have used Linan and Chen (2009) items tested through a 7-point Likert scale (from totally disagree to totally agree). We have supplemented SN with 5 more items and PA with 2 more with considerations to Autio (2001), Ajzen (1991) and Katono (2011) scales adding the role of university to the mix. The constructs were tested with the newly added items, and all were proven reliable (Table 2). Social norms were lowest out of the TPB constructs with a Cronbach alpha of 0.734 and after testing if the scale would improve if we deleted some of the items, it was proven it worked best with all the items tested.

Table 2. Reliability of hypothesised models constructs

CONSTRUCT	NUMBER OF ITEMS	CRONBACH ALPHA
SN	8	0.734
PBC	6	0.923
PA	7	0.893
EI	6	0.961

PBC and EI for which we included the classic measures from Linan and Chen (2009) proved to be excellently reliable constructs with a Cronbach alpha of

0.923 and 0.961 respectively. PA for which we added an additional measure also proved to have good reliability with a Cronbach alpha of 0.893. This meant that the model's trustworthiness of findings was confirmed, and the conclusions made were based on accurate and consistent data.

We have checked the validity of items for each construct through Exploratory factor analysis (EFA) and have concluded that all constructs have internal validity (as shown in Table 3) above the advised 0.5 value. PA items ranged in validity from 0.614 to 0.898, PBC's were between 0.780 and 0.896 while EI's validity ranged from 0.834 to 0.937.

SN on the other hand was classified as multidimensional, which was logical since we used measures describing 3 different effects on the participant, those being: social support, extent of importance (of the social circle) and lastly university support as an added important factor of every student's journey. All the measures were valid in explaining the construct for their specific dimension and have been in the range 0.785-0.914 (Table 4).

Table 3. Validity scores of items for PBC, PA and EI constructs

CONSTRUCT	VALIDITY OF ITEMS	VARIANCE EXPLAINED
PBC	0.780- 0.898	72.42%
PA	0.614- 0.898	62.67%
EI	0.834- 0.937	81.17%

Table 4. Items validity across the components of the subjective norms construct

Rotated Component Matrix			
STATEMENTS	Component		
	1	2	3
SN1	0.855	0.009	0.141
SN2	0.913	0.022	0.02
SN3	0.785	0.149	0.295
SN4	0.149	0.759	0.123
SN5	0.108	0.891	-0.115
SN6	-0.113	0.880	0.125
SN7	0.345	0.014	0.831
SN8	0.043	0.09	0.914
EXPLAINED VARIANCE	77.53%		

The figures above also show the percentage of variance when all the items were tested against their respective constructs. All the constructs are well explained with variance well above the threshold of 50% (Samuels, 2017). Looking at the descriptive statistics of the main constructs (Table 5) we see that all have a positive connotation as they are above the middle value of 4.

It is notable that the PBC is the variable with the lowest mean which we presume is because only around 50% of the sample have had proper entrepreneurial education and only 30% had entrepreneurial experience. This sample is then deemed to have lower levels of PBC not only lacking the necessary know-how and skills that would make them feel more in control, but also not feeling confident in their own abilities due to the same. SN surprisingly has the second highest mean, even with putting in the additional items to the construct and expanding its reach to not only family, but other influences. This implies that the addition of university support items and inclusion of colleagues in the social circle validates the high mean value compared to other research done in similar cultural environments.

Table 5. Means and deviations of the constructs

Construct	Mean	Standard Deviation
EI	4.796	1.541
PBC	4.209	1.379
SN	4.805	1.014
PA	5.255	1.183

Confirming results of Arnaut et Al. (2022) sample, PA was the strongest rated construct, and this might as well be according to Lüthje C. & Frank, N. (2003) due to the involvement of education in PA growth. The sample itself was made of more than half of students that received some form of entrepreneurial education. All these students were more exposed to the positives (and the negatives) of entrepreneurship as a career shaping their attitudes in the meantime through introductions of courses, mentors, and role- models.

When we go further to test the correlations of the constructs included in the model as shown in Table 6, it is quite visible all of them correlate and all with a value of $p<.001$. Entrepreneurial intention is strongly correlated with PA and moderately to PBC while having weak (but significant) correlation with SN and EE which could potentially mean that they don't fit the model in describing EI.

Table 6. Correlations between the constructs

CORRELATIONS	EI	PBC	SN	PA
EI	1	.649**	.234**	.795**
PBC		1	.358**	.619**
SN			1	.242**
PA				1
**. Correlation is significant at the 0.01 level				

One important relationship we found worth mentioning is choosing of university compared to the constructs where we have gotten significant (p<.001) correlation between the university we attend and all constructs. In Table 7 we see PBC was found to be most affected cementing the notion that entrepreneurial knowledge and experiences are not equally distributed in all institutions. The difference is most noticeable if looking at those privately owned universities compared to governmentally owned. The effect is visible in most cases due to the governmental plans and strategies for SME growth that are misaligned and skewed towards some other goals and objectives rather that entrepreneurship. That in turn leads to students unprepared for opening their own enterprise, but incapable of finding a job in a country where unemployment rate stood at 57.5 percent in 2021. This motivated young people to find employment where opportunities are not lacking and caused one of the biggest brain-drains in Europe in these last 10 years.

Table 7. University choice effect sizes on constructs

Construct	Measure	Point Estimate	Effect size
SN	Eta-squared	0.129	Medium
PBC	Eta-squared	0.154	Large
PA	Eta-squared	0.106	Medium
EI	Eta-squared	0.112	Medium

After running the proposed model through a linear regression analysis and testing the potential effects of different factors on entrepreneurial intention we have concluded that the model makes sense as significance is at p < .001 and the TPB factors together explain 66.9% of EI (Table 8).

Table 8. Proposed model summary extracted from SPSS

Model Summary			
Model	R	Adjusted R Square	Sig. F Change
1	.820[a]	0.669	<0.001
a. Predictors: (Constant), SN, PA, PBC			

Looking at Table 9 we can confirm that only PA and PBC have a significant influence on the entrepreneurial intention, while SN is an insignificant predictor. Interestingly SN is also negative hence if it were significant, it would be considered to have a deterring effect to entrepreneurial intention.

Table 9. Significance and effects of constructs in influencing EI

Coefficients[a]			
Model	Standardized Coefficients	t	Sig.
CONSTRUCT	Beta	-2.293	.023
PBC	.257	5.891	<.001
PA	.639	15.198	<.001
SN	-.012	-.346	.730
a. Dependent Variable: EI			

From the different types of analyses, we have done throughout our research we have gathered many important and noticeable results, that will surely be valuable references for future research on similar topics in Bosnia and Herzegovina and worldwide. A regression analysis of our proposed model proved that Hypothesis 1 is confirmed with personal attitudes not only being significant influence on students EI, but also having the strongest effect on them at a beta of 63.9%, meaning that if the mean of PA improved for 1 due to the before mentioned improvements in the media, education and infrastructure, EI would proposedly improve for 0.639. As proven by other research (Krueger et Al. 1993) exogenous factors such as education and experiences are often mediated through personal attitudes, so we can presume that PA influence is to some degree due to a person's background.

Hypothesis 2 was rejected as social norms were found to be an insignificant influence on entrepreneurial intention. Added to that as mentioned it showed a negative beta, meaning the improvement of SN would cause decrease in EI. Kalayci E. (2017) also showed a negative effect of SN through her case studies, proving that opposition to entrepreneurship in the family circle can stagnate the entrepreneurial process. This is not uncommon as many researchers up to this point have concluded the same due to different factors like cultural backgrounds, the countries collectivistic/individualistic nature etc. Krueger et Al. (2000) proved the insignificance of SN on EI, and looking at Bosnia and Herzegovina studies so did Arnaut et Al. (2021) and these studies serve as confirmation of our work. Šestić et al. (2017) on the other hand found SN very significant, so further studies investigating this would be valuable for support.

Perceived behavioural control significantly influences students' entrepreneurial intentions and thus proves Hypothesis 3. It has a beta of .257 or strength in improving EI of 25.7%. It was very important to prove this hypothesis due to its close relationship with education and experience. Research like Remeikiene et Al (2013) and Peterman and Kennedy (2003) would reconfirm that improvement of education is highly influential in improvement of PBC and thus we consider it a valuable influence on the EI through the PBC.

Finally, Hypothesis 4 was confirmed, so we proved that the classic TPB model predicts entrepreneurial intention with $p<0.001$ significance and a 0.669 variance meaning our model explains 66.9% of TPB. This is deemed to be an acceptable amount of variance explained based on previous research and it is quite high considering entrepreneurship being not the most controllable behaviour. Wang and Wong (2004) for example found that TPB is limited in predicting EI in developing countries but based on our sample we managed to reach a significant explanatory power through the use of the TPB model.

4. Conclusion

Based on the literature reviewed and the conclusions of fellow researchers, we have shaped our study to investigate all interesting and relevant relationships among groups, constructs and tested the explanatory effect of TPB on EI as the main goal. The results to some degree showed that exposure to education improves all the other constructs and especially EI with those exposed to entrepreneurial education having a .53 higher mean than those without exposure. The summary of our tested hypotheses below in Figure 2 shows the hypotheses accepted and rejected based on our sample and research.

Looking at the classical TPB constructs, we have disproven the direct effect of SN on EI reconfirming the findings of Krueger et Al, (2000). Although this might have been due to different reasons like the items added to the original scale, the sample, or some other factors. If we take into consideration that others like Dick and Rallis, (1991) proved effect of SN on PA and PBC and seeing significant correlations between these classic constructs in our own study, a

mediating effect of SN on EI through PA and PBC might be proposed for future studies to investigate.

HYPOTHESIS	
H1: Personal attitudes towards entrepreneurship significantly influence students' entrepreneurial intention.	ACCEPTED
H2: Social norms significantly influence students' entrepreneurial intention.	REJECTED
H3: Perceived behavioural control significantly influences students' entrepreneurial intention.	ACCEPTED
H4: PA, PBC and SN together as parts of the TPB explain the entrepreneurial intentions of students.	ACCEPTED

Figure 2. Summary of tested hypotheses

We believe research into the effects of TPB and entrepreneurial education on entrepreneurial intention could show more significant practical implications for both policymakers and educational institutions. This could improve the design of educational programs that foster entrepreneurial thinking, improve skills, and influence intentions, all concluding in improved rates of entrepreneurial activity and economic growth. The fact alone that those who attended entrepreneurial education courses have higher EI is for us enough to discuss improving the education system following the work of Fayolle (2006) who proposed the same.

Except the quality of the program itself we also believe many factors like gender, culture, prior entrepreneurial experience, and personal traits can all influence how individuals respond to entrepreneurial education. Understanding these nuances can help customise programs to a number of students with different learning styles and backgrounds.

It would be valuable to research the long-term effects of education on EI, so future research could provide insights into the rate at which entrepreneurial education along with the TPB as its vehicle leads to actual enterprise creation and success through some experimental format. Longitudinal studies tracking students who have participated in entrepreneurial education can shed light on the long-term impact of these interventions and be useful for future educational strategies.

Our research reconfirms the importance of a positive image of entrepreneurship as a career fostering stronger PA and the improvements in PBC created though university studies and the network that is created during this time. Both go hand in hand in creating more intention to open businesses in Bosnia and Herzegovina as proven by our study. This in turn would not only improve the state of the job market, but also the country's economy as a whole in the long run.

References

1. Ajzen, I. (1985). From intention to actions: A theory of planned behavior. In J. Kuhl, & J. Beckman (Eds.), Action control: From cognition to behavior (pp. 11-39).https://doi.org/10.1007/978-3-642-69746-3_2
2. Ajzen, I. (1991), The theory of planned behavior, Organizational Behavior and Human Decision Processes, Volume 50, Issue 2. https://doi.org/10.1016/0749-5978(91)90020-T
3. Ajzen, I. (2002), Perceived Behavioral Control, Self-Efficacy, Locus of Control, and the Theory of Planned Behavior. Journal of Applied Social Psychology, 32: 665-683. https://doi.org/10.1111/j.1559-1816.2002.tb00236.x
4. Alferaih, A. (2017). Weight- and meta-analysis of empirical literature on entrepreneurship: Towards a conceptualization of entrepreneurial intention and behaviour. The International Journal of Entrepreneurship and Innovation, 18(3), 195-209. https://doi.org/10.1177/1465750317722114
5. Alferaih A. (2022), Starting a New Business? Assessing University Students' Intentions towards Digital Entrepreneurship in Saudi Arabia, International Journal of Information Management Data Insights, Volume 2, Issue 2.https://doi.org/10.1016/j.jjimei.2022.100087
6. Arnaut, D., Stanić, M. i Bećirović, D. (2022). Exploring entrepreneurial alertness and entrepreneurial intention in times of the COVID-19 pandemic. Management, 27 (1), 237-249. https://doi.org/10.30924/mjcmi.27.1.13
7. Astuti, Rifelly Dewi and Martdianty, Fanny (2012) "Students' Entrepreneurial Intentions by Using Theory of Planned Behavior: The Case in Indonesia," The South East Asian Journal of Management: Vol. 6: No. 2, Article 3.https://doi.org/10.21002/seam.v6i2.1317
8. Autio, E., Keeley, R. H., Klofsten, M., Parker, G. G. C., & Hay, M. (2001). Entrepreneurial Intent among Students in Scandinavia and in the USA. Enterprise and Innovation Management Studies, 2(2), 145–160. https://doi.org/10.1080/14632440110094632
9. Bandura, A. (2002), Social Cognitive Theory in Cultural Context. Applied Psychology, 51: 269-290. https://doi.org/10.1111/1464-0597.00092
10. Block, Jörn Hendrich; Kohn, Karsten; Miller, Danny; Ullrich, Katrin (2014) : Necessity Entrepreneurship and Competitive Strategy, IZA Discussion Papers, No. 8219, Institute for the Study of Labor (IZA), Bonn. http://dx.doi.org/10.2139/ssrn.2448795
11. Byabashaija, Warren & Katono, Isaac. (2011). The impact of college entrepreneurial education on entrepreneurial attitudes and intention to start a business in Uganda. Journal of Developmental Entrepreneurship (JDE). 16. 127-144.https://doi.org/10.1142/S1084946711001768
12. Ryan, R. M., & Deci, E. L. (2020). Intrinsic and extrinsic motivation from a self-determination theory perspective: Definitions, theory, practices, and future directions. Contemporary Educational Psychology, 61, Article 101860. https://doi.org/10.1016/j.cedpsych.2020.101860
13. Dick, T. P., & Rallis, S. F. (1991). Factors and influences on high school students' career choices. Journal for Research in Mathematics Education, 22(4), 281–292. https://doi.org/10.2307/749273
14. Fayolle, A., Gailly, B. and Lassas-Clerc, N. (2006), "Assessing the impact of entrepreneurship education programmes: a new methodology", Journal of European Industrial Training, Vol. 30 No. 9, pp. 701-720. https://doi.org/10.1108/03090590610715022
15. Gibson, Donald & Barron, Lisa. (2003). Exploring the impact of role models on older employees. Career Development International. 8. 198-209. DOI: 10.1108/13620430310482571

16. Jr Norris F. Krueger & Alan L Carsrud (1993) Entrepreneurial intentions: Applying the theory of planned behaviour, Entrepreneurship & Regional Development, 5:4, 315-330, https://doi.org/10.1080/08985629300000020

17. Kalayci E. (2017) Stakeholder Relationships in the Framework of R&D-based Startups: Evidence from Turkey. Foresight and STI Governance, vol. 11, no 3, pp. 61–70. http://dx.doi.org/10.17323/2500-2597.2017.3.61.70

18. Karimi, S., J.A. Biemans, H., Lans, T., Chizari, M. and Mulder, M. (2014), "Effects of role models and gender on students' entrepreneurial intentions", European Journal of Training and Development, Vol. 38 No. 8, pp. 694-727. https://doi.org/10.1108/EJTD-03-2013-0036

19. Kautonen, T., Palmroos, J. (2010) The impact of a necessity-based start-up on subsequent entrepreneurial satisfaction. Int Entrep Manag J 6, 285-300.https://doi.org/10.1007/s11365-008-0104-1

20. Krueger, N., Reilly, M.D., & Carsrud, A.L. (2000). Competing models of entrepreneurial intentions. Journal of Business Venturing, 15, 411-432.https://doi.org/10.1016/S0883-9026(98)00033-0

21. Linán, F. & Chen, Y.W. (2009). Development and Cross-Cultural Application of a Specific Instrument to Measure Entrepreneurial Intentions. Entrepreneurship Theory and Practice, 33(3), 593-617. https://doi.org/10.1111/j.1540-6520.2009.00318.x

22. Lüthje C. & Frank, N. (2003). The Making of an Entrepreneur, Testing a Model of Entrepreneurial Intent Among Engineering Students at MIT. R&D Management,33 (2),135-147. https://doi.org/10.1111/1467-9310.00288

23. Nicole E. Peterman and Jessica Kennedy (2003);Enterprise Education: Influencing Students' Perceptions of Entrepreneurship Volume 28, Issue 2;https://doi.org/10.1046/j.1540-6520.2003.00035.x

24. Remeikiene, Rita, Dumciuviene, Daiva and Startiene,, Grazina, (2013), Explaining Entrepreneurial Intention of University Students: The Role of Entrepreneurial Education, p. 299-307, ToKnowPress. http://www.toknowpress.net/ISBN/978-961-6914-02-4/papers/ML13-258.pdf

25. Samuels, Peter. (2017). Advice on Exploratory Factor Analysis. https://www.researchgate.net/publication/319165677

26. Šestić, M., Bičo Ćar, M., Pašić-Mesihović, A., & Softić, S. (2017). Poduzetničke namjere studenata poslovnih studija u Bosni i Hercegovini. Obrazovanje za poduzetništvo-E4E: znanstveno stručni časopis o obrazovanju za poduzetništvo, 7(2), 147-160. https://hrcak.srce.hr/191721

27. Wang, Clement & Wong, Poh Kam. (2004). Entrepreneurial Interest of University Students in Singapore. Technovation. 24. 163-172. https://doi.org/10.1016/S0166-4972(02)00016-0

28. Zaidatol Akmaliah Lope Pihie, Afsaneh Bagheri, Z. Haslinda Abdullah Sani,(2013); Knowledge of Cognition and Entrepreneurial Intentions: Implications for Learning Entrepreneurship in Public and Private Universities,Pages 174-181,ISSN 1877-0428, https://doi.org/10.1016/j.sbspro.2013.10.219.

Dražena Gašpar, PhD, Full-time professor[1]
Ivica Ćorić, PhD, CEO[2]
Mirela Mabić, PhD, Assistant professor[3]

Review paper

IS COMPOSABLE ENTERPRISE THE KEY TO DIGITAL TRANSFORMATION?

Abstract

Using computers and other digital devices is now standard practice in most businesses. Business and personal communication, execution of business tasks, and finding solutions to various business and social challenges are all made possible by digital technology. The digital future of business offers nearly infinite potential for the creation of value for companies. The proliferation of clouds, the increasing number of networked devices, and the increasing number of requirements at the network's edge are all factors in the development of modern business infrastructures. However, the way business is conducted is being forever altered by digitalization. Organizations are rethinking their architecture strategies and adopting a more modular approach to keep up with the rapid pace of technological advancement. That allows them to construct, assemble, and reassemble essential elements of their businesses with lightning speed, allowing them to capitalize on opportunities as they arise and adapt to threats as they arise without succumbing to their effects. In order to facilitate growth and change, composable businesses are built from modular components that can be easily swapped out. The paper's main goal is to investigate whether transformation to the composable enterprise is the best road to its effective digital transformation. According to the findings of a critical review of recently published works, developing a composable enterprise architecture necessitates close collaboration among many parties because it removes traditional barriers between business and IT, allowing businesses to provide clients with more personalized application experiences.

Key words: *Composable Enterprise, Digital Transformation, Modular Components.*

1 Faculty of Economics, University of Mostar, Bosnia and Herzegovina, drazena.gaspar@ef.sum.ba
2 "HERA" Software Company, Mostar, Bosnia and Herzegovina
3 Faculty of Economics, University of Mostar, Bosnia and Herzegovina

1. Introduction

The rapid advancement of information and communication technology (ICT) and globalization has created an environment where businesses of all sizes are forced to adapt quickly or risk being left behind. In addition to facilitating regular professional and personal communication, work completion, entertainment, and problem-solving, digital technology also helps address a wide range of societal and business issues. Cloud computing, artificial intelligence (AI), Big data analytics, blockchain, augmented and virtual reality, the Internet of Things (IoT), robotics, etc., are at the forefront of this digital transformation, which the COVID-19 epidemic has further accelerated in both business and society.

In the literature and practice, the terms digital transformation and digitalization are frequently used interchangeably. Some researchers, however, have sought to differentiate between the two (Bockshecker et al., 2018). As defined by Parida et al. (2019, p. 12), digitalization is the "application of digital technology to innovate a business model and generate new income streams and value-producing opportunities in industrial ecosystems." Digitalization provides chances for businesses to increase internal efficiency (processes), introduce brand-new products and services, and/or create whole new business models (Parviainen et al., 2017). Vial (2019) defines "digital transformation" as "a process that tries to better an entity by triggering major changes to its features using combinations of information, computation, communication, and networking technologies."

According to these definitions, "digitalization" refers to incorporating digital elements into a company's business model, products, and services. In contrast, "digital transformation" refers to the more all-encompassing process of adapting an entire company to work with digitalization.

Achieving a successful digital transformation necessitates close alignment of four dimensions (Matt et al., 2015):

1) technology use, including a company's perspective on the use of cutting-edge technologies and readiness for the use of new technologies;
2) value creation shifts associated with technology adoption;
3) structural shifts related to the incorporation of new digital activities into existing organizational structures; and
4) financial aspects can act as a driver or result of the transformation.

Most essential, businesses must have standardized procedures and knowledge management to successfully undergo digital transformation (Berman, 2012). Investments in digital technologies might not necessarily provide positive returns. Several studies suggest that organizational capabilities, such as organizational learning (Tippins et al., 2003), leadership style (Seah et al., 2010; Verdú -Jover et al., 2014), and an adaptive organizational culture (Alos-Simo et al., 2017), are more important than technical knowledge for achieving success.

Operational processes, resources, and internal and external users should all be a part of the transformation (Henriette et al., 2015). According to Lenka et al. (2017), investing in hardware with smart subcomponents (such as sensors, digital user interfaces, and software applications) is a common first step in the process of digital transformation. Connectivity is the next step, including ports, antennas, software, and Internet protocols. Analytic capability, the third step, refers to using development rules, business logic, and algorithms to convert massive amounts of data into predictive insights and directions for action.

Digital transformation offers companies practically limitless opportunities to generate business value. The potential for data-driven business strategies and information products is stronger than ever, and data and analytics have emerged as key drivers of company strategy.

The cloud, networked devices, and requirements at the network's periphery are all growing trends in enterprise infrastructures. Leaders in cloud and edge infrastructure and operations (I&O) need to be creative with regard to network security, workload deployments, and edge infrastructure extension.

Problems with visibility and monitoring/management arise when working with cloud-native applications. Digital business transformation initiatives are at risk if I&O leaders are unable to utilize machine learning (ML) and artificial intelligence (AI) technology to comprehend the relationships and performance of dispersed systems (Lindner, 2022).

Business processes do not end at the application boundary. The benefits afforded by digital technology have become essential differentiators, especially as the world recovers from the pandemic and other disruptive market issues. Companies that can take advantage of enormous volumes of data are proving to be more agile and resilient. In order to better respond to business shifts, organizations must adopt a portfolio of applications that are more easily created, disassembled, and extended (Lindner, 2022).

As the rate of upheaval and unpredictability rises, businesses must adapt by placing greater emphasis on business design and architecting composability across numerous interrelated perspectives. Its structure must be designed using modular components to transform a company into a composable business. The modular design provides the flexibility for the business to reorganize and refocus as required in response to external (or internal) variables like a change in client values or a disruption in the supply chain or materials (Panetta, 2020).

Those in charge of corporate architecture and technological innovation need to start paying more attention to business design and architecting composability across numerous connected perspectives if they want to succeed.

The aim of this paper is to research whether transformation to the composable enterprise is the best road to its effective digital transformation.

The paper is structured as follows. After an introduction, the next section explains composable enterprise, its principles, and its fundamental characteris-

tics. The section that follows discusses the bond between composable enterprise and digital transformation. The paper comes to a close with a conclusion, challenges, and next steps.

2. Composable enterprise

As a result of technological advancements, business processes are becoming more adaptable, and workflows and applications are less likely to collapse under the pressure of innovation or other outside influences. Today, it is crucial for businesses to be able to quickly modify their workflows and the technologies that support them in response to shifting market conditions. Companies that switched to cloud computing no longer had to worry about maintaining their own servers, data centers, or apps. The following stage is composability.

Composability is a paradigm of system architecture that facilitates the construction of complex systems from modular, independently operating parts. That facilitates the assembly of novel systems from preexisting parts. The primary goal of composability is to take a whole technology stack and turn it into a single, fluid work environment. That is accomplished by having workflows bounce between applications without forcing the user to go between applications (WalkMe, 2023) manually.

The ability to innovate and quickly adjust to shifting business needs is at the heart of "composability," including a company's culture, technology, and processes. In business, composability refers to a modular structure that allows for easy reorientation and restructuring (Quixy, 2023).

Business architectures in the digital age must be prepared for uncertainty and ongoing change. The composable enterprise prioritizes flexibility over efficiency. There is no longer a single use case or purpose for which a system, process, or worker exists. Digital disruptors are increasingly sweeping away the calcified, creaking corporate systems and processes that have been ingrained in firms for decades. Markets are shifting, and customer expectations are rising due to the rise of online and app-based businesses enabled by cloud computing, open application programming interfaces (APIs), data analytics, mobile devices, social media, and the Internet of Things. To truly deliver value, composability, a close relative of integration, requires in-depth familiarity with the stakeholders and their business demands (Abbiati et al., 2021).

Composable enterprises are connected businesses with business processes enabled by cloud and API services obtained and leveraged from external suppliers or through internal data centers. Composable enterprises can grow in scope by developing digital skills that can be used by third parties (Forbes, 2015).

According to Gartner, a composable enterprise is *"an organization that delivers business outcomes and adapts to the pace of business change. It does this through the assembly and combination of packaged business capabilities*

(PBCs).PBCs are application building blocks that have been purchased or developed." (Gaughan et al., 2020).

Composable enterprise refers to using software components that can be swapped out for one another to construct, innovate, and modify corporate processes in response to internal and external changes. Simply put, it facilitates the growth and adaptation of businesses. With the help of extensive stakeholder cooperation, businesses may build a composable enterprise architecture that blurs the lines between business and IT to provide customers with more individualized application experiences.

2. 1. Core principles of composability

Converting a business to a composable business requires enterprises to keep up with technological innovation, rethink their architecture strategies, and adopt a more modular approach, maximizing their ability to build, assemble, and reassemble core business elements to quickly seize market opportunities and respond to disruptors and threats while maintaining resilience.

The Gartner concept of composable business is based on four fundamental principles (Panetta, 2020):

- Discovery
- Modularity
- Orchestration
- Autonomy

Discovery is the process of learning about and using new design possibilities and parts so that modifications may be directed, tracked, and kept safe. The firm must be able to easily find and comprehend each part in a catalog or marketplace (Natis, 2023). A solid inventory of Packaged Business Capabilities (PBAs) that aligns with the company's vision is provided by Enterprise Architecture's catalog of Business Capabilities aligned with IT assets. Companies can adapt more quickly to the ever-increasing rate of change in the business world by adhering to this principle (Panetta, 2020).

Modularity is the practice of dividing a domain into independently scalable and change-manageable parts. When it comes to IT, modularity means having the freedom to rearrange components as needed. Business models are the source of modularity. The principle of autonomy will force the modularity of the component to be determined by the business (Natis, 2023). Because each team or component needs to be self-sufficient and has input into its own output, they will voice a desire for modularity. That idea guarantees increased adaptability using structural alterations.

Orchestration is the process of prescribing and negotiating interactions between components in order to facilitate recomposition and formation. Connectivity between components is standardized and based on patterns, and each part of the system has clearly stated capabilities articulated through services

(Natis, 2023). Each item is handled by a process that orchestrates how the pieces fit together within the PBC, assisting in standardization. That principle assures improved leadership because leaders must rethink their business models and include application procurement, implementation, and maintenance in their growth strategies (Panetta, 2020).

Autonomy describes the practice of keeping individual parts of a system from being overly reliant on one another. The notion of autonomy, which is based on business demands, drives the modularity of the component; therefore, the two concepts go hand in hand (Natis, 2023). That principle is essential for maintaining resilience (Panetta, 2020). When it comes to preparing for disruptions in resources and processes, business continuity plans are specifically tailored to solve the difficulties encountered in the past. The danger of using outdated business models is something they fail to see. Maintaining smooth operations requires a business plan that can withstand interference from the outside world.

As these principles of composable business are put into practice, a composable enterprise emerges. Since a composable enterprise architecture eliminates conventional boundaries between business and IT, it enables enterprises to give customers more tailored application experiences, but this requires close collaboration across numerous stakeholders. The composable business principles are essential for businesses to thrive during periods of upheaval.

2. 2. Building blocks of the composable enterprise

To make an enterprise composable, its structure must be designed using modular, easily swapped-out components. These building pieces can be thought of as Lego bricks that can be stacked, rearranged, and even thrown away as needed (Quixy, 2023). That allows companies to break down cumbersome old applications into smaller, more manageable pieces. Figure 1 shows the three

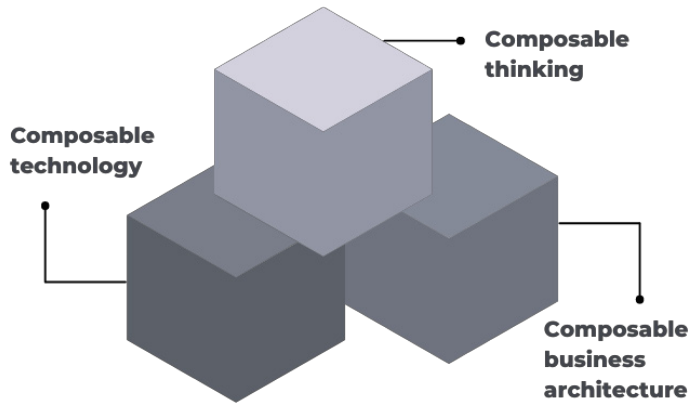


Figure 1. Building blocks of composable business (Quixy, 2023)

essential components of a composable business as described by Gartner (Panetta, 2020):

1) Composable thinking
2) Composable business architecture
3) Composable technologies

The composable way of thinking promotes the belief that "anything is composable". Composable thinking paves the door for a quicker, more adaptable approach to meeting ever-evolving consumer demands. The information inside and outside the company is encouraged to be shared and sought. Enterprises can be directed in what to compose and when to produce it by combining composable thinking with the ideas of modularity, autonomy, orchestration, and discovery.

Composable business architecture strengthens organizational adaptability and resilience. If companies' structural capacities are enhanced, they can modify and reinvent their products and services. Thanks to the compositional nature of a business architecture's structural capabilities, enterprises are given tools to design their operations. Using a composable business design requires careful consideration of the following (Quixy, 2023):

- The composable business architecture has three dimensions: engagement, technology, and capability.
- Composable business architecture supplements the preexisting business architecture rather than replacing it. Organizations can use it as a lens and a guide for making technology investment decisions and launching new business activities to help them reap the benefits of digital acceleration.
- It is not a business model but can help companies prepare for digital acceleration.
- It's not a formal structure, but it can pave the way for spontaneous groups to develop and work together.
- Industry-specific business architectures can be gradually updated with the help of the composable business architecture's individual building blocks. Doing it all at once is neither desirable nor required.

Enterprise architects must prioritize IT and business alignment to create a composable design. It offers a fresh perspective on figuring out how everything already fits together. Enterprise architects include flexibility in design as they switch to composability, allowing businesses to prepare for various scenarios. Gartner predicts that businesses will adopt a platform for creating and modifying application experiences that brings together high-end and low-code composition capabilities accessible to IT and business users alike. Unlike traditional applications, the composed application experience can be recomposed on demand if the user's role or best practices change (Sabourin, 2020).

Packaged business capabilities (PBCs), as the primary composable architectural components that make this possible, are shown in Figure 2. They reflect a clearly defined business capability that business users understand and are packaged for automated use (Free, 2021). When designing applications, it is crucial to think about what will be on the inside and what will be on the outside as the components are broken down, and the boundaries are defined. Connecting the various IT components (such as PBCs) together is the key, and application programming interfaces (APIs) are the means to accomplish this. While not everything needs to be a PBC, rising connectedness is anticipated generally.

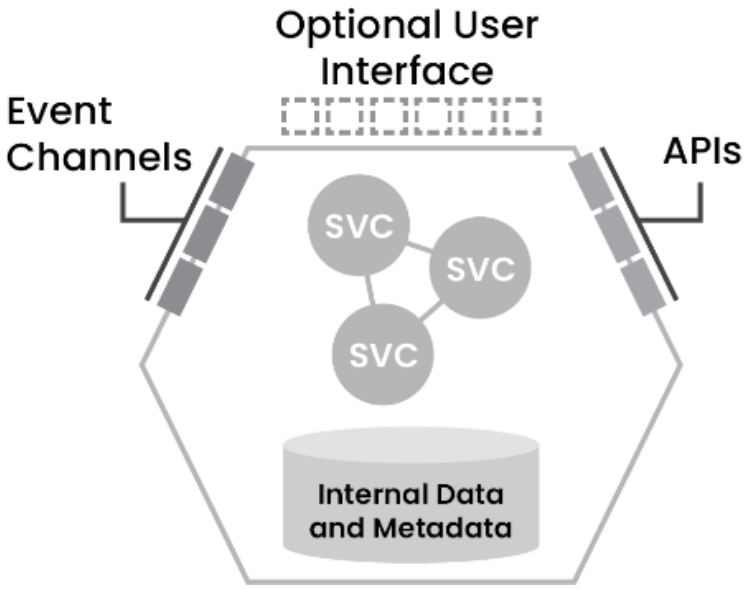


Figure 2. PBC - Packaged business capability (Free, 2021)

The internal data and metadata needed to carry out business requirements must be included in PBCs since they are software components that implement well-defined and autonomous business capabilities. A composable application results from multiple PBCs being stitched together and, potentially, front-ended with a user interface. These individual applications can then be combined into portfolios of business capabilities. The "glue" that connects these PBCs (Figure 2) can be APIs or Event Channels. Without knowing the inner workings of each other's code, applications can communicate with one another through APIs (RedHat, 2022). An application programming interface (API) serves as a conduit via which two applications can share information and interact with one another.

An API is developed before a composable application is implemented, and the means through which it will be provided are specified. Developers start the development process by discussing the API with prospective clients. They begin developing the actual app by making use cases and API prototypes. This approach to creating apps is known as "API-First development." In API-First Development, APIs are built before applications, which is a paradigm shift in

the API design process that represents the company's goals and aspirations (Lameriks, 2018).

Composable technologies are the tools of the present and the future. The technology's interrelated pieces propel the goals of product design and the idea of composability. Agility and adaptability are of paramount importance. It promotes enterprise-wide transparency, openness, and increased connectivity and reuse (Quixy, 2023).

Any company that values swift, risk-free, and efficient transformation will profit from application composition. However, not every business has the same sense of urgency or level of readiness regarding composability. Leaders in the fields of business application and software development should adjust their strategies accordingly. In today's business world, flexibility is crucial for survival. Enterprises should change their software architecture to one based on modular, interoperable components and application programming interfaces (APIs) and their corporate structure to one based on self-governing, geographically dispersed teams capable of producing high-quality results quickly. In that way, they manage and standardize growth democratically.

3. Digital transformation and composable enterprise

Leveraging new technologies to their full potential is more important than ever as businesses anticipate the technical and economic changes that the future may bring. Companies can boost their growth rates and introduce innovations to their processes with the help of digital transformation. A digital business model that involves a gradual shift to an innovative activity foundation and an adjustment to the digital ecosystem in which the organization operates should be developed in tandem with digital business transformations. Some fundamental features of the digital transformation of businesses are (Bochulia, 2021):

1) Evaluation of risks and threats. During the decision-making process for a company's digital transformation, it's essential to identify the proportion of activity revenue that could be jeopardized by adopting digital innovation and abandoning a tried-and-true business model.
2) 2. Digital skills acquisition. They are implementing widespread changes in employee training and upgrading the company's software and hardware to help employees gain the digital skills necessary to complete a company's digital transformation and guarantee its continued digital development.
3) Determining the optimal version of a new model. Parameter estimation for various digital business models aims to select the one that offers the best overall risk/reward profile for implementing digital transformations. The organization can settle on a course of action, adopt an existing model, or create its own variant based on one of the traditional digital business models.

4) Defining the source of digital competence. The survival and growth of each company depend on a set of fundamental skills.

5) Evaluating readiness for digital partnership. The digital partnership ensures more transparency and access to more information, both organized and unstructured, which alters the standard method of interacting with one's internal and external surroundings. When making the shift to building new information ties, businesses must determine whether or not they are prepared to make digital partnerships.

6) Ensuring the development of digital culture. Securing the enterprise's transition to digital operations by creating a company-wide digital culture and disseminating information about its benefits to employees at all levels of management.

Business leaders today regard digital transformation as the catalyst for a whole new way of thinking about what it means to be in business in the current world. Time is of the essence in digital transformation, as are the iterative modifications to the original program of digital change that must be made in accordance with their guiding principles. By focusing on these fundamental elements, fine-tuning the changes program, and taking steps to strengthen the organization, the business finds a stable footing in its chosen digital transformation direction.

3. 1. Digital transformation benefits and challenges

Understanding the benefits and challenges of digital transformation is essential for taking leadership of digital transformation. That includes having a thorough familiarity with the new systems and processes that are driving new enterprises, as well as how they interact and what they are capable of providing.

Key benefits of digital transformation can be synthesized from literature (Khin & Ho, 2019; Hai, 2021; Shofawati, 2019; Kraus et al., 2022; Morze & Strutynska, 2021; Thales, 2023) as follows:

- Increasing customer satisfaction. Never before have consumers had such lofty anticipations. Customers, on the one hand, want businesses to cater to their specific requirements. Conversely, they prefer automation to manual intervention for things like software access, updates, and deactivation/reactivation. The ability to apply powerful digital tools and methods, such as automated procedures, is an obvious benefit of digitalization in business. Improved client satisfaction is a direct result of these digitalized procedures.
- Driving data-based insights. Companies will be able to collect and analyze data that may be turned into profitable insights thanks to digital transformation. In the past, businesses may not have collected and utilized data at all, or it may have been dispersed across a number of unconnected platforms. Strong data collecting, centralized data stor-

age, and the development of tools to evaluate and translate data into knowledge that encourages informed business decision-making will all be made possible by digital transformation.

- Enabling software monetization. It is common knowledge nowadays that organizations may maximize their return on investment (ROI) and make the transition from a product-centric to a software-centric focus by monetizing their proprietary software.
- Enabling high-quality user experience. Companies that place a premium on creating value understand that they are not just selling their customers a product but an experience. Through the use of automation, artificial intelligence (AI), and self-service technologies, digital transformation makes it possible to create stunning, effortless user experiences.
- Encouraging collaboration and improving communication. Businesses today require a digital platform that fosters internal communication and cooperation across all departments to increase creativity and production. When an organization undergoes a digital transformation, inefficient ways of communicating and sharing ideas are eliminated, as are unnecessary steps and delays. Businesses that digitize their internal communications will see gains in efficiency, accountability, and innovation, giving them a competitive edge.
- Increasing agility. Most enterprises now realize that adaptability and the capacity for change are crucial for surviving the current era of rapid digital transformation. The products they use, the sources of income they can count on, and the needs of their customers have all shifted significantly over the past few years. The enterprise will be able to foresee problems and prepare for them with the help of a digital business environment, ensuring their continued success.
- Limiting human error. Eliminating time-consuming and error-prone manual data entry and human inefficiencies is a significant pro of digital operations. Compared to manual processes, which are prone to human mistakes, digital ones are intrinsically more streamlined and secure.
- Encouraging an environment of employee excellence. Having support from upper management is crucial for a smooth digital transformation. The enterprise must foster an environment where all employees are convinced that the digitalization of business processes would be beneficial. The enterprise should invest in the digital education of its employees if it wants to win their support. Namely, the company's best resource is its talented workforce.
- Increasing operational efficiency. Integrating with back-end systems, automating delivery procedures and product updates, enabling cross-device activation, managing various product versions, and more allow the business to streamline manual processes and cut expenses. The organization will be able to save time and money by switching to digital business procedures, and employee frustration will decrease.

- Enabling future digital growth. All subsequent corporate expansion may be traced back to the initial act of digital transformation. A lack of investment in digital business transformation will result in the company's rapid obsolescence. The shift to digital is inevitable. The organization needs to undergo significant changes if it is to weather the global digital tsunami. After that happens, the organization can reap the full benefits of digital transformation for years to come.

Although digital transformation brings significant advantages, its implementation may encounter barriers and challenges. According to the literature (Cichosz et al., 2020; Checchinato et al., 2021; Vogelsang et al., 2019; Matt et al., 2020), the main challenges and barriers to digital transformation can be grouped as follow:

- Human - insufficient digital skills of employees, shortages of IT specialists on the external labor market, internal resistance to change, lack of managers' knowledge about how to accomplish change
- Technological - Technology and digital divides between cities and rural areas and developed and developing nations limit the scaling-up of digitalization, IT security issues, and lack of access to a stable Internet connection.
- Financial - a lack of appropriate financing possibilities and financial resources for the upfront cost of investments in new technologies.
- Organizational - Organizational inflexibility/ unwillingness to change (typified by hard-to-change organizational routines, processes, and traditional ethos of the organization). The business model of the firm is perceived underpinned by face-to-face interactions. Productivity is being undermined by employee stress brought about by the intensification of work.
- Legal - national laws and regulations can create hostile conditions for new technologies adoption,
- Environmental - lack of government support for digitalization, underdeveloped education system or poorly designed education system towards digitalization and limited government skill formation initiative on digitalization, Lack of government investment in infrastructure

3. 2. Nexus between composable enterprise and digital transformation

Digital transformation entails not only embracing digital technologies but also redesigning business procedures to accommodate the rapid development of technology and utilizing applications to continuously improve business processes.

In general, enterprises are hesitant to abandon the solutions they have been using for years for financial reasons (investment in equipment, software, and employee training) and apprehension about new, untested technology. The

composable architecture allows enterprises to maximize earlier IT expenditures while also benefiting from the introduction of new solutions by combining existing and new solutions (internal and external) through a layer of a unique composition platform and an integrated data layer.

Although digital transformation is widely regarded as one of the primary drivers of composable enterprise success, its impact is reciprocal. Building a composable enterprise accelerates the digital transformation process in reverse. Precisely, the benefits of developing a composable enterprise overlap with the benefits of digital transformation, which amplifies the effect of digital transformation (Table 1).

Table 1. The bond between digital transformation and composable enterprise

Digital transformation	Composable enterprise
Increasing customer satisfaction	Because traditional barriers between business and IT are removed with a composable enterprise architecture, businesses may provide customers with individualized application experiences.
Driving Data-Based insights	Enterprises can manage and integrate infrastructure components with a single, unified API. It enables a versatile network, which is essential in today's data centers. That allows businesses to leverage massive amounts of data to become more adaptable and resilient.
Enabling software monetization	The composable architecture allows enterprises to maximize earlier IT expenditures while also benefiting from the introduction of new solutions by combining existing and new solutions (internal and external) through a layer of a unique composition platform and an integrated data layer.
Enabling high-quality user experience	The composable organization has the ability to design and test limitless experiences to acquire high-quality user experience because every aspect of its software may be extended and altered to match a range of usages and consumer wants.
Encouraging collaboration and improving communication	Teams in a composable organization rely heavily on integration and cooperation when developing software products. To ensure continuous integration across the board, the company requires a platform that acts as a marketplace for teams to share and discover components, facilitates consumption and integration, and simplifies upgrades and changes.

Digital transformation	Composable enterprise
Increase agility	The rapid delivery provided by autonomous teams in a composable enterprise enables the business to meet its customers' needs and outperform its rivals. With component-driven software, teams can easily divide features into incremental releases that can be sent to production more frequently.
Limiting human error	The application of intelligent software makes a composable infrastructure smarter than conventional infrastructure. A composable system can scan for setup mistakes and find accessible resources. As an added bonus, it suggests ways to address these issues.
Encouraging an environment of employee excellence	Since product teams have extensive industry expertise, they can gain a competitive edge if they are allowed to release frequently without being slowed down by coordinating with other groups.
Increasing operational efficiency	A more adaptable and responsive infrastructure is available for any business. Since resources can be rearranged on the fly, applications and services can be distributed more quickly.
Enabling future digital growth	Scaling up or down is simple because businesses may add or remove resources as needed. The platforms' utilization can be scaled up at the business's desired rate, allowing the underlying infrastructure to keep up with its rapid expansion.

Developing and implementing composable enterprises, like digital transformation, may confront impediments and challenges. The following three issues are related to the composable enterprise and stem from its underlying philosophy (Santiago, 2020; WalkMe, 2023):

- Finding the proper middle ground for an application scope - A packaged application in a modular enterprise must be functionally specified. It's loosely connected, reusable, and self-contained, but the scope of work must be constrained inside a well-thought-out single business capability. It's easier said than done, but it's basically a mini-app. The packed application may have several APIs and entities but must adhere to 'business capability boundaries.' It can scale dynamically and independently; a single business unit or team maintains a packaged application.
- The barrier in innovation teams - Developers and IT positions within a business unit are becoming more common. Every year, an increasing number of businesses embrace the decentralized structure on the people side by forming an 'innovation team' within their line-of-business teams. That is unquestionably a positive step forward. However, linguistic bar-

riers and user-friendliness issues develop due to internal and external alignment. Outside of the team, developers still rely on technical advice and expertise for enterprise-wide frameworks and best practices. Product managers and other business roles aren't working closely enough with developers to create product functionality and an end-to-end user experience. There is still a significant amount of practice disconnect in this type of team; the extent of disconnect may be judged by the quality of applications produced by the team.

- Managing complexity - A composable enterprise promotes a distributed system design to enable rapid development and faster innovation through decentralization, including software and application stack independence amongst teams. However, the role of lifecycle management has not been diminished — maintain/manage/operate or governance as one of the cycles. Governance is a vital concern for a modular enterprise, which includes interoperability, orchestration, security, and analytics. It is critical to have a visibility platform to handle data interactions amongst packaged apps in real-time and offline.

While composability is not a brand new approach to business and software (architecture) development, its unique viewpoint on how components work together makes composable enterprise design so exciting. It's a novel approach to organizing and integrating its parts (APIs, PBCs) with modern technologies like the cloud, SaaS, iPaaS, and AI. Teams and organizations should keep democratization at the forefront of the project at all times as they move through each stage of the composable business journey. The organization's technological infrastructure is secondary in importance to the overall change. Success requires the interplay of people, culture, and policies. Organizational maturity and adaptability determine the rate of change. The world of consumption is changing at an unprecedented rate, and a genuinely composable organization is one that is ready for disruption, can deliver experiences at the speed of customer demand, and actively leads innovation.

4. Conclusion

Leveraging new technologies to their full potential is more important than ever as businesses anticipate the technical and economic changes that the future may bring. Enterprises can boost their growth rates and introduce innovations to their processes with the help of digital transformation. A comprehensive understanding of the new systems and processes driving new enterprises, including how they interact and what they are capable of producing, is essential for those who want to take the reins on digital transformation. As a result of digital interaction and analytical decision-making, this change will yield more than just efficiency and reduced processing costs. Creating a digital business model that involves a gradual shift to an inventive activity foundation and an adjustment to the digital ecosystem of business should go hand in hand with any digital transformation.

A two-way link between digital transformation and the composability approach is often considered a company's reaction to digital transformation. Establishing a composable enterprise rests on digital transformation, and vice versa; the latter strongly influences the former.

The paper shows how digital transformation can have a multiplicative effect by combining it with the benefits of creating a composable organization. Thus, it was determined that, given the current state of technology, the best path to a successful digital transformation is the transition to a composable enterprise.

With composability, businesses can build flexible, robust workflows without relying on a small pool of expertise to accommodate change. By allowing for composability in applications, providers can offer consumers the ability to customize apps or services for their unique use cases, and businesses can free up developers to focus on revenue-generating projects rather than retooling their IT infrastructure. Workflows and the technologies that allow them must be flexible enough to quickly adjust to changing business needs.

The advantages of the composable enterprise (PBC, cloud, APIs, SaaS, etc.) also pose the most significant obstacles to its expansion and widespread acceptance. An awareness of the process of establishing PBCs and APIs, as well as mutual understanding between members of fusion teams composed of business context experts and technology experts, may be crucial to the success of developing composable enterprises. It is impossible to definitively establish which level of granularity to use or even how to describe a business capability that should be packaged in PBC without first understanding the characteristics of the business environment. That is the greatest obstacle facing this corporate architecture and a critical factor in determining its future.

References

1. Abbiati, E., D'Antonio, A.C., Coraretti, E., Canducci, M., Alessi, M., Maradei, P. (2021). Where Your Business Meets Innovation. DIGITAL ECOSYSTEMS & COMPOSABLE SOLUTIONS, https://www.eng.it/resources/whitepaper/doc/digital-ecosystems/ENG21_WP_Digital_Ecosystems_eng_
2. web_.pdf, last accessed 2023/07/19
3. Alos-Simo, L., Verdu-Jover, A. J., & Gomez-Gras, J.-M. (2017). How transformational leadership facilitates e-business adoption. *Industrial Management and Data Systems*, *117*(2), 382–397.
4. Berman, S. (2012). Digital transformation: opportunities to create new business models. *Strategy & Leadership*, *40*(2), 16–24.
5. Bockshecker, A., Hackstein, S., &Baumöl, U. (2018). Systematization of the term digital transformation and its phenomena from a socio-technical perspective a literature review. In Twenty-Sixth European Conference on Information Systems (ECIS). AIS.
6. Bochulia, T. (2021). Digital business transformation: Trends, innovative models, a development program. E3S Web of Conferences 307, 02001, https://doi.org/10.1051/e3sconf/202130702001

7. Checchinato, Francesca, Andreas Hinterhuber, and Tiziano Vescovi. 2021. The Key Challenges of Digital Transformation. https://www.routledge.com/blog/article/the-key-challenges-of-digital-transformation, last accessed 2023/07/05

8. Cichosz, Marzenna, Carl MarcusWallenburg, and A. Michael Knemeyer. 2020. Digital Transformation at Logistics Service Providers: Barriers, Success Factors and Leading Practices. The International Journal of Logistics Management 31: 209–38.

9. Free, D. (2021). The Composable Enterprise, https://bian.org/wp-content/uploads/2021/12/BIAN-The-Composable-Enterprise-2021-12-08.pdf, last accessed 2023/06/29

10. Forbes (2015). Leading the Emerging Composable Enterprise. Forbes Insights - CIOs to Step Up as Chief Innovation Officers, https://www.forbes.com/forbesinsights/mulesoft_cio/index.html, last accessed 2023/07/10

11. Gaughan, D.,Natis, Y.,Alvarez, G., O'Neill, M. (2020): Future of Applications: Delivering the Composable Enterprise, https://www.gartner.com/en/doc/465932-future-of-applications-delivering-the-composable-enterprise, last accessed 2023/06/09

12. Hai, N. T. (2021). Barreiras de transformação digital para pequenas e m´edias empresas no Vietnã hoje. *Laplage Em Revista, 7*(3A), 416–426. https://doi.org/10.24115/ S2446-6220202173A1424p.416-426

13. Henriette, F. E., Mondher, F., & Boughzala, I. (2015). The shape of digital transformation: a systematic literature review. In Ninth Mediterranean Conference on Information Systems (MCIS), Samos, Greece.

14. Khin, S., & Ho, T. C. (2019). Digital technology, digital capability and organizational performance. *International Journal of Innovation Science, 11*(2), 177–195. https://doi.org/10.1108/ijis-08-2018-0083

15. Kraus, S., Durst, S., Ferreira, J. J., Veiga, P., Kailer, N., & Weinmann, A. (2022). Digital transformation in business and management research: An overview of the current status quo. *International Journal of Information Management, 63*, Article 102466. https://doi.org/10.1016/j.ijinfomgt.2021.102466

16. Lameriks, M. (2018). Oracle API Platform Cloud Service: Design-First approach and using Oracle Apiary, https://technology.amis.nl/cloud/oracle-api-platform-cloud-service-design-first-approach-using-oracle-api, last accessed 2023/07/07.

17. Lenka, S., Parida, V., & Wincent, J. (2017). Digitalization capabilities as enablers of value co-creation in servitizing firms. *Psychology & Marketing*, *34*(1), 92–100.

18. Lindner, J. (2022) Composability – Quick wins in a world of constant change. E-3 Magazine, December2021/January 2022, https://www.oracle.com/a/ocom/docs/applications/erp/composability-quick-wins-in-a-world-of-change.pdf, last accessed 2023/07/01

19. Matt, C., Hess, T., & Benlian, A. (2015). Digital transformation strategies. Business and Information Systems Engineering, *57* (5), 339–343.

20. Matt, Dominik T., Vladimír Modrák, and Helmut Zsifkovits, eds. 2020. Industry 4.0 for SMEs: Challenges, Opportunities and Requirements. Cham: Springer International Publishing.

21. Morze, N. V., & Strutynska, O. V. (2021). Digital transformation in society: Key aspects for model development. *Journal of Physics: Conference Series, 1946*(1), Article 012021. https://doi.org/10.1088/1742-6596/1946/1/012021

22. Natis, Y. (2023). How to design enterprise applications that are composable by default. https://www.computerweekly.com/feature/How-to-design-enterprise-applications-that-are-composable-by-default, last accessed 2023/07/11

23. Panetta, K. (2020). Gartner Keynote: The Future of Business is Composable. https://www.gartner.com/smarterwithgartner/gartner-keynote-the-future-of-business-is-composable, last accessed 2023/07/08

24. Parviainen, P., Kääriäinen, J., Tiihinen, M., & Teppola, S. (2017). Tackling the digitalization challenge: How to benefit from digitalization in practice. *International Journal of Information Systems and Project Management*, *5*(1), 63–77.

25. Parida, V., Sjödin, D., & Reim, W. (2019). Reviewing literature on digitalization, business model innovation, and sustainable industry: Past achievements and future promises. Sustainability, *11* (2), 391-409. https://doi.org/10.3390/su11020391

26. RedHat (2022). What is an API?, https://www.redhat.com/en/topics/api/what-are-application-programming-interfaces, last accessed 2022/12/07.

27. Quixy (2023). Composable Business 101: Everything you need to know. https://quixy.com/blog/composable-business-101-everything-you-need-to-know/#:~:text=%E2%80%9CComposability%E2%80%9D%20is%20a%20term%20that,rapidly%20to%20changing%20business%20needs, last accessed 2023/07/29

28. Sabourin, R. (2020). EDA Finds a Welcome Home as Part of Gartner's "Composable Business". https://solace.com/blog/event-driven-architecture-gartner-composable-business/, last accessed 2023/07/29

29. Santiago, A. (2020). The challenges that lie ahead amid the rise of the composable enterprise. https://blogs.mulesoft.com/digital-transformation/challenges-amid-rise-of-the-composable-enterprise/, last accessed 2023/07/17

30. Seah, M., Hsieh, M. H., & Weng, P. D. (2010). A case analysis of Savecom: The role of indigenous leadership in implementing a business intelligence system. *International Journal of Information Management*, *30*(4), 368–373.

31. Shofawati, A. (2019). The role of digital finance to strengthen financial inclusion and the growth of SME in Indonesia. *KnE Social Sciences, 3*(13), 389–407. https://doi.org/10.18502/kss.v3i13.421

32. Thales (2023). The Benefits of Digital Transformation. https://cpl.thalesgroup.com/software-monetization/benefits-of-digital-transformation, last accessed 2023/07/22

33. Tippins, M. J., & Sohi, R. S. (2003). It competency and firm performance : is organizational learning a missing link ? *Strategic Management Journal*, *24*, 745–761.

34. Verdú-Jover, A. J., Alós-Simó, L., & Gómez-Gras, J. M. (2014). *Strategic flexibility in e-business adapters and e-business start-ups, Hankbook of Strategic e-Business Management,*. (F. J. Martínez-López, Ed.). Heidelberg: Springer.

35. Vial, G. (2019). Understanding digital transformation: A review and a research agenda. Journal of Strategic Information Systems, *28* (2), 118–144. https://doi.org/10.1016/j.jsis.2019.01.003.

36. Vogelsang, Kristin, Kirsten Liere-Netheler, Sven Packmohr, and Uwe Hoppe. 2019. Barriers to Digital Transformation in Manufacturing:

37. Development of a Research Agenda. Available online: https://aisel.aisnet.org/hicss-52/in/digital_transformation/3/, last accessed 2023/07/29

38. WalkMe (2023). What is composability? https://www.walkme.com/glossary/composability/

Assist. Prof. Dr. Irfan Djedović[1]
Assist. Prof. Dr. Edin Djedović[2]
BoA Nadina Omerhodžić[3]

Original scientific paper

IMPACT OF MACROECONOMIC FACTORS ON STOCK MARKET INDICES: EMPIRICAL EVIDENCE FROM GERMANY AND MALAYSIA

Abstract

This study investigates the impact of the exchange rate, Federal Funds rate (FFR), inflation (CPI), industrial production index (IPI), and CBOE market volatility index (VIX)on stock market indices in both a developed and a developing economy. The research provides empirical evidence regarding the relationship between these macroeconomic factors and stock market performance, shedding light on their influence in different economic contexts.

Using comprehensive datasets from the selected economies, the study employs econometric techniques such as regression analysis to examine the effects of these factors on stock market indices. Data for the study is obtained from the International Monetary Fund database and investing.com. Data spans from January 2015 to August 2022.

The findings suggest that the exchange rate has a statistically significant impact on stock market returns in both countries, while the CBOE market volatility index (VIX) has a statistically significant impact on stock market returns in Germany. The other observed macroeconomic variables did not show a significant impact on stock market returns in the observed countries. The results provide valuable insights for investors, policymakers, and market participants, enabling them to make informed decisions and develop effective risk management strategies.

Key words: *Stock market, macroeconomic factors, developed economy, developing economy, regression analysis.*

1 International Burch University, Francuske Revolucije bb, Sarajevo, irfan_djedovic@hotmail.com
2 Faculty of Law, University of Tuzla, edin.djedovic@untz.ba
3 International Burch University, Sarajevo, Francuske Revolucije bb, Sarajevo, nadina.omerhodzic@stu.ibu.edu.ba

1. Introduction

A stock exchange, also known as a stock market or a bourse in continental Europe, is a regulated market for the selling and acquisition of assets such as stocks, bonds, and shares. In most nations, the stock exchange serves two purposes. It ensures the liquidity of securities as a ready market, encouraging consumers to put their resources into business investment. Second, it transfers capital among enterprises as a pricing mechanism by calculating prices that represent the genuine investment worth of a company's shares.

Economists and people involved in the financial sphere rely on stock market indexes. Long-term regularities that aid in understanding the behavior of financial participants, the growth of the economy, and international comparisons require consistent indices. Financial indices are also important for traders and investors looking for a quick and easy way to get a summary of what's going on in the stock market. To assess the performance of stock markets, a wide range of indexes have been developed throughout history. These components have exploded in popularity in recent years.

The stock market is an important part of a country's economy. It transfers investment funds from stock investors to stock borrowers, which is essential for a thriving economy. A stock market is essentially a market where securities (stocks, bonds, and other financial instruments) are traded.

As Djedović & Djedović (2018) state, in order to comprehend stock market reports, it is crucial to recognize that the prices of securities and other financial instruments in the long term correspond to economic and political fundamentals and trends. These fundamentals are external to the markets, encompassing economic and political factors that govern trends in specific securities, groups of securities, or even the entire market. Over the long term, these factors determine stock movements and impact the value of all financial instruments. Generally, stock prices tend to increase during favorable economic conditions and decrease when the economy is weak. Numerous factors can influence stock prices, some with immediate effects while others have long-term consequences. Examples of these fundamentals include changes in industrial production, inflation rates, and other similar factors (Djedović & Djedović, 2018). By understanding the underlying principles governing stock markets, we can explore the economic foundations that affect security prices. This paper aims to investigate the influence of external factors on the stock market in Germany and Malaysia, specifically focusing on inflation, industrial production, interest rates, exchange rates, and the CBOE market volatility index (VIX).

This research focuses on analyzing the relationship between the stock market index in Germany and Malaysia, including DAX (DE30) index representing the German stock market, and KLSE (FTSE Malaysia KLCI) representing the Malaysian stock market, and macroeconomic variables from January 2015 to August 2022.

The objective of this study is to examine the existence and nature of the relationship between key factors that have historically influenced conventional in-

dices both regionally and globally, and the DAX and KLCE indexes representing Germany and Malaysia. Specifically, the research aims to determine the extent of influence that macroeconomic factors have on the indexes.

The significance of this study is manifold. It provides valuable insights for policymakers to comprehend the impact of their policies on the DAX and KLSE indexes. It also assists investors in understanding how the market may respond to changes in macroeconomic factors. Lastly, researchers can utilize the findings to assess policy impacts and predict future movements of the DAX and KLSE indexes.

In the following sections of the study presented is a relevant literature review which is a base for the model development. Furthermore, provided is information regarding the data and methodology used in the study. In the last sections, presented are the results and the main conclusions of the study.

2. Literature review

Previous studies have examined the relationship between stock market returns and macroeconomic variables. These studies have demonstrated significant connections between stock markets and macroeconomic variables across different countries (Djedovic & Djedovic, 2018). "While the association between stock markets and economic activities is evident regardless of causality, a standardized set of macroeconomic variables has yet to be established. The selection of macroeconomic variables to explore the determinants of the stock market tends to vary slightly among studies. However, Abdul Rahman et al. (2009) suggest that inflation rates, money growth, interest rates, industrial production, reserves, and exchange rates are the most common significant factors in explaining stock market movements" (Djedović & Djedović, 2018).

In the following paragraphs presented are the relevant macroeconomic variables that potentially have an impact on stock market indices, as well as the empirical evidence regarding this relationship. This section is based on past relevant study work completed by different researchers for various nations and time periods.

2. 1. Stock market indices and the macroeconomic indicators

"While the association between the stock market and economic activities is quite obvious regardless of its causality direction, a standardized set of macroeconomic variables is not found. Macroeconomic variables selected to examine the determinants of the stock market tend to be slightly different in various studies. However, Abdul Rahman et al. (2009) suggest that the rate of inflation, money growth, interest rates, industrial production, reserves, and exchange rates are the most popular significant factors in explaining the stock market movement" (Djedović & Djedović, 2018).

As Abdul Rahman et al. (2009) suggests that there are several studies that determine factors affecting stock prices such as studies by Sadorsky (2003), Ibrahim and Aziz (2002), Mavrides (2000), and Chen (2003).

2. 2. Interest rate (Federal Funds Rate) and stock market indices

Bartram (2002) mentions that there are several ways through which interest rates affect the performance of companies. Furthermore, Martinez-Moya et al. (2013) mention this relationship as well and argue that "the interest rate influences both the future cash flows for companies and the discount rate to value these companies and, hence, the stock price of the company".

Due to the importance of interest rates in shaping the stock prices of the companies, besides domestic monetary variables, we included in the study a foreign interest rate, namely US Federal Funds Rate (FFR), to capture international influence on both stock markets. Due to some econometric limitations, domestic interest rates are not included in the study.

In the study conducted by Mohd. Yusof and Abd. Majid (2007) on the Malaysian stock market, it is found that the Federal funds rate has a significant direct impact on the Malaysian stock market behavior.

Chebbi and Derbali (2019) empirically investigated the impact of US monetary policy surprises on the volatility of stock market returns for euro-area countries. They found a significant response of volatility to an expected component of the target rate change. Furthermore, they highlight homogeneity in the responsiveness of European stock markets to US news announcements.

There are also different studies that investigate the relationship between domestic interest rates and stock markets. We highlight a few of them. Misra, P. (2018) investigated the relationship between the Indian stock market index (BSE Sensex) and macroeconomic indices. Data used for research is from April 1999 to March 2017. The results of their study suggest that there is a long-run impact of interest rates on the stock market index.

Furthermore, Ahmed (2008) researched the impact and nature of relationships between key macroeconomic indicators and the stock market index in India. Data reference is for the period March 1995 to March 2007, on a quarterly basis. It is concluded that stock prices in India lead economic activities except for interest rate movement. Results imply that interest rate serves a leading role in the stock index movement.

Adam and Tweneboah (2008b) tested for cointegration between macroeconomic indices and the stock index in Ghana. The assaying is on time intervals from January 1991 to April 2007 based on quarterly data. The article found that macroeconomic variables and stock prices in Ghana are cointegrated, implying a long-term link. The VECM analysis reveals that interest rates have a considerable impact on the stock market.

N. Apergis and S. Eleftheriou (2002) conducted an empirical investigation on the link between stock prices, inflation, and interest rates in Greece from the year 1988 to 1999. Monthly data on stock prices, as assessed by the ASE stock price general index, is used in the empirical analysis. The results show that interest rates and stock prices are favorably associated, although this relationship is statistically negligible.

2. 3. CPI – Inflation and stock market indices

The findings of N. Apergis and S. Eleftheriou (2002) support the theory that stock prices and inflation are related. Despite the strong association that the literature claims, empirical evidence obtained in their analysis show that stock values in ASE follow inflation rather than nominal interest rate fluctuations. The findings show that continuously decreasing inflation tends to lead to a real increase in stock values because lower inflation means lower risk to the economy.

Furthermore, the Vector Error Correction Model (VECM) applied by Misra (2018) demonstrates that inflation and BSE Sensex have a long-run causal relationship as well as a short-run causal relationship between inflation and the BSE Sensex stock index.

Floros (2008) investigated the link between stock returns and inflation in his study. For the period from 1988 to 2002, he used monthly data from the Athens Stock Exchange Price Index and the Greek Consumer Price Index to test this association. A set of equations adding lagged inflation values shows a negative but not significant influence of lagged inflation on stock returns. Furthermore, by using the Johansen cointegration test the results of a study conducted by Floros (2008) found show that there is no long-run link between stock returns and inflation.

In her study, Shiblee (2009) examined the impact of inflation, GDP, unemployment, and money supply on the stock price of the industrial sector. The research was based on the New York Stock Exchange from the period of 1994 to 2007. She found that inflation is expected to have a minor impact on the stock market index.

Ibbotson G. and Chen P. (2001) estimated the long-run stock market returns in the real economy. Annual historical stock returns are decomposed into supply components such as inflation and GDP per capita from the years 1926 to 2000. The results show that nominal earnings growth including inflation account for most of the return of the stock market.

2. 4. Index of Industrial Production (IPI) and stock market indices

McMillan (2016) presented research that investigates predictability and stock market returns forecasting using twenty-five variables. The data is collected on a quarterly basis throughout the sample period, which runs from January 1973

to April 2014. The results show that in the key group of variables that predict changes in expected returns is GDP acceleration. Furthermore, Misra (2018) suggested that the Index of Industrial production has a long-run impact on the BSE Sensex.

Boubakari A. and Jin D. (2010) used time series data from five Euronext economies to investigate the causation link between the stock market and economic growth over the period from January 1995 to April 2008. The Granger causality test was performed to determine whether there was a causal link between stock market indexes and economic growth (GDP and FDI). The study's findings imply that the stock market and economic growth are linked in some nations where the stock market is liquid and active. The causative link is opposed in nations with a small and less liquid stock market.

In their study, Paramati R. and Gupta R. (2013) conducted a study for the period from April 1996 to March 2009, using the monthly Index of Industrial Production (IIP) and quarterly Gross Domestic Product (GDP) data. The monthly results demonstrate a bidirectional association between IIP and stock prices (BSE and NSE), but the quarterly data show that there is a unidirectional relationship between NSE and GDP, which goes from GDP to NSE.

2. 5. Exchange rate and stock market indices

In his work, Rasiah R. (2010) examines the long-run correlations and short-run dynamic interactions between the stock market and key macroeconomic factors in Malaysia from January 1980 to December 2006. The cointegration test and the vector error correction model show that real stock returns and the real exchange rate have positive long-run connections. Furthermore, Misra, P. (2018) suggests that there is a long-run impact of the exchange rate, on the BSE Sensex index.

T. Siddiqui and Y. Abdullah (2015) researched how to anticipate stock values using predictable patterns. The study's variables include the USD-INR exchange rate, crude oil prices, and key stock indexes in the United States the Eurozone, China, and Japan. Daily data from January 2004 to December 2013 is used in the study. The stock exchange data from international stock markets allow for overnight changes in market sentiment. Also, the correlations between macroeconomic conditions and stock return were established by Adam and Tweneboah (2008b). According to the findings, exchange rates have a small impact on stock price movements.

2. 6. CBOE market volatility index (VIX) and stock market indices

As a proxy for market volatility, the CBOE market volatility index (VIX) is used. "The implied volatility index is the trademark of the Chicago board options exchange and is introduced in 1993 and in 2003 modified" (Thielen 2016).

Nazlioglu et. al (2015) investigated the impact of VIX on the Islamic stock Markets and conventional stock markets. Study results suggest that the conventional stock market is sensitive to the VIX index in both positive and negative directions due to uncertainty and fear, and this is a regular behavior in these cases.

"Delisle et al. (2011) and Van Ahn Mai et al (2015) conclude that the rise of the VIX is negatively related to future stock returns, but there is no relation between the fall of the VIX and future stock returns. They conclude that 'VIX innovations are a priced risk factor only when VIX rises, and not when it declines" (Thielen, 2016).

Sarwar and Khan (2017) found that increases in VIX lead to significant immediate and delayed declines in emerging market returns in all periods. Furthermore, the study conducted by Sarwar (2012) focuses on VIX-returns analysis. The results suggest a strong negative contemporaneous relation between daily changes in VIX and U.S. stock market returns. This relation is stronger when VIX is higher and more volatile. The results also show that there is a similar relationship between VIX and equity returns in China, Brazil, and India in the specific periods.

3. Data and Methodology

Using comprehensive datasets from the selected economies, the study will employ econometric techniques such as regression analysis to examine the effects of these factors on stock market indices. Data for the study is obtained from the International monetary fund database, the Federal Statistical Office of Germany, the Central Bank of Malaysia, the Federal Reserve's database, and investing.com on a monthly basis, spanning from January 2015 to August 2022. The data will be statistically analyzed using Microsoft Excel and EViews software. Ordinary Least Squares Regression will be used to study the relationship. All necessary diagnostics tests including normality, serial correlation, and heteroscedasticity will be run.

As introduced previously testing will use data from Germany as a developed and Malaysia as a developing country.

The data utilized for the investigation will be derived from secondary sources. The main source for macroeconomic data used for Germany and its indicators is the Federal Statistical Office of Germany. Macroeconomic data for Malaysia is collected from the Central Bank of Malaysia.

The multiple regression econometric models used in the study, which include the following variables, can be expressed as:

$$\textit{Stock Market Index growth}\ (\text{Germany}) = \beta 0 + \beta 1 * d\textit{Exchange rate} + \beta 2 * \textit{Industrial Production Index growth} + \beta 3 * \textit{CPIgrowth} + \beta 4 * \textit{VIX} + \beta 5 * d\textit{Federal Reserves Rate} + \beta 6 * \textit{VIXgrowth index} + \varepsilon$$

Stock Market Index growth (Malaysia) = β0 + β1 * dExchange rate + β2 * Industrial Production Index growth + β3 * CPIgrowth + β4 * VIX + β5 * dFederal Reserves Rate + β6 * VIXgrowth index + ε

In the models:

- *Stock Market Index* represents the dependent variable, which is the value of the stock market index being predicted.
- *Exchange rate* is an independent variable that denotes the foreign exchange rate.
- Industrial Production Index (used as a proxy for GDP) is an independent variable that measures industrial production.
- CPI growth is an independent variable representing the inflation rate.
- CBOE market volatility index (VIX) is an independent variable that represents the Volatility Index, which measures the expected market volatility.
- Federal Reserves Rate is an independent variable indicating the interest rate set by the U.S. Federal Reserve.

β0, β1, β2, β3, β4, β5, and β6 are the regression coefficients that represent the impact of each independent variable on the dependent variable. ε represents the error term in the model, accounting for the unexplained variation not captured by the included independent factors.

The growth rate of the series is estimated by subtracting the value at time t - 1 from the series value at time t and dividing it by the series value at time t as shown in Eq. (1), where Gt is the growth rate at time t, Bt is the series value at time t and Bt-1 is the series value at time t - 1.

Equation 1.
$$\boldsymbol{G_t} = \frac{B_t - B_{t-1}}{B_{t-1}} x100$$

4. Results

In the following parts presented are the results of the study. Ordinary least squares regression analysis was applied to examine the effects of the set of independent variables influencing the stock market return in developed and developing economies, represented respectively by Germany and Malaysia.

4. 1. Descriptive statistics

Table 1 presents the summary statistics of the key variables in this study related to Germany.

Table 1. Descriptive statistics - Germany

	DAX_INDEX	CPI	EXCHANGE_RATE	FEDFUNDS	IPI	VIX
Mean	12358.91	112.3903	101.8722	0.840652	108.2982	18.88152
Median	12311.9	111.7202	101.9307	0.4	108.8778	16.37
Maximum	15884.86	127.3739	104.3858	2.42	126.2699	53.54
Minimum	9495.4	105.6088	98.29645	0.05	77.20127	9.51
Std. Dev.	1606.179	4.967424	1.407191	0.827915	8.536214	7.637585
Skewness	0.455496	1.218237	-0.280809	0.68467	-0.69801	1.657591
Kurtosis	2.636128	4.243303	2.397838	1.956247	4.344654	6.78436

Source: Authors' calculation

Table 2 presents the summary statistics of the key variables in this study related to Malaysia.

Table 2. Descriptive statistics - Malaysia

	KLCI_INDEX	CPI	EXCHANGE_RATE	FEDFUNDS	IPI	VIX
Mean	1647.626	119.6261	5.774567	0.840652	110.9744	18.88152
Median	1651.655	120.5	5.807268	0.4	112.1224	16.37
Maximum	1870.37	128.2	6.189792	2.42	130.7784	53.54
Minimum	1350.89	109.9	5.016211	0.05	77.00413	9.51
Std. Dev.	110.4841	4.016391	0.224588	0.827915	8.970241	7.637585
Skewness	-0.062051	-0.369997	-1.661173	0.68467	-0.60207	1.657591
Kurtosis	2.651337	2.747373	6.262275	1.956247	4.310105	6.78436

Source: Authors' calculation

4. 2. Unit root tests

Table 1 and Table 2 present the results of Augmented Dickey-Fuller unit root tests for the variables used in the research models for Germany and Malaysia. The results showed that all variables are stationary at the level, meaning that they do not have unit roots.

Table 3. Unit root tests - Germany

	Test Statistics	
Variables	Level	1st Difference
DAX GROWTH[1]	-10,0172*	
DEXCHANGE[1]	-8,675*	
DFED[1]	-3,737*	
INFLATION[1]	-4,0666*	
IPIGROWTH	-10,97599*	
VIXGROWTH	-12,259*	

Note: [1] Indicates Augmented Dickey-Fuller test, * indicates the series is stationary at 5% significance level

Table 4. Unit root tests - Malaysia

Test Statistics		
Variables	Level	1st Difference
KLCI GROWTH[1]	-10,46*	
INFLATION[1]	-7,240*	
DFED[1]	-3,737*	
DEXCHANGE[1]	-8,974*	
IPIGROWTH	-13,074*	
VIXGROWTH	-12,259*	

Note: [1] Indicates Augmented Dickey-Fuller test, * indicates the series is stationary at 5% significance level

4. 3. Residual Diagnostics

In the following Tables presented are the results of the residual diagnostics for the research models. Namely, the results of the residual diagnostics are covering the Normality test, Serial correlation LM test, and Heteroscedasticity tests for Germany and Malaysia.

The normality of distribution is tested using the Jarque-Bera test. As shown in Figure 1 (Germany) the estimated model using EViews software shows JB=3.746, with a probability of 0.153, pointing to the conclusion that on any commonly used significance level, we do not reject the null hypothesis on the normality of distribution of relation errors. Furthermore, as shown in Figure 2 (Malaysia) the estimated model using EViews software shows JB=4.160, with a probability of 0.1248, pointing to the conclusion that on any commonly used significance level, we do not reject the null hypothesis on the normality of distribution of relation errors.

Figure 1. Results of the Jarque-Bera Test - Germany

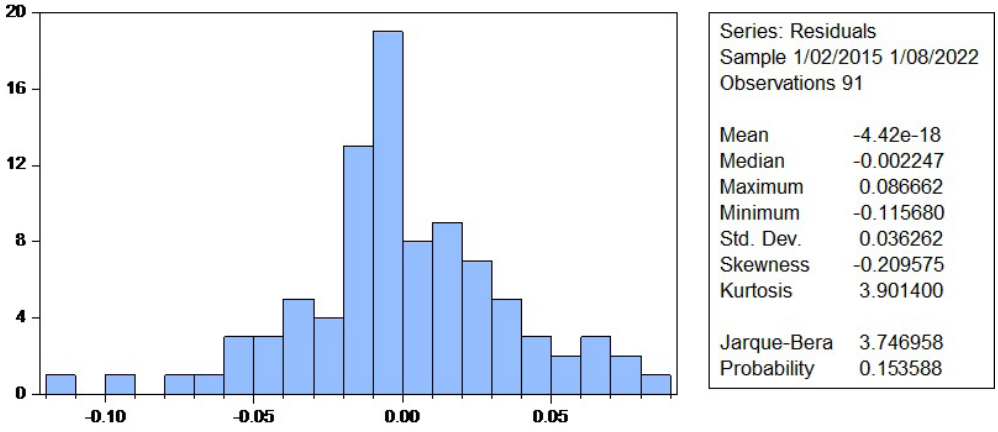
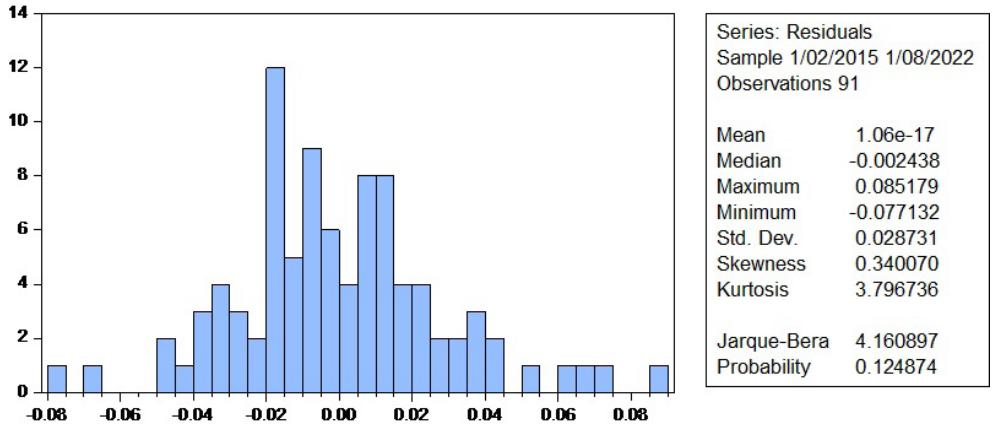


Figure 2. Results of the Jarque-Bera Test - Malaysia



Autocorrelation has been tested using the Breusch-Godfrey LM test for autocorrelation (Tables 3 and 4). With a level of significance of 5%, we can confirm the null hypothesis stating there is no autocorrelation in the models that can be accepted.

Table 5. Results of the Breusch-Godfrey LM Test for Autocorrelation -Germany

Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	1.478050	Prob. F(2,83)	0.2340
Obs*R-squared	3.129563	Prob. Chi-Square(2)	0.2091

Table 6. Results of the Breusch-Godfrey LM Test for Autocorrelation -Malaysia

Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	0.366117	Prob. F(2,83)	0.6945
Obs*R-squared	0.795790	Prob. Chi-Square(2)	0.6717

To address the potential heteroscedasticity problem that is common in time series, we have conducted a Breusch-Pagan-Godfrey Heteroscedasticity test using EViews software. The results of the test are presented in Tables 5 and 6. The null hypothesis assumes homoskedasticity. Given that the probabilities are all greater than 0.05, shown in Table 5 for Germany, and that the probabilities of Malaysia shown in Table 6, are also greater than 0.05, we do not reject the null hypothesis and conclude that the variances are homoscedastic for each model.

Table 7. Results of Breusch-Pagan-Godfrey Heteroscedasticity test – Germany

Heteroskedasticity Test: Breusch-Pagan-Godfrey			
F-statistic	0.776799	Prob. F(5,85)	0.5691
Obs*R-squared	3.976458	Prob. Chi-Square(5)	0.5528
Scaled explained SS	5.033025	Prob. Chi-Square(5)	0.4119

Table 8. Results of Breusch-Pagan-Godfrey Heteroscedasticity test – Malaysia

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	1.390376	Prob. F(5,85)	0.2361
Obs*R-squared	6.879914	Prob. Chi-Square(5)	0.2297
Scaled explained SS	8.393819	Prob. Chi-Square(5)	0.1358

Thus, all the presumptions have been confirmed, and the results of the regression model including the economic determinants of stock market returns can be used to conclude the German and Malaysian case.

Table 9. The summary output of the regression model – Germany

Dependent Variable: DAXGROWTH
Method: Least Squares
Date: 04/28/23 Time: 16:46
Sample (adjusted): 1/02/2015 1/08/2022
Included observations: 91 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DEXCH	-0.023947	0.006951	-3.445195	0.0009
DFED	-0.020916	0.023067	-0.906740	0.3671
INFLATION	1.245149	0.886250	1.404962	0.1637
IPIGROWTH	-0.068113	0.041114	-1.656674	0.1013
VIXGROWTH	-0.108061	0.012947	-8.346389	0.0000
C	0.005659	0.004377	1.292854	0.1996

R-squared	0.512867	Mean dependent var	0.003353
Adjusted R-squared	0.484212	S.D. dependent var	0.051955
S.E. of regression	0.037313	Akaike info criterion	-3.675272
Sum squared resid	0.118344	Schwarz criterion	-3.509721
Log likelihood	173.2249	Hannan-Quinn criter.	-3.608483
F-statistic	17.89806	Durbin-Watson stat	2.324306
Prob(F-statistic)	0.000000		

Regression estimates of economic determinants of stock market index return (DAX) in Germany show a statistically significant impact of exchange rate and VIX growth rate on stock market index return in Germany. Federal Funds Rate, inflation, and IPI growth did not show a statistically significant impact on stock market index (DAX) return in Germany. Both the exchange rate and VIX growth rate have a negative coefficient. The F-statistic equals 17.898 with a corresponding empirical significance level of 0,000, thus showing that the regression model is statistically significant at 5% significance.

Table 10. The summary output of the regression model – Malaysia

Dependent Variable: KLCIGROWTH
Method: Least Squares
Date: 05/10/23 Time: 13:20
Sample (adjusted): 1/02/2015 1/08/2022
Included observations: 91 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CPIGROWTH	-0.191280	0.651205	-0.293732	0.7697
DFED	0.025207	0.019236	1.310412	0.1936
DEXCH	-0.084392	0.030308	-2.784505	0.0066
IPIGROWTH	-0.000709	0.000405	-1.750589	0.0836
VIXGROWTH	-0.000534	0.000453	-1.178108	0.2420
C	0.086743	0.042404	2.045656	0.0439

R-squared	0.163419	Mean dependent var	-0.001309
Adjusted R-squared	0.114209	S.D. dependent var	0.031412
S.E. of regression	0.029564	Akaike info criterion	-4.140853
Sum squared resid	0.074293	Schwarz criterion	-3.975301
Log likelihood	194.4088	Hannan-Quinn criter.	-4.074063
F-statistic	3.320817	Durbin-Watson stat	2.160599
Prob(F-statistic)	0.008680		

Regression estimates of economic determinants of stock market index return (KLCI) in Malaysia show a statistically negative significant impact of exchange rate on stock market index return in Germany at a 5% significance level. Furthermore, regression estimates of economic determinants of stock market index return (KLCI) in Malaysia show a statistically negative significant impact of IPI growth on stock market index return in Malaysia at a 10% significance level. However, Federal Funds Rate, inflation, and VIX growth did not show a statistically significant impact on the stock market index (KLCI) return in Malaysia. Both the exchange rate and IPI growth rate have a negative coefficient. The F-statistic equals 3.32 with a corresponding empirical significance level of 0.00868, showing that the regression model is statistically significant at 5% significance.

The results of the study show that for both countries and indices that are investigated, the exchange rates have a significant negative impact on stock market returns. However, the coefficients are very low. It should be taken into consideration that the exchange rate is the price of a unit of a given currency in relation to other currencies. "The performance and profitability of industries and companies that are major exporters or heavy users of imports are considerably affected by the exchange rate against major currencies of the world" (Osamwonyi, 2003). Therefore, it is not unexpected that the exchange rate has a significant impact on the stock market returns.

Furthermore, economic theory asserts that the exchange rate is an important variable in developing a comprehensive understanding of the behavior of stock prices and index movements. Maysami et al. (2004) state that the "deprecia-

tion of countries' currencies will lead to an increase in demand for their exports and thereby increasing cash flows to the country, assuming that the demand for exports is sufficiently elastic". This can be one of the reasons for having a significant and negative influence of exchange rates on stock market returns in both countries. Study results are in line with the results of several other studies that found a significant impact of exchange rate on stock market returns (Maysami and Sims (2002, 2001a, 2001b)).

The results also suggest that the CBOE market volatility index (VIX) has a statistically significant impact on stock market return in Germany, while in Malaysia it is not the case. The reasoning for this difference might be that the German stock market is more interconnected with the global markets and that reflections of the fear or implied volatility which is represented by the CBOE market volatility index (VIX) are easily transmitted to the German stock market, while the Malaysian stock market is immune to these effects since Malaysian linkage with the international and western economies is weaker. The results can be beneficial for the investors when creating their investment portfolios, as well as for the stock market trading timing in the observed countries and corresponding indices.

5. Conclusion

In this study, a review of relevant literature related to determinants of stock market returns was presented, as well as empirical evidence from Germany and Malaysia. Potential determinants of stock market returns used in this study include the industrial production index (IPI) as a proxy for GDP, exchange rate, inflation rate, implied volatility index (VIX), and federal funds rate. For the purpose of the study, monthly basis data, spanning from January 2015 to August 2022 is collected from several sources including the International monetary fund database, the Federal Statistical Office of Germany, the Central Bank of Malaysia, the Federal Reserve's database, and investing.com.

The data is statistically analyzed using Microsoft Excel and EViews software. Ordinary Least Squares Regression is used to study relationships.

The results of the empirical analysis confirmed that the exchange rate has a statistically significant negative impact at 5% significance on stock market returns in both countries, which is also in line with the abovementioned empirical literature and the theory. On the other side, the implied volatility index (VIX) has a statistically significant impact at 5% significance on stock market returns in Germany, while the impact in Malaysia is insignificant. It is expected that VIX has an impact, in both countries, however, the level of openness and interconnectedness of the Malaysian market to the world markets could be a reason for the insignificant result. While in Germany, considered a developed economy, this impact is transmitted smoothly.

The rest of the results, related to the other macroeconomic variables used in the research model, namely inflation rate, federal funds rate, and industrial pro-

duction index did not show a statistically significant impact at 5% significance on the stock market returns in the two observed countries.

The main limitations of this study is that only two stock market indices were taken into consideration when exploring the determinants of stock market returns, and that the data used for the study spans from 2015 to 2022. A larger number of observations, as well as the usage of more indices from different countries, would provide a better ground for more comprehensive conclusions. Furthermore, the R-squared value of the econometric model in the Malaysian case is quite low, suggesting that other variables should be included in the model, to strengthen the analysis and the model itself. Therefore, it is advisable to analyze more countries and indices, increasing the number of observations and reconsidering the econometric models, by eventually adding additional explanatory variables.

The results can be beneficial for the investors when creating their investment portfolios, as well as for the stock market trading timing in the observed countries and corresponding indices.

References

1. Abdul Rahman, A., Mohd Sidek, N.Z. & Hanim Tafr, F. (2009). "Macroeconomic determinants of Malaysian stock market", African Journal of Business Management, 3(3), 95-106.
2. Adam, A. M., & Tweneboah, G. (2008b). Macroeconomic Factors and Stock Market Movement: Evidence from Ghana. SSRN Electronic Journal.
3. Anari, A., & Kolari, J. (2001). Stock prices and inflation. Journal of Financial Research, volume 24, 587–602.
4. Apergis, N., & Eleftheriou, S. (2002). Interest rates, inflation, and stock prices: the case of the Athens Stock Exchange. Journal of Policy Modeling, 24(3), 231–236.
5. Bartram, S.M. (2002). The interest rate exposure of nonfinancial corporations. European Finance Review, 6(1), 101–125.
6. Baskin J.B. (1988), "The development of corporate financial markets in Britain and the United States, 1600-1914 : overcoming asymmetric information", Business history review, LXII, 199-237
7. Boubakari, A., & Jin, D. (2010). The Role of Stock Market Development in Economic Growth: Evidence from Some Euronext Countries. International Journal of Financial Research, 1(1).
8. Cakici, N., & Zaremba, A. (2020). Misery on Main Street, Victory on Wall Street: Economic Discomfort and the Cross-Section of Global Stock Returns. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3730645
9. Chebbi, T. and Derbali, A. (2019) 'US monetary policy surprises transmission to European stock markets', Int. J. Monetary Economics and Finance, Vol. 12, No. 1, pp.3–14.
10. Chen, L., & Zhang, L. (2009). The Stock Market and Aggregate Employment. SSRN Electronic Journal.

11. Chen, M.H. (2003). Risk and Return: CAPM and CCAPM. Q. Rev. Econ. Fin. 43, 369-393.

12. Chen, S., & Hsu, C. C. (2018). Do Stock Markets Have Predictive Content for Exchange Rate Movements? SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3098610

13. Djedović, E., & Djedović, I. IMPACT OF MACROECONOMIC VARIABLES ON STOCK MARKET INDEX IN BOSNIA AND HERZEGOVINA.

14. Floros, C. (2008). Stock Returns and Inflation in Greece. Applied Econometrics and International Development, Vol. 4(No. 2, 2004).

15. Ghulam Sarwar & Walayet Khan (2017) The Effect of US Stock Market Uncertainty on Emerging Market Returns, Emerging Markets Finance and Trade, 53:8, 1796-1811, DOI: 10.1080/1540496X.2016.1180592

16. Hautcoeur, P. C. (2006). The Early History of Stock Market Indices, with Special Reference to the French Case. The Early History of Stock Market Indices, with Special Reference to the French Case.

17. Ibbotson, R. G., & Chen, P. (2001). Stock Market Returns in the Long Run: Participating in the Real Economy. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.274150

18. Ibrahim, M.H. & Aziz, H. (2003). Macroeconomic variables and the Malaysian equity market: A view through rolling subsamples. J. Econ. Stud, 30(1), 6-27. https://doi.org/10.1108/01443580310455241

19. Li, Y., & Suominen, M. (2020). Equity Returns, Unemployment, and Monetary Policy. SSRN Electronic Journal.

20. Martinez-Moya, P., Ferrer-Lapena, R. and Escribano-Sotos, F. (2013). Relationship between interest rate changes and stock returns in Spain: a wavelet-based approach. Working Paper, Department of Economics and Finance, UCLM. Spain, 1-24.

21. Mavrides, M. (2000). Granger Causality Tests of Stock Returns: The U.S. and Japanese Stock Markets. Manage. Financ. 26(12), 13-25.

22. Maysami, R. C., Howe, L. C., & Hamzah, M. A. (2004). Relationship between macroeconomic variables and stock market indices: Cointegration evidence from stock exchange of Singapore's All-S sector indices. Jurnal pengurusan, 24(1), 47-77.

23. Maysami, R. C. and Sim, H. H. (2002). Macroeconomics variables and their relationship with stock returns: error correction evidence from Hong Kong and Singapore. The Asian Economic Review, 44(1), 69-85.

24. Maysami, R. C. and Sim H. H. (2001a). An empirical investigation of the dynamic relations between macroeconomics variable and the stock markets of Malaysia and Thailand. Jurnal Pengurusan, 20, 1-20.

25. Maysami, R. C. and Sim H. H. (2001b). Macroeconomic forces and stock returns: a general-to-specific ECM analysis of the Japanese and South Korean markets. International Quarterly Journal of Finance, 1(1), 83-99.

26. McMillan, D. G. (2016). Which Variables Predict and Forecast Stock Market Returns? SSRN Electronic Journal.

27. Misra, P. (2018). An Investigation of the Macroeconomic Factors Affecting the Indian Stock Market. Australasian Accounting, Business and Finance Journal, 12(2), 71–86.

28. Nazlioglu, S., Hammoudeh, S., & Gupta, R. (2015). Volatility transmission between Islamic and conventional equity markets: Evidence from causality-in-variance test. Applied Economics, 47(46), 4996-5011.

29. Paramati, S. R., & Gupta, R. (2013). An Empirical Analysis of Stock Market Performance and Economic Growth: Evidence from India. SSRN Electronic Journal.

30. Rasiah, R. V. R. (2010). Macroeconomic Activity and the Germanyn Stock Market: Empirical Evidence of Dynamic Relations. SSRN. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1667079

31. Sadeghi, M. (1992). Stock Market Response to Unexpected Macroeconomic News: The Australian Evidence. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.884889

32. Sadorsky, P. (2003). The Macroeconomic Determinants of Technology Stock Price Volatility. Review of Financial Economics, 12, 191-205. https://doi.org/10.1016/S1058-3300(02)00071-X

33. Ghulam Sarwar. (2012). Is VIX an investor fear gauge in BRIC equity markets?, Journal of Multinational Financial Management, Volume 22, Issue 3, Pages 55-65, ISSN 1042-444X, https://doi.org/10.1016/j.mulfin.2012.01.003.

34. Savor, P. G., & Wilson, M. I. (2009). Asset Returns and Scheduled Macroeconomic News Announcements. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.1342933

35. Shahid, A. (2008). Aggregate Economic Variables and Stock Markets in India. International Research Journal of Finance and Economics, 14, 141–164.

36. Shiblee, L. S. (2009). The Impact of Inflation, GDP, Unemployment, and Money Supply On Stock Prices. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.1529254

37. Siddiqui, T., & Abdullah, Y. (2015). Developing a Nonlinear Model to Predict Stock Prices in India: An Artificial Neural Networks Approach. SSRN. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2692367

38. Stillman, R. (1986). Dow Jones Industrial Average: History and Role in an Investment Strategy. Irwin Professional Pub.

39. Thielen B. (2016). Volatility and stock market returns: CAN VOLATILITY PREDICT STOCK MARKET RETURNS? Tilburg University, Faculty of Economics and Business Administration, Department of Finance.

Websites

1. https://data.oecd.org/germany.htm
2. https://www.bnm.gov.my/
3. investing.com
4. data.imf.org

doc.dr.sc. Kasim Bajramović, dipl.ing.rudarstva[1]
Irhad Bajramović[2],
Irfan Bajramović[3]

Professional paper

ELECTRO-HYDRAULIC CONTROL OF SECTIONS MECHANISED UNDERGROUNDS IN THE "BEGIĆI-BIŠTRANI" PIT RMU "KAKANJ"

Abstract

The subject of this work are the sections of the mechanized hydraulic substructure, which were installed in the "Begići-Bištrani" pit of the RMU "Kakanj". The complex of mechanized wide front (KMŠČ) consists of wide-front sections with electronic control equipment: signal control units "SCU-signal control unit" or control units, and they are installed on each section to ensure management and monitoring of other technological functions of the system. The results of the research show us that knowledge of world technology, modern mining techniques and the quality of human resources must give new momentum to underground coal exploitation in terms of mass creativity, which will later be taken over by new technological solutions. Real possibilities in the realization of these development tasks are provided by electro-hydraulic control. The starting point for the use of electro-hydraulic control is a quality database. The traditional approach to the database mainly represents a centralized database for underground exploitation, as a recurrence of centralized computer centers and information systems. In the segment of the construction of electro-hydraulic control sections of the mechanized substructure in the "Begići-Bištrani" pit of the RMU "Kakanj", it is necessary to perform additional analyzes related to the change in the dynamics of data reading, and the implications of such changes. The implications of the fundamental theorem are, therefore, that informatics includes both people (human intellect) and technology, and that in practice it is an interactive partnership. What people can do with information resources depends primarily on what they know about the task at hand. This work aims to show how electro-hydraulic control of sections of mechanized substructure, automation and information technology can improve safety in mines, improve measures and actions to prevent injuries at work, occupational diseases, other diseases related to work and protection of the working environment.

Key words: *Automation, information technology, electro-hydraulic, computer programs, mining.*

1 PhD in Mining Engineering, ZD RMU Kakanj d.o.o. Kakanj (Kakanj Coal Mine) and Docent at Faculty of Mechanical Engineering, University of Zenica and Docent at Faculty IUT University of Travnik, kasim.bajramovic@mf.unze.ba
2 Bachelor-Information Technology Engineer; irhadbajramovicbajra@gmail.com
3 Bachelor road traffic Engineer, irfanbajramovic@gmail.com

1. Introduction

The KMŠČ installed in the pit "Begici-Bištrani", in the excavation field OP-I, consists, among other things, of wide-faced sections with electronic control equipment: signal control units "SCU-signal control unit" or control units, and they are installed on each section to ensure the management and monitoring of other technological functions of the system (Elaborat, 2015).

Sections of the mechanized substructure KMŠČ are controlled electrohydraulic via a superior monitoring and control system. The equipment of the electric control system, produced by the German company EEP - Pramatic, consists of:

- server – for work monitoring and archiving of the main settings and implementation of the basic management algorithm;
- self-safe electrohydraulic control units installed on each substructure section (SCU);
- sets of executive electromagnetic valves;
- and each section with two pressure sensors and a cylinder position sensor between the front conveyor and the section,
- power supply units in explosion-proof design,
- main conductors with connectors,
- monitor for visualization IPC 19`.

Under normal conditions, the server should be installed in the first or last section of the wide front, together with the associated control unit. The server unit (VZ) is connected via a profiBUS cable PR116-250 to the pit IPC (Industrial Personal Computer).

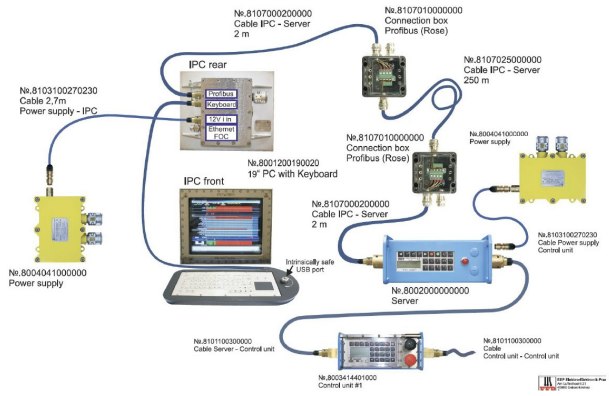


Figure 1. Connection of server unit VZ

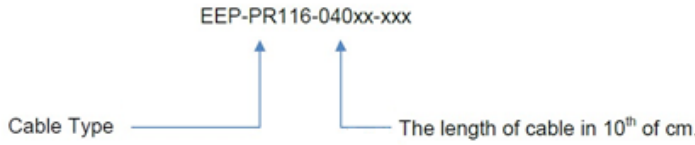
Source: DRP of delivery and assembly of SHP "BW 15/36 POz" with associated equipment and coal mining by wide-purpose mining method with roof demolition with SHP "BW 15/36POz" and excavation machine "Eickhoff" SL-300 in mining field OP-I in pit "Begici-Bištrani" plant "Haljinici" JP "Elektroprivreda BiH" d.d. Sarajevo, ZD RMU "Kakanj" d.o.o. Kakanj - Book II; electrical part (2016).

Cables for connecting servers are shown in Table 1, provided by the equipment manufacturer.

Abbreviation	Description	Order No.	Device Type
K 1	Cable SCU – SCU	8101100350000	PR116-04035
K 3	Cable Power supply – SCU	8103100200160	PR116-04120-160
K 4	Cable SCU – Pressure sensor	8104100220180	PR116-04222-180
K 7	Cable SCU – Odometric system	8105100200160	PR116-04320-160
PS	Power supply in an explosion-proof housing	8004041000000	EEP-PR116-081-Da
VZ	Server unit	8002000000000	PR116/V/H/16M
SKWU	Plug SKWU	8406100000000	PR116-04500
SCU	Single Control unit (SCU)	8003414401000	EEP-PR116/S/H/08/CP

Table 1. Cables for connecting servers

The method of labeling cables, according to table 1, is given in the following example:



Pit computer IPC type PR111a enables communication and visualization of underground equipment, as well as communication from the pit to the "on-call mine" room outside.

Together with the corresponding keyboard, this IPC (Industrial Personal Computer) serves as an interface between the connected equipment and the user. It can receive data from the equipment, but also manage and transmit information to change the settings and parameters of the connected underground equipment (for example: broad-front control system).

With a 19" screen (max. resolution 1600x1200) it shows a very clear visualization of work sequences and status.

Figure 2. IPC front view

Source: DRP of delivery and assembly of SHP "BW 15/36 POz" with associated equipment and coal mining by wide-purpose mining method with roof demolition with SHP "BW 15/36POz" and excavation machine "Eickhoff" SL-300 in mining field OP-I in pit "Begici-Bištrani" plant "Haljinici" JP "Elektroprivreda BiH" d.d. Sarajevo, ZD RMU "Kakanj" d.o.o. Kakanj - Book II; electrical part (2016).

2. SSD (solid-state drive)

An SSD (solid-state drive) is built into the server as a hard disk with a capacity of 640GB, which is used to store data of certain values and time frames.

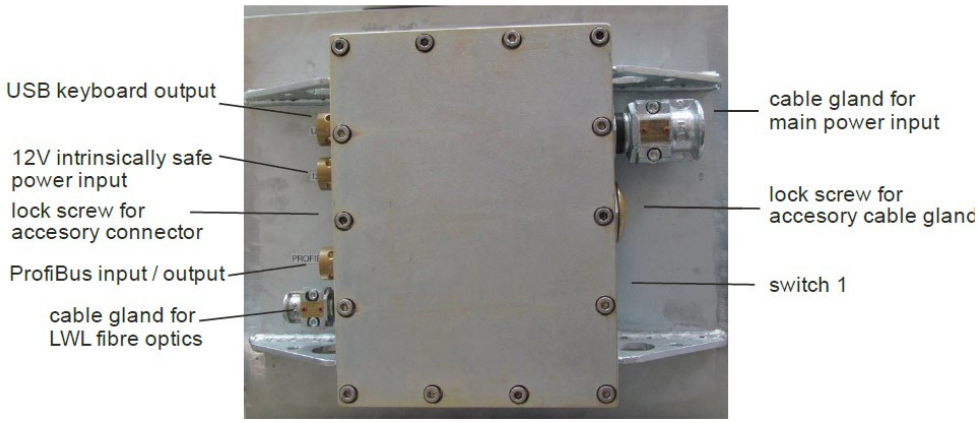


Figure 3. Rear view of the IPC

Source: DRP of delivery and assembly of SHP "BW 15/36 POz" with associated equipment and coal mining by wide-purpose mining method with roof demolition with SHP "BW 15/36POz" and excavation machine "Eickhoff" SL-300 in mining field OP-I in pit "Begici-Bištrani" plant "Haljinici" JP "Elektroprivreda BiH" d.d. Sarajevo, ZD RMU "Kakanj" d.o.o. Kakanj - Book II; electrical part (2016).

The IPC (Industrial Personal Computer) is equipped with an explosion-proof case with two partitions:

- in the front part there is a panel with a PC, connection boards and a power supply unit;
- in the rear part there is a connection for power supply and distribution.

The steel frame on the front is attached with 54 screws to the case. In order to protect the screen from external damage, a triple glass with a safety film between the layers is installed.

On the left side of the back of the IPC (Industrial Personal Computer) there is:

- Self-safe 12V power supply connection from an external power supply unit for powering self-safe components inside the IPC (Industrial Personal Computer);
- Keyboard connection for entering parameters using the keyboard or for controlling the program with an integrated touch-pad. It is also used to transfer data from or to the USB (Universal Serial Bus) memory, when the USB memory is connected to the keyboard.
- Position for additional connection. The place is closed with a protective screw.
- ProfiBus connection for sending and receiving data between control units and IPC (Industrial Personal Computer) via ProfiBus (PROcess FIeld BUS) protocol.
- Cable entry for the implementation of an optical cable for the connection with the server on the surface. The cable gland is secured with a safety screw against accidental loosening.

On the right side of the back of the IPC (Industrial Personal Computer) there is:

- Cable gland for the implementation of the main power line. The cable gland is secured with a safety screw against accidental opening.

- Position for additional connection. The place is closed with a protective screw.
- Main switch for internal power supply. The attachment has no end point and can be rotated left or right; for on/off, the switch must be turned 180° (using a triangular key). For this operation, the dust cover must first be removed from the switch.

To access the area where the connections are located, it is necessary to remove the back panel. Installation and maintenance of this device can only be performed by a trained and authorized person.

3. Connecting the server to the power grid

Each cable connection to the IPC (Industrial Personal Computer) is realized through special inlets and connectors. The appearance of all connectors and the arrangement of conductors in the connector is given in the technical instructions of the equipment manufacturer.

The presentation of the connection of the server to the power grid is given in Figure 4.

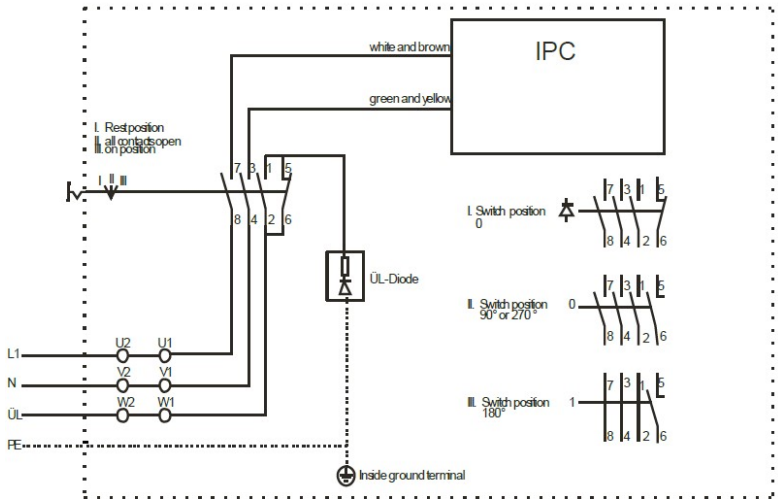


Figure 4. Display of the server's connection to the power grid

Source: DRP of delivery and assembly of SHP "BW 15/36 POz" with associated equipment and coal mining by wide-purpose mining method with roof demolition with SHP "BW 15/36POz" and excavation machine "Eickhoff" SL-300 in mining field OP-I in pit "Begici-Bištrani" plant "Haljinici" JP "Elektroprivreda BiH" d.d. Sarajevo, ZD RMU "Kakanj" d.o.o. Kakanj - Book II; electrical part (2016).

Before operating the system, everyone must read the appropriate instructions for assembly, operation and maintenance, and especially carefully and in detail, the safety rules. Only the latest versions of the official instructions are valid. In case of any problems in the installation, functioning and maintenance of the system, it is necessary to immediately contact the manufacturer of the equipment (Vujić, 2012).

4. Computer keyboard

The IPC (Industrial Personal Computer) keyboard serves as an interface between the equipment and the user.

The keyboard has 82 keys and a built-in touchpad. The connection cable is 1,3 m long and is connected using the SKK-24 connector (SKK-energy and sensor connection cable). The housing is made of anti-static plastic. The built-in USB Hub (Universal Serial Bus) allows the user to load and save data to a USB memory stick with a maximum current consumption of 100 mA.

Figure 5. Keyboard layout for PC IPC

Source: DRP of delivery and assembly of SHP "BW 15/36 POz" with associated equipment and coal mining by wide-purpose mining method with roof demolition with SHP "BW 15/36POz" and excavation machine "Eickhoff" SL-300 in mining field OP-I in pit "Begici-Bištrani" plant "Haljinici" JP "Elektroprivreda BiH" d.d. Sarajevo, ZD RMU "Kakanj" d.o.o. Kakanj - Book II; electrical part (2016).

5. Control units "SCU"

"SCU" control units are installed on each section to ensure control and monitoring of section functions. To monitor the pressure in the hydraulic columns, the section is equipped with a pressure sensor. Additionally - a measuring rod (odometric system) is installed in the base cylinder, which is connected to the corresponding "SCU" for measuring the stroke, speed of progress and relative position of the base cylinder of the section and the complete section.

The power supply unit for self-safe voltage supply is built into the explosion-proof housing. One power supply unit up to 4 control units plus an optional server (VZ) are located next to the electrical equipment on the transport conveyor.

The server has the task of parameterizing and monitoring all control units.

The server uses the PROFIBUS interface for communication with other equipment.

Each control unit (SCU) has an infrared receiver that communicates with the infrared transmitter on the digging machine, and with this communication, the current position of the digging machine in the broad front can be determined.

With the help of control units on individual sections, the complex hydraulic system of the sections can be handled. It is possible to manage individual sections, and group or sequential management.

The control units also enable blocking of control for a given section, and blocking of control of the entire control bus.

6. Electro-hydraulic steering

All operating parameters of the mechanized substructure, data related to sensors and settings, and the position of the harvester are presented on the monitor for visualization. The monitor, as an anti-explosion protected device, made in “impenetrable armor”, is placed next to the equipment used to control the conveyors.

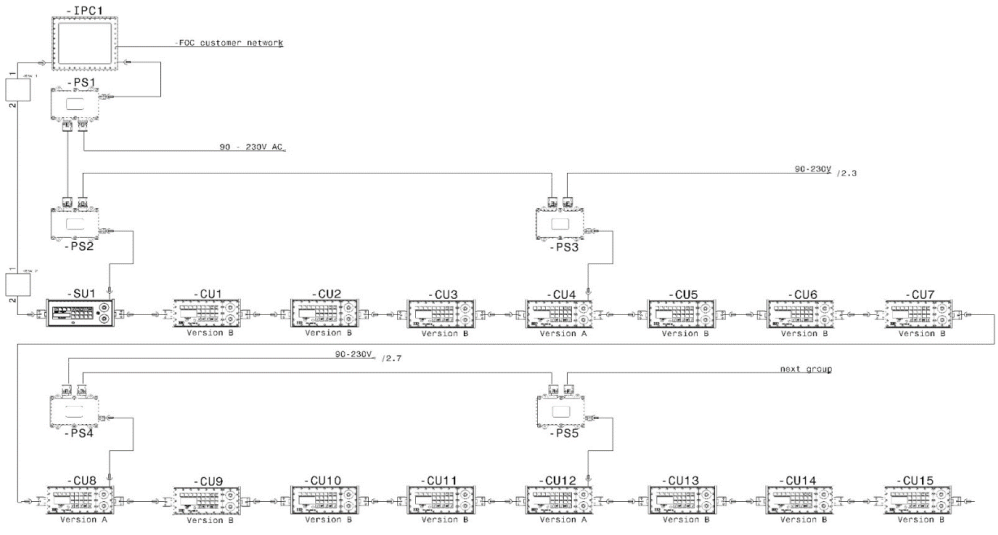
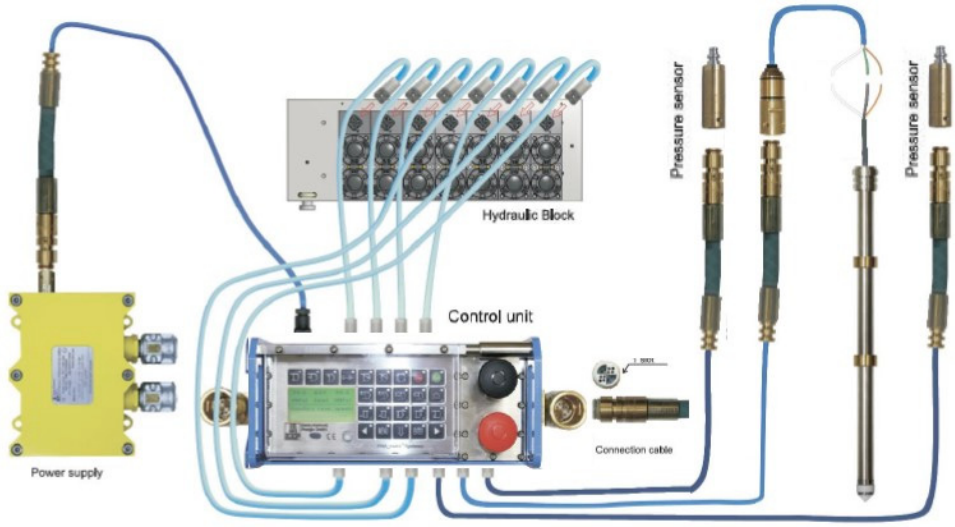


Figure 6. Scheme of the electrohydraulic control system of the mechanized substructure section

Source: DRP of delivery and assembly of SHP "BW 15/36 POz" with associated equipment and coal mining by wide-purpose mining method with roof demolition with SHP "BW 15/36POz" and excavation machine "Eickhoff" SL-300 in mining field OP-I in pit “Begici-Bištrani” plant “Haljinici” JP “Elektroprivreda BiH” d.d. Sarajevo, ZD RMU "Kakanj" d.o.o. Kakanj - Book II; electrical part (2016).

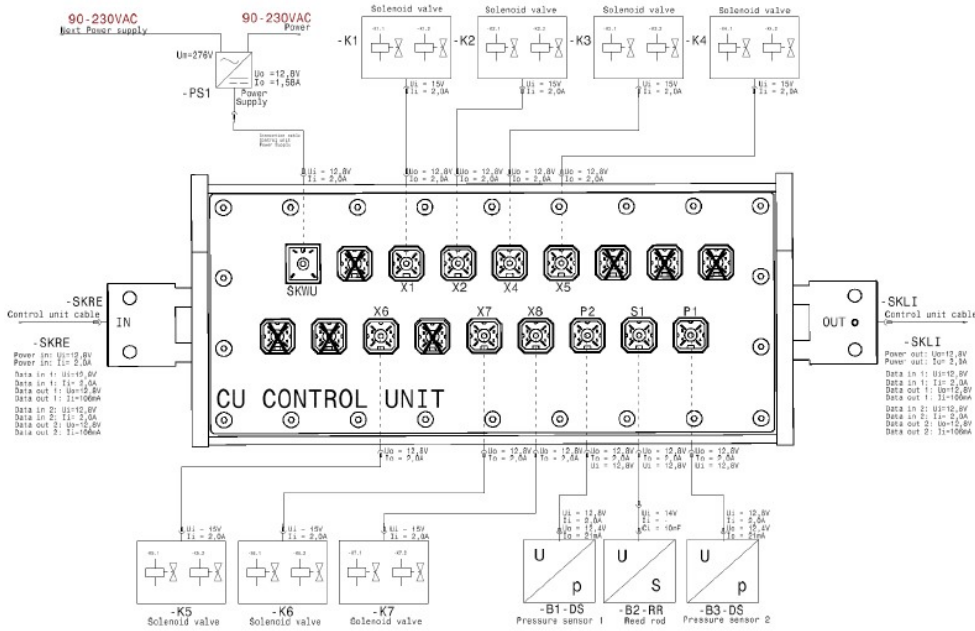
Figures 6 and 7 show the equipment of each substructure section and the entire electro-hydraulic control system. Certain elements of electrohydraulic control have been tested and certified in accordance with UE, CE (certificatum) norms and the ATEX (Atmosphera EXplosibles) directive and have certificates issued by the competent state commission for "Ex" devices in Bosnia and Herzegovina.

Figure 7. Display of the control unit (SCU) functionally connected with sensors and solenoid valves



Source: DRP of delivery and assembly of SHP "BW 15/36 POz" with associated equipment and coal mining by wide-purpose mining method with roof demolition with SHP "BW 15/36POz" and excavation machine "Eickhoff" SL-300 in mining field OP-I in pit "Begici-Bištrani" plant "Haljinici" JP "Elektroprivreda BiH" d.d. Sarajevo, ZD RMU "Kakanj" d.o.o. Kakanj - Book II; electrical part (2016).

Figure 8. Connection diagram of the SCU control unit



Source: DRP of delivery and assembly of SHP "BW 15/36 POz" with associated equipment and coal mining by wide-purpose mining method with roof demolition with SHP "BW 15/36POz" and excavation machine "Eickhoff" SL-300 in mining field OP-I in pit "Begici-Bištrani" plant "Haljinici" JP "Elektroprivreda BiH" d.d. Sarajevo, ZD RMU "Kakanj" d.o.o. Kakanj - Book II; electrical part (2016).

7. Conclusion

Electro-hydraulic control of mechanized subgrade sections in pits involves the use of electricity and hydraulics to control mechanisms in the pit, such as raising and lowering the subgrade or moving heavy loads. This technology is often used in mining to facilitate the process of mining raw materials and transporting materials.

The management of substructure sections is usually done through a control unit that contains electro-hydraulic valves and sensors for monitoring the substructure position. Depending on the specifics of the system, it is also possible to set up remote monitoring for subgrade management outside the pit.

Electro-hydraulic control of sections of the mechanized substructure in the pit "Begići-Bištrani" RMU "Kakanj" is a technology that enables more effective and safer work phases. The starting point for the use of electro-hydraulic control is a quality database. The traditional database approach is mainly a centralized database. In the construction segment of the electro-hydraulic control

of sections of the mechanized substructure in the “Begići-Bištrani” pit of the RMU (Dark Coal Mine) “Kakanj”, it is necessary to perform additional analyzes related to the change in the dynamics of data reading and the implications of such changes.

References

1. DRP dopreme i montaže SHP "BW 15/36 POz" sa pripadajućom opremom i otkopavanja uglja širokocelnom otkopnom metodom sa zarušavanjem krovine sa SHP "BW 15/36POz" i otkopnom mašinom "Eickhoff" SL-300 u otkopnom polju OP-I u jami "Begici-Bištrani" pogona "Haljinici" JP "Elektroprivreda BiH" d.d. Sarajevo, ZD RMU "Kakanj" d.o.o. Kakanj - Knjiga II; elektro dio. Kakanj, 2016.
2. ELABORAT „Uspostava Centralnog dispečerskog sistema“ za potrebe ZD RMU „Kakanj“ d.o.o. Kakanj; Kakanj, august 2015.
3. Vujić, S. (2012). Automatizacija i upravljanje procesima u rudarstvu. Beograd: Akademija inženjerskih nauka Srbije.

Valerij Grašič, PhD[1]

Preliminary communication

COMPARATIVE ANALYSIS OF DIFFERENT SEGMENTS OF AIR QUALITY SENSORS FOR THE FIELD OF SMART ENVIRONMENT AND THEIR IMPORTANCE FOR THE DEVELOPMENT OF SMART CITIES

Abstract

The development of smart cities is considered to consist of several sub-fields and to be conditioned by an ever-increasing number of sensors and IoT devices. These sensors' data are freely available to a large extent, which is why we call them open data. The field of our research is the smart environment as part of a smart city, more specifically the field of air quality. The mentioned area is very important because through it we can evaluate the quality of the air, both for example, if the quality is bad or if the quality is good. If the quality is bad, it has a negative effect on people's health. But if the quality is very good, this is an additional argument for raising the quality of people's lives. For the example of one of the Slovenian cities, we are interested in a comparative analysis of the use of a combination of many different sensor segments. Because in the case of air quality, the sensors can not only be different, but they can also be of completely different quality and offer different capabilities. We are interested in the difference between the sensors, what this means for the air quality measurement itself, what is with the openness of the data, and how is the connection of the data from these different sensors. We are also interested in how we can better assess the air quality for a certain micro-location based on all this data. The given research with the analysis and comparison of different segments of air quality sensors will help us in preparing a comprehensive approach to the control and management of air quality and, consequently, to the development of smart cities.

Key words: *Smart City, Smart Environment, Air Quality, IoT, Open Data.*

1 Valerij Grašič, PhD, Telekom Slovenije, Cigaletova 17, 1000 Ljubljana, Slovenia, valerij.grasic@telekom.si

1. Introduction

Smart cities are still at their beginnings. They add intelligence to existing city systems, enabling more to be done with less. The development of smart cities is considered to consist of several sub-fields and to be conditioned by an ever-increasing number of sensors and IoT devices. These sensors are freely available to a large extent, which is why we call them open data. The field of our research is the smart environment as part of a smart city, more specifically the field of air quality.

Scientific evidence shows that environmental risks are responsible for a major share of cardiovascular disease, which is the most common cause of death in Europe (EEA, 2022). According to the World Health Organization, air pollution causes 7 million premature deaths a year (UNEP, 2022). PM2.5 poses the greatest health threat and is often used as a metric in legal air quality standards. When inhaled, PM2.5 is absorbed deep into the bloodstream and linked to illnesses such as stroke, heart disease, lung disease and cancer (EEA, 2022). To address this air pollution crisis, experts warn that governments must take urgent action to strengthen air quality regulation, including monitoring capacity to track PM2.5 and other pollutants.

There are initiatives in the field of air improvement throughout Slovenia. Participation in the Varcities project by Novo mesto is also a big step forward (Varcities, 2023). For all these cases we are interested in a comparative analysis of the use of a combination of many different sensor segments. Because in the case of air quality, the sensors can not only be different, but they can also be of completely different quality and offer different capabilities.

We are interested in the difference between the sensors, what this means for the air quality measurement itself, what is with the openness of the data, and how is the connection of the data from these different sensors. We are also interested in how we can better assess the air quality for a certain micro-location based on all this data.

The rest of the paper is organized as follows. First, the definition of the problem is given. Then comes the approach to evaluation. The main part is the air quality evaluation. And finally, there is a conclusion and a look into the future.

2. Problem definition

2. 1. Development of smart cities

Information and communication technology enables the transformation of traditional cities into smart cities (Mohanty, Choppali and Kougianos, 2016).

There are several definitions of smart cities. According to the definition by the European Commission, a smart city is a place where traditional networks and

services are made more efficient by the use of digital and telecommunication technologies for the benefit of its residents and businesses (European Commission, 2019). According to the definition of the UK government, the concept of smart cities is not static (Department for Business Innovation and Skills, 2013), because there is no absolute definition of a smart city or an endpoint, but rather a process or a series of steps that make cities more alive and flexible and therefore able to respond more quickly to new challenges. One of the formal definitions of a smart city claims that a smart city connects physical infrastructure, information technology infrastructure, social infrastructure, and business infrastructure to foster the collective intelligence of the city (Mohanty, Choppali and Kougianos, 2016).

2. 2. Improving air quality

Air pollution is a complex mixture of solid particles, liquid droplets, as well as gases. It can come from many sources, for example, household fuel burning, industrial chimneys, traffic exhausts, power generation, open burning of waste, agricultural practices, desert dust and many other sources.

The field of air quality improvement is the subject of various guidelines. Since 2011, WHO has been compiling and publishing ground measurements of air quality and, specifically, the annual mean concentrations of particles PM2.5 and PM10 (WHO, 2023). Under the European Green Deal's zero pollution action plan, the European Commission set the goal to reduce the number of premature deaths caused by PM2.5 by at least 55% by 2030, compared to 2005 (EEA, 2022). Additionally, in 2020, the European Commission initiated a revision of the ambient air quality directives, aiming to align the air quality standards more closely with the WHO recommendations. Besides this, the field of air quality improvement is also the subject of other research (Chen, 2022).

2. 3. Improving situational awareness

An important question in the field of smart cities is how to increase situational awareness. The issue of increasing situational awareness is fundamentally important for the field of natural disasters and catastrophes (Middleton, Middleton and Modafferi, 2014). Such a solution is a system that includes alarm detection during emergency events (Grašič & Mileva Boshkoska, 2018). The issue of a smart city is not only about a simple alarm system but also about intelligence, such as the issue of classifying incoming calls for a smart city (Grasic, Kos and Mileva-Boshkoska, 2018; Grašič, 2021).

However, the increase in situational awareness is not only limited to the area of control over natural disasters and catastrophes, which is the area of a safe city but is also relevant to the area of a smart environment, which includes environmental control and air quality. The issue includes both the establishment of the appropriate infrastructure (Popović, Radovanovic, Vajs, Drajic and Gligorić,

2022; UNEP, 2022) and the monitoring system itself (Malche, Maheshwary and Kumar, 2019). And finally, the topic is not only a technological challenge but also a question of how good air quality helps us improve the quality of our living (Enrico et al, 2023).

3. Approach to evaluation

3. 1. Air quality parameters

The main air pollutants include PM2.5 and PM10 (particles with an aerodynamic diameter of equal or less than 2.5 μm, and 10 μm respectively), ozone (O3), nitrogen dioxide (NO2), carbon monoxide (CO) and sulphur dioxide (SO2) (EEA, 2022; NIJZ, 2021; UNEP, 2022; WHO, 2023).

PM 2.5: Fine particulate matter (PM2.5) can penetrate through the lungs and further enter the body through the bloodstream, affecting all major organs. Exposure to PM2.5 can cause diseases both to our cardiovascular and respiratory system, provoking, for example, stroke, lung cancer and chronic obstructive pulmonary disease (COPD).

O3: Ozone at ground level is one of the major constituents of photochemical smog and it is formed through the reaction with gases in the presence of sunlight. It is bad for human health. Ozone pollution mostly occurs in the summer. Ozone exposure can affect the frequency of asthma, worsen the severity of the disease and the development of lung functions. It can also affect premature mortality. It is created when sunlight reacts with certain chemical emissions (for example nitrogen dioxide, carbon monoxide and methane). These chemicals can come from industrial facilities, car exhaust, gasoline vapours and other sources.

NO2: Nitrogen dioxide is a gas commonly released from fuel combustion in the transportation and industrial sectors. Nitrogen dioxide is a reddish-brown gas with a pungent, acrid odour. It is a natural byproduct of bacterial respiration, volcanos, and lightning. Chronic exposure to NO2 can cause respiratory effects. NO2 creates ozone.

CO: Carbon monoxide is a colourless, odourless and tasteless toxic gas produced by the incomplete combustion of carbonaceous fuels such as wood, petrol, charcoal, natural gas, and kerosene.

SO2: Sulphur dioxide is a colourless gas with a sharp odour. It is produced from the burning of fossil fuels (coal and oil) and the smelting of mineral ores that contain sulphur.

3. 2. Air quality evaluation methods

Various organizations have launched various initiatives to control air quality. Also on this basis, several criteria for checking air quality were created.

The World Health Organization's Air Quality Guidelines (AQG) serve as a global target for national, regional and city governments to work towards improving their citizen's health by reducing air pollution. The WHO Ambient Air Quality Database (WHO, 2023) compiles data on ground measurements of annual mean concentrations of pollutants.

In 2020, the European Commission initiated a revision of the ambient air quality directives, aiming to align the air quality standards more closely with the WHO recommendations (EEA, 2022). It also set the goal to reduce the number of premature deaths caused by PM2.5 by at least 55% by 2030, compared to 2005.

AQI (Air Quality Index) is the EPA's (U.S. Environmental Protection Agency) index for reporting air quality (AirNow, 2023). The AQI works like a thermometer that runs from 0 to 500 degrees. However, instead of showing changes in the temperature, the AQI is a way of showing changes in the amount of pollution in the air.

CAQI (Common Air Quality Index) is the air quality index used in Europe (EEA, 2023). CAQI has five ranges, with the values presented on a scale from 0 (very low) to 100 (very high). It is a relative measure of the amount of air pollution.

3. 3. Sensors and solutions for air quality control

Various sensors and air quality control systems were used for the purpose of air quality control evaluation.

Airly: Airly sensors (Airly, 2023) are small devices that measure the level of outdoor air pollution and key weather parameters. Airly API enables integration with applications and provides raw data for research and scientific papers on air pollution.

Varcities: Within the project Varcities (Varcities, 2023) for the city of Novo mesto sensors for air quality and key weather parameters have been provided.

Telekom: Telekom Slovenia (Telekom, 2023) provides solutions for air quality and key weather parameters.

Meteoblue: The solution of Meteoblue (Meteoblue, 2023) is a meteorological service created at the University of Basel, Switzerland. It is one of the most accurate global weather data, which combines over 40 weather models to get the most likely forecast.

AirNow: AirNow (AirNow, 2023) reports air quality using the official U.S. Air Quality Index (AQI), a colour-coded index designed to communicate whether air quality is healthy or unhealthy for you. It is in partnership with the U.S. Envi-

ronmental Protection Agency, National Oceanic and Atmospheric Administration (NOAA), National Park Service, NASA, Centres for Disease Control, and tribal, state, and local air quality agencies.

Windy: The solution of Windy (Windy, 2023) is one of the most popular and widely used meteorological services.

ARSO: This is a meteorological service (Meteo.si, 2023) covering the territory of Slovenia country.

IQAir: IQAir operates the world's largest free real-time air quality information platform (IQAir, 2023). It engages an ever-growing number of global citizens, organisations, and governments. Also, it collaborates with organisations like UNEP (United Nations Environmental Program) and Greenpeace. The solution combines global readings from validated air quality monitors in 6,475 locations in 117 countries, territories, and regions.

3. 4. Air quality in Slovenia

The analysis of pollution sources shows that it originates in Slovenia particle pollution mainly by road traffic, especially in heavily trafficked urban areas centres, in poorly ventilated basins the cause of pollution is also emissions from heating devices and industrial sources (NIJZ, 2021). It is estimated that when pollution would decrease, also mortality rates would be reduced - the number of premature deaths would decrease.

The city of Novo mesto joined the Varcities (Varcities, 2023) project, which deals with air and living quality. The project officially started in September 2020, and it will last until February 2025. The vision of Varcities is to implement nature-based actions in cities. It sets the ambitious target to advance innovation across different urban scales by fully exploiting nature-based solutions from a digital, social, and cultural perspective. Due to this, the city of Novo mesto has established a digital environment intended for monitoring air quality, microclimate parameters and the movement of people and traffic.

4. Evaluation of air quality

The evaluations are described below. In terms of time, the evaluations were made in the following terms:

- 23/07/2023 afternoon (between 15:00 and 17:00), which was the main term for the evaluation,
- One day, one week or one month before,
- At the end of June, when sand from the Sahara came over Slovenia.

4. 1. Evaluations of different approaches

An evaluation of different approaches is made. Table 1 shows this evaluation with maximum values allowed, where all the values are in μm. The WHO Air quality guidelines recommend levels and interim targets for all key air pollutants. For WHO recommended 2021 AQG levels compared to 2005 air quality guidelines are presented.

Table 1. Evaluation of the different approaches

Pollutant	Averaging Time	WHO 2005	WHO 2021	Slovenia
PM10	Annual	20	15	40
	24-hour	50	45	50
PM2.5	Annual	10	5	20
	24-hour	25	15	
O3	Peak season	-	60	
	8-hour	100	100	180 (1 hour) 120 (8 hours)
NO2	Annual	40	10	40
	24-hour	-	25	200 (1 hour)
SO2	24-hour	20	40	350 (1 hour) 125 (24 hours)
CO		-	4,000	10,000 (8 hours)

4. 2. Evaluation of sensors

An evaluation of sensors and solutions is made. Table 2 shows this evaluation. For each parameter, it is specified whether the sensor or solution supports it (+) or not (-).

Table 2. Evaluation of sensor possibilities

	ARSO	Airly	Varcities	Meteo blue	Windy	AirNow	IQAir
CAQI	+	+	+	+	-	-	-
AQI	-	-	-	-	+	+	+
PM10	+	+	+	+	+	+	+
PM2.5	+	+	+	+	+	+	+
SO2	+	+	-	+	+	+	-
NO2	+	+	+	+	+	+	+
O3	+	+	+	+	+	+	+
CO	+	+	-	+	+	+	+
API	+	+	-	+	+	+	+
Free Open Data	+	-	-	-	-	+	-
Forecast	-	-	-	yes	yes	yes	+
History	yes	1 day	yes	yes	-	yes	+
Support for the whole of Slovenia	+	+	-	+	+	-	+

4. 3. Evaluation for given city Novo mesto

In the case of the given city, sensors from Airly, Varcities (above the platform from Telekom Slovenia) and ARSO were used for evaluation.

Figure 1 shows the air quality at the end of June when sand from the Sahara came over Slovenia.

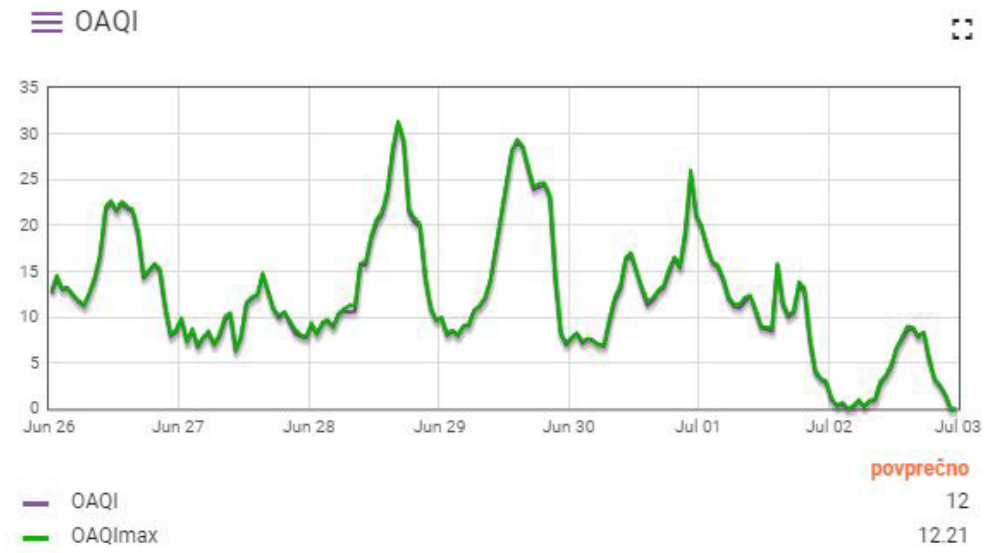


Figure 1. Air quality by Varcities sensors at the end of June

Figures 2 and 3 show air quality in two parking lots using sensors from the Varcities project.

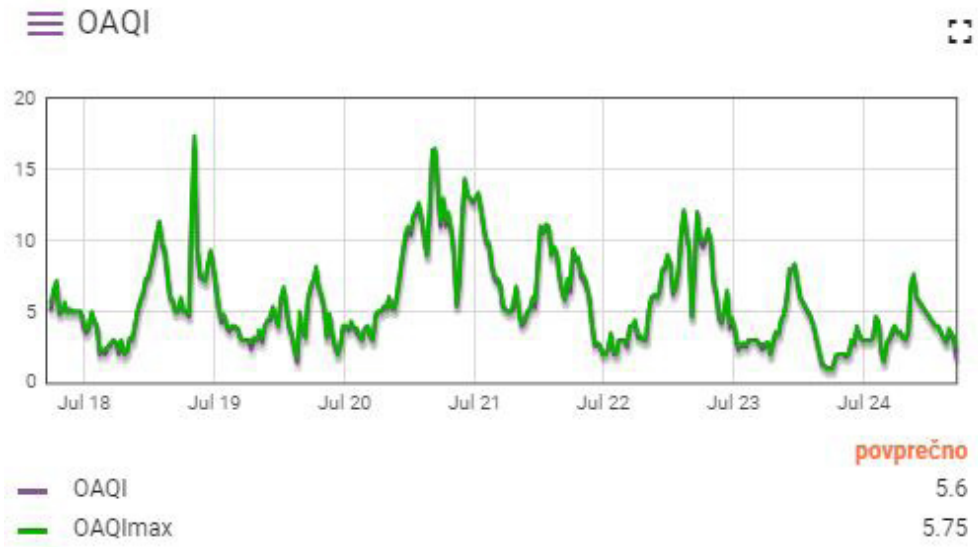


Figure 2. Air quality by Varcities sensors (parking place Musiceva)

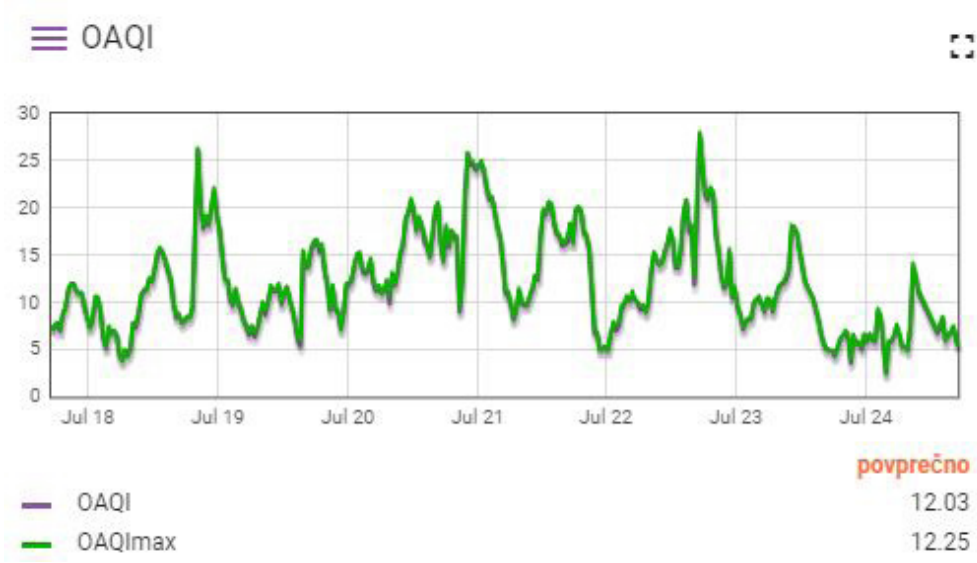


Figure 3. Air quality by Varcities sensors (parking place Valenticevo)

Figure 4 shows the air quality by ARSO sensors.

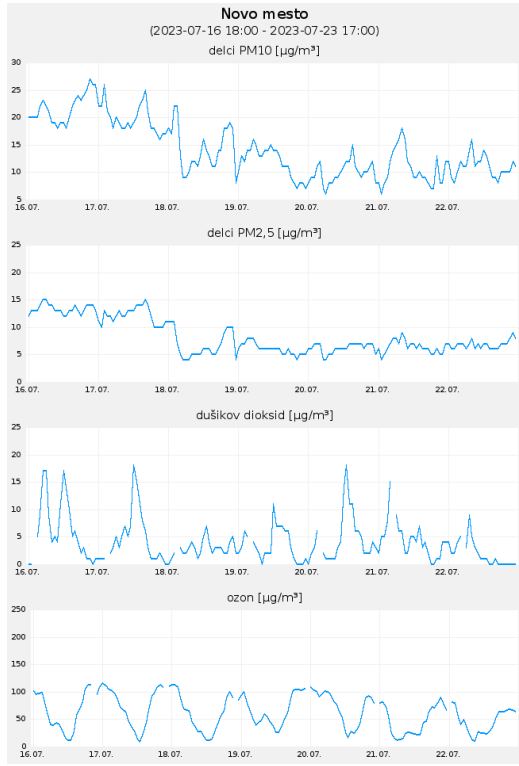


Figure 4. Air quality by ARSO

Figure 5 shows the air quality by Airly sensors.

Figure 5. Air quality by Airly sensors (for 23/07/2023 at 17.00)

4. 4. Evaluation of the whole of Slovenia

In the case of the whole of Slovenia, the evaluation is based on ARSO data, worldwide weather systems, Airly sensors, and small weather devices.

Figure 6 shows the air quality for the given day. It is from ARSO, and the air quality is divided into classes, as defined by CAQI.

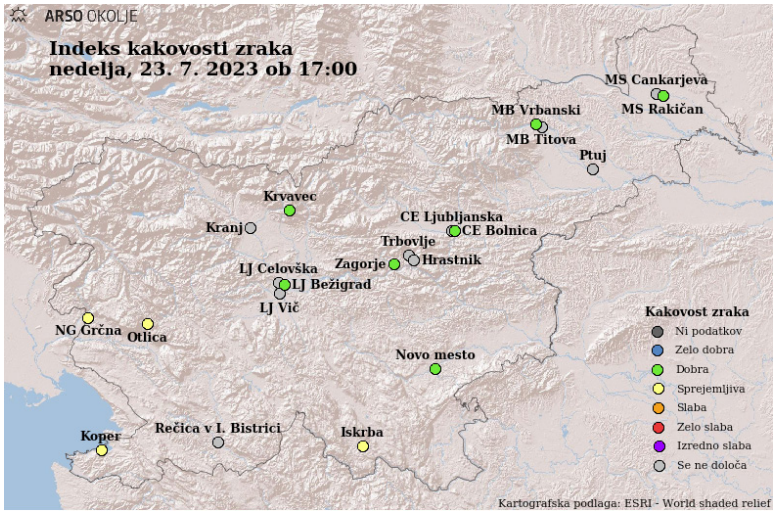


Figure 6. Air quality by ARSO defined as CAQI quality classes for a given day

Figure 7 shows the air quality for PM10 for a given day given by ARSO. These are not all measurements, but a model calculation. The Figure shows days data (top left), at 7 am (top right), at 12 am (bottom left) and 5 pm (bottom right).

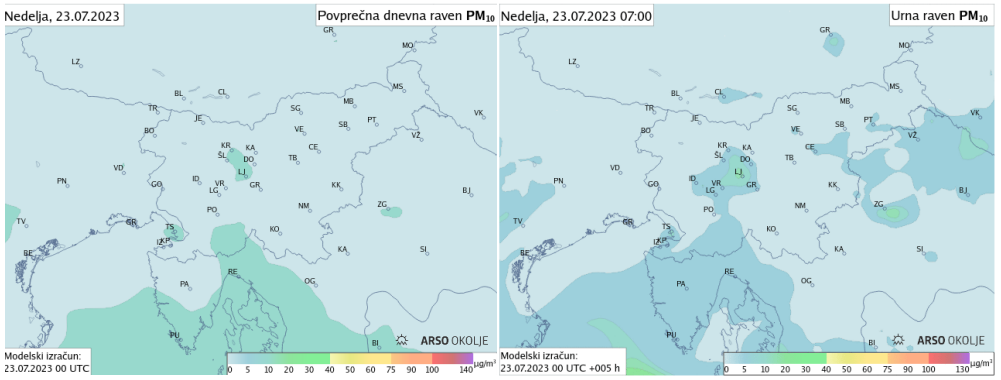


Figure 7. Air quality for PM10 given by ARSO for a given day

Figure 8 shows the air quality defined by Windy for a given time and day.

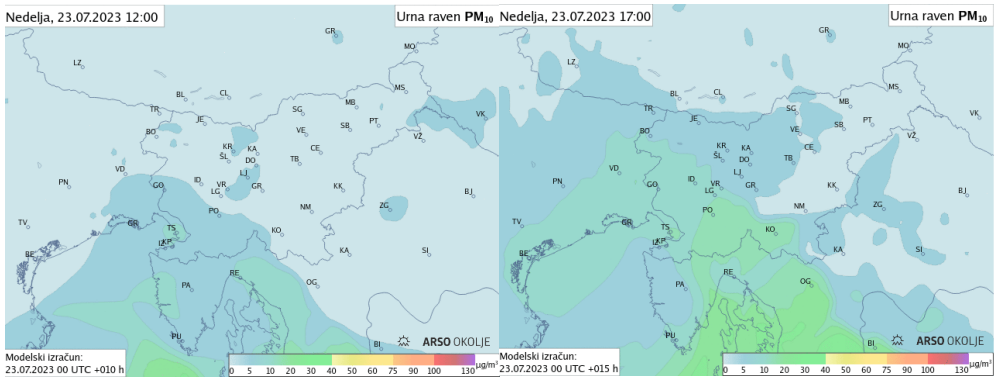


Figure 8. Air quality defined by Windy for a given time and day

Figure 9 shows the air quality for a given day given by Airly for Ljubljana. The Figure shows data at 7 pm for the previous day (top left), at 7 am (top right), at 12 am (bottom left) and at 5 pm (bottom right).

Figure 9. Air quality as defined by CAQI classes by Airly for a given day for Ljubljana

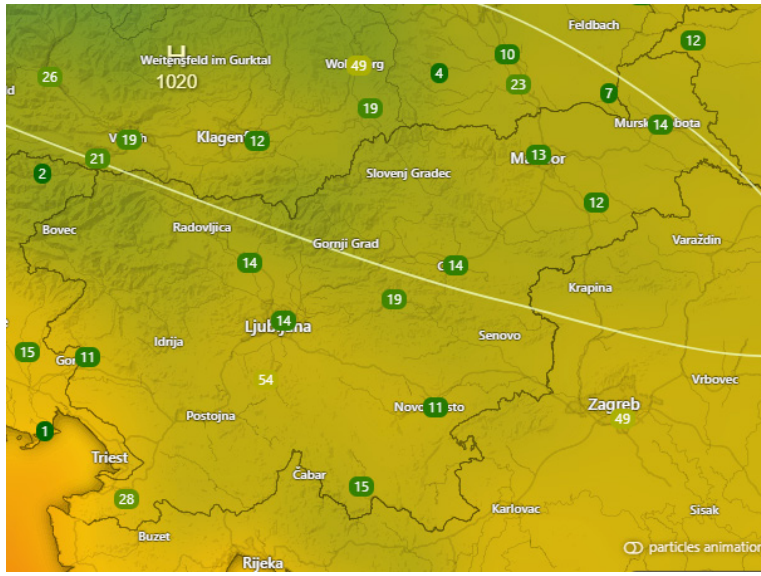


Table 3 shows data for Slovenia. It includes data that was freely available, both from ARSO, as well as from some small weather stations in Slovenia.

Table 3. Air quality data from sensors in Slovenia (23.7.2023 at 14.00 to 17.00)

	Velenje[1]	Tolmin[2]	Rakitna[3]	Hrvatini[4]	Novo mesto ARSO	Ljubljana ARSO	Limit value
PM10 now	8	4	12	10	12	15	50
PM10 24h		2	8		13	13	
PM2.5 now	0	3	12	5	9	9	
PM2.5 24 h		2	8		8	8	
CO					72	150	10.000
O3 now	90				67	112	180
O3 24 h						103	120
CO2						200	
NO2	4				1	4	200
SO2 now	6					21	350
SO2 24 h				+			125

2 Weather Velenje, https://www.velenje.si/o-velenju/spletna-kamera-in-vreme/
3 Weather Tolmin, https://www.vremetolmin.si/
4 Weather Rakitna, http://rakitna.zevs.si/weather27/
5 Weather Hrvatini, https://lukan.streznik.org//vreme/index.html

5. Discussion

The issue of air quality control is a very topical issue with many options. In addition, we learned the following:

Small weather stations are a welcome addition to the network of existing measuring sites.

From a sensor quality standpoint, three levels of sensor quality exist. These are professional (such as ARSO, or from Ljubljana city), very high-quality sensors (such as Airly, or smaller weather stations) which still have good quality, and then sensors for wide use.

From the point of view of pollution data, these can be divided into three groups: the main polluter, the key polluters and the wider range of parameters involved in pollution.

In Slovenia, for the observed period, the high level of ozone turned out to be a big problem. However, this was not highlighted well enough.

There is some confusion when it comes to monitoring air quality, as the guidelines are different, for example between the US (AQI) and Europe (CAQI), and the values also change over time (like WHO values).

From a UX standpoint, the best approach is from AirNow (only available in the US).

If we went to real-time monitoring, then it would be necessary to make some more changes in the direction of UX. From the point of view of the end user, only he gets certain information. For example, in the direction of clearly defining what the pollution is in the micro-location, what are the dangers in a wider area (like ozone in Slovenia), what is the main cause and what are the forecasts (like AirNow).

A great challenge for the future would also be to show the value of a certain micro-location, considering data from different sources of systems and sensors.

6. Conclusion

The development of smart cities consists of several sub-fields and is conditioned by an ever-increasing number of sensors and IoT devices. In the paper, we looked at the evaluation of air quality control. Pollutants tied to human and environmental health impacts include PM2.5, PM10, ground-level ozone, nitrogen dioxide and sulphur dioxide.

The focus of the evaluation was on one of the Slovenian cities, while simultaneously comparing it with control in the whole of Slovenia. We have evaluated the difference between the sensors, what this means for the air quality measurement itself, what is with the openness of the data, and how is the connection of the data from these different sensors.

Based on all this data, we can better approach observation, monitoring and increase situational awareness even for certain micro-location. The given research with the analysis and comparison of different segments of air quality sensors will help us in preparing a comprehensive approach to the control and management of air quality and, consequently, to the development of smart cities.

References

1. Airly (2023). Airly. Available at: https://airly.org/. Accessed: 20/07/2023.
2. AirNow (2023). AirNow. Available at: https://www.airnow.gov/. Accessed: 20/07/2023.
3. Chen, G. (2022). Investigation of Organic Aerosol Sources across Europe using Novel Source Apportionment Techniques. Doctoral Thesis. ETH Zurich. Available at: https://doi.org/10.3929/ethz-b-000575526. Accessed: 20/07/2023.
4. Department for Business innovation & Skills. (2013). Global Innovators: International Case Studies on Smart Cities Smart Cities Study (Bis research paper no. 135). Available at: https://www.gov.uk/government/publications/smart-cities-international-case-studies-global-innovators. Accessed: 05/07/2019.
5. EEA (2022). Air quality in Europe - 2022. EEA Report No. 05/2022. Available at: https://www.eea.europa.eu/publications/air-quality-in-europe-2022/. Accessed: 20/07/2023.
6. EEA (2023). European Air Quality Index. Available at: https://airindex.eea.europa.eu/Map/AQI/Viewer/. Accessed: 20/07/2023.
7. European Commission (2019). Smart Cities - Smart Living. Shaping Europe's digital future. Available at: https://ec.europa.eu/digital-single-market/en/smart-cities. Accessed: 07/07/2019.
8. Grasic, V., Kos, A. & Mileva-Boshkoska, B. (2018). Classification of incoming calls for the capital city of Slovenia smart city 112 public safety system using open Internet of Things data. International Journal of Distributed Sensor Networks. 14(9). Available at: https://journals.sagepub.com/doi/full/10.1177/1550147718801703. Accessed: 05/08/2022.
9. Grašič, V. & Mileva Boshkoska, B. (2018). Public safety system with alarm triggering based on J48 decision trees classification. Zbornik radova. Prva međunarodna naučna konferencija o digitalnoj ekonomiji DIEC 2018. 1. pp. 115–125. Available at: http://ipi-akademija.ba/file/zbornik-diec-2018/43. Accessed: 05/08/2022.
10. Grašič, V. (2021). Napovedovanje števila dohodnih klicev na sistem za klic v sili 112 ob uporabi odprtih podatkov interneta stvari. Faculty of Information Studies (FIS) in Novo mesto. Doctoral thesis. Available at: http://revis.openscience.si/IzpisGradiva.php?id=7758&lang=slv&prip=dkum:12580869:d4. Accessed: 05/08/2022.
11. IQAir (2023). IQAir. Available at: https://www.iqair.com/. Accessed: 20/07/2023.
12. Malche, T., Maheshwary, P. & Kumar, R. (2019). Environmental Monitoring System for Smart City Based on Secure Internet of Things (IoT) Architecture. Wireless Personal Communications. 107. pp. 2143–2172. Available at: https://doi.org/10.1007/s11277-019-06376-0. Accessed: 20/07/2023.
13. Meteo.si (2023). Slovenian Environmental Agency. Available at: https://meteo.arso.gov.si. Accessed: 24/07/2022.
14. Meteoblue (2023). Meteoblue. Available at: https://www.meteoblue.com/. Accessed: 20/07/2023.

15. Middleton, S. E., Middleton, L. and Modafferi, S. (2014). Real-time crisis mapping of natural disasters using social media. IEEE Intelligent Systems. 29(2). pp. 9–17. doi: 10.1109/MIS.2013.126.

16. Mohanty, S. P., Choppali, U. and Kougianos, E. (2016). Everything you wanted to know about smart cities: The Internet of things is the backbone. IEEE Consumer Electronics Magazine. 5(3). pp. 60–70. Available at: https://doi.org/10.1109/MCE.2016.2556879. Accessed: 05/07/2019.

17. NIJZ (2021). Ocena vpliva onesnaženosti zraka z delci PM2.5 na umrljivost v krajih s prekomerno onesnaženim zrakom Opazovalno obdobje za oceno: 017 -2019. NIJZ. Available at: https://nijz.si/wp-content/uploads/2021/02/porocilo_pm_2017-2019.pdf. Accessed: 20/07/2023.

18. Popović, I., Radovanovic, I., Vajs, I., Drajic, D. & Gligorić, N. (2022). Building Low-Cost Sensing Infrastructure for Air Quality Monitoring in Urban Areas Based on Fog Computing. Sensors. 22(3):1026. Available at: https://doi.org/10.3390/s22031026. Accessed: 20/07/2023.

19. Sella, E., Meneghetti, C., Muffato, V., Borella, E., Carbone, E., Cavalli, R., Pazzaglia, F. (2023). The influence of individual characteristics on perceived restorativeness and benefits associated with exposure to nature in a garden. Frontiers in Psychology. 14. Available at: https://www.frontiersin.org/articles/10.3389/fpsyg.2023.1130915. Accessed: 20/07/2023.

20. Telekom (2023). Telekom Slovenia. Available at: https://www.telekom.si/. Accessed: 20/07/2023.

21. UNEP (2022). How is air quality measured? Available at: https://www.unep.org/news-and-stories/story/how-air-quality-measured. Accessed: 20/07/2023.

22. Varcities (2023). Varcities. Available at: https://varcities.eu/. Accessed: 20/07/2023.

23. WHO (2023). WHO ambient air quality database, Update 2023, 6th edition (V6.0). Available at: https://www.who.int/data/gho/data/themes/air-pollution/who-air-quality-database. Accessed: 20/07/2023.

24. Windy (2023). Windy. Available at: https://www.windy.com/. Accessed: 20/07/2023.

Selena Kurtić ME[1]
Mustafa Bešić, MSS[2]

Preliminary communication

REVIEWING STUDENT PROJECTS USING AI

Abstract

The rise of artificial intelligence (AI) has impacted various domains, including education, where the need for efficient assessment methods has grown. This paper explores the application of AI in reviewing student projects, examining its benefits, challenges, and implications for education. The objectives of this paper are twofold. Firstly, we will delve into the various AI techniques employed in the reviewing process, including natural language processing (NLP), machine learning, and computer vision. We will explore how these technologies enable the analysis of textual, visual, and multimedia elements present in student projects, facilitating more comprehensive and insightful assessments. Secondly, we will discuss the implications and considerations surrounding the adoption of AI in education, including concerns related to privacy, ethics, and the role of professors in the AI-assisted review process. This paper further aims to shed light on the challenges and limitations of implementing AI-based review systems, highlighting the need for careful validation, data quality assurance, and interpretability of results. Additionally, we will examine the potential benefits for students, instructors, and educational institutions, such as improved feedback delivery, increased consistency in evaluations, and enhanced learning outcomes. By exploring the use of AI in reviewing student projects, we hope to contribute to the ongoing discussion on leveraging technology to enhance educational practices and to provide insights into the potential future directions of AI-assisted assessment methods.

Key words: *ChatGPT, Student Projects, NLP, Machine Learning, Computer Vision.*

1 Master of Engineering Informatics, Internacionalna poslovno-informaciona akademija Tuzla, selena.kurtic@yahoo.com
2 Master of Social Science Informatics, Internacionalna poslovno-informaciona akademija Tuzla, besic.mustafa@yahoo.com

1. Introduction

In recent years, the emergence of artificial intelligence (AI) has revolutionized various domains, including education. One notable area of interest is the application of AI in reviewing student projects. This paper delves into the use of AI techniques to enhance the evaluation process of student projects, exploring the benefits, challenges, and implications associated with this approach.

Traditionally, the reviewing and assessment of student projects have been labor-intensive and subject to potential biases. However, the advent of AI technologies offers promising opportunities to streamline and improve this process. By leveraging AI algorithms and computational tools, instructors can assess student projects more efficiently and objectively, while providing valuable feedback tailored to individual students.

One of the key advantages of employing AI in the reviewing process is its ability to handle large volumes of student work. AI algorithms can quickly analyze and process diverse project types, such as written reports, multimedia presentations, and coding assignments. This scalability allows instructors to provide timely feedback and assessments, fostering a more productive and engaging learning environment.

Moreover, AI techniques enable a more objective evaluation process. By utilizing machine learning and natural language processing, AI algorithms can analyze the content, structure, and quality of student projects, reducing the potential for subjective biases. This objectivity ensures a fair and consistent assessment for all students (Dimitrova, Mizoguchi and B. du Boulay, 2009).

However, the implementation of AI in reviewing student projects also poses challenges and considerations. Privacy concerns surrounding student data and the ethical implications of automated assessments need careful attention (Carolyn Penstein Rosé et al., 2018). In addition, striking the right balance between AI-driven evaluation and human involvement is crucial to maintain the educational value of instructor-student interactions.

This paper aims to explore the various AI techniques employed in the reviewing of student projects, including natural language processing, machine learning, and computer vision. It will examine case studies and research findings that showcase the effectiveness of AI-based evaluation systems. Furthermore, the paper will address the potential limitations and considerations of using AI in this context, emphasizing the importance of striking a balance between technology and pedagogy(Carolyn Penstein Rosé et al., 2018).

Ultimately, this research contributes to the ongoing dialogue on leveraging AI technologies in education. By shedding light on the benefits, challenges, and ethical considerations of reviewing student projects using AI, this paper aims to inform educators, policymakers, and researchers about the potential of AI-driven evaluation methods to enhance the learning experience and promote academic growth.

1. 1. Exposition

The education system has long relied on instructors manually reviewing and assessing student projects, a process that is time-consuming, subjective, and susceptible to human biases. However, recent advancements in artificial intelligence (AI) have opened up new possibilities for enhancing the evaluation of student work. AI technologies, such as machine learning, natural language processing, and computer vision, offer the potential to automate and improve the reviewing process.

The exposition of this paper focuses on the use of AI in reviewing student projects, highlighting its advantages over traditional manual methods. By leveraging AI algorithms, instructors can overcome the limitations of manual review, such as scalability, subjectivity, and timeliness (Morteza Dehghani and Boyd, 2022). AI-powered systems have the capacity to handle large volumes of student work efficiently, ensuring timely feedback and assessment. Furthermore, AI techniques enable more objective evaluations, reducing the impact of subjective biases in the assessment process.

The potential benefits of employing AI in the reviewing process extend beyond efficiency and objectivity. AI algorithms can analyze different types of student projects, ranging from written reports to multimedia presentations and coding assignments. This versatility allows for a comprehensive evaluation of various project aspects, including content quality, organization, creativity, and technical proficiency. With AI, instructors can provide more detailed and tailored feedback to individual students, promoting their learning and growth.

However, using AI in reviewing student projects is not without challenges. Privacy concerns and ethical considerations arise when handling student data and automating assessments (Dimitrova, Mizoguchi and B. du Boulay, 2009). Striking the right balance between AI-driven evaluation and human involvement is crucial to ensure the educational value of instructor-student interactions. The exposition explores these challenges and considerations, emphasizing the need for responsible implementation and continuous evaluation of AI systems.

By exploring the potential of AI in reviewing student projects, this paper aims to contribute to the growing body of knowledge surrounding AI's role in education. It sets the stage for a deeper examination of the AI techniques employed, their effectiveness, and the implications for both educators and students. Furthermore, it calls for thoughtful and responsible integration of AI technologies in educational practices to enhance the evaluation process and promote meaningful learning experiences.

2. Education and AI

The use of artificial intelligence in education represents a new challenge that has experienced its expansion precisely with the emergence of the ChatGPT

tool, which is a creation of the company OpenAI. The public had its first direct contact with artificial intelligence through the use of the ChatGPT tool.

Today, with the rapid development of technology and the rapid advancement of artificial intelligence, and with the focus of all industries being precisely on artificial intelligence, the question arises about the quality and moral principles in education. Artificial intelligence has significantly changed the way specific knowledge is acquired. Previously, researchers had to spend a significant amount of time cycles to confirm or refute certain scientific evidence, while today, through the use of artificial intelligence, the time required for analysis, study, and drawing conclusions on a particular issue has been greatly reduced. AI has advanced to the extent that it can now analyze learning patterns of individuals and groups, their interests, specific knowledge, and weaknesses. Based on the conducted analysis, AI can create new patterns to isolate certain knowledge or enhance it, depending on the set goal.

Through its development, AI can tailor specific knowledge to each student and focus on the individual's growth within the group. Personalized learning towards each individual increases motivation and reduces the gap among students attending a particular subject.

The use of AI in education doesn't have to be direct; we also have an indirect application where, by utilizing AI tools, we can enable the development of an educational plan and program that aligns with each student's interests, knowledge, and more. AI tools can assist students in solving tasks and explain to them, in simple terms, the procedures that happen behind the scenes of solving a task. Students can verify information during the course of the educational process using AI tools, gather literature, search sources, check citations, highlight key parts, explore certain questions, and so on (Aminzadeh, Cenk Temizel and Yasin Hajizadeh, 2022).

With the emergence of AI, questions of morality and ethics arise. It is necessary to properly prepare AI tools so that they find their place in education in an ethical manner, preventing students from misusing AI to create content and presenting it as their own, thus violating all ethical codes in the world of education. In addition to ethical principles, there are principles of transparency, accountability, personal data protection, and more. There are numerous challenges that need to be addressed first before AI can officially start being used in educational institutions; currently, all tools are still in the preparation phase.

3. Description of the Research

The research is designed in such a way that through the analysis of completed project tasks and submitted samples, a verification, evaluation, and grading of project tasks are performed. In this example, students are required to submit a project task written in the C++ programming language. The task description involves creating a terminal application through which they will navigate using menu commands numbered from 1 to n. The application is designed to

include features such as display, addition, deletion, and other arbitrary actions by students. Students worked on project tasks in groups.

In this research project, we have three samples that we will test and on which we will perform an analysis and evaluation of the submitted project task.

3. 1. Research Objective

The main goal of the research is to utilize the methods and techniques currently at our disposal to attempt to determine the extent to which the analyzed project task has been completed using artificial intelligence and, if possible, present this in percentages or numerical values ranging from 1 to 10.

3. 2. Criterion and Description of the Criterion

Artificial intelligence is constantly evolving, making it very challenging to keep track and provide a definitive judgment on whether a piece of source code has been written by artificial intelligence or is the personal work of an author. Currently, there are several parameters that can reveal whether a code has been written using AI, but it is necessary to thoroughly examine everything and evaluate each part separately.

Criteria for Analysis are:

- Unusual patterns and styles,
- Lack of consistency,
- Changes in code writing style,
- Use of rare functionalities,
- Simple tasks,
- Combination of multiple languages or algorithms.

Description of the mentioned criteria:

1) Unusual patterns and styles, in this aspect, it is easiest to recognize whether a code has been written using artificial intelligence. The structure and style may vary several times within a single project; this is crucial considering that students are expected to work independently on project tasks. The complexity of their code can be at a low or medium level.
2) Lack of consistency, AI can sometimes create code that lacks consistency in writing style and structure, which may indicate code generation.
3) Sudden changes in style, if abrupt changes in code writing style are identified, there may be suspicion of AI involvement.
4) Use of rare functionalities, a generator may employ functionalities or concepts that were recently introduced to the programming language or are present in a newer version of the programming language.

5) Simple tasks, AI excels at performing simple tasks successfully, so the use of artificial intelligence might be suspected on repetitive simple tasks.

6) Combination of multiple languages or algorithms, if a combination of different programming languages and algorithms not typically associated is observed, it could be a clear sign of AI generation.

3. 3. Criterion assessment

Criterion assessment is presented using a Likert scale ranging from 1 to 5, where a score of 1 represents the lowest-rated criterion, while a score of 5 represents the highest-rated criterion. The following table displays the criterion ratings.

Table 1. Criterion Assessment Score

Value	Description
1	It doesn't matter at all
2	It doesn't matter
3	Neither important nor unimportant
4	It matters
5	It matters a lot

The next table presents the evaluation of each criterion separately and determines its significance for recognizing AI-generated code.

Table 2. Display of Criterion Assessment

Criterion	Rating
Unusual patterns and styles	5
Lack of consistency	4
Changes in code writing style	5
Use of rare functionalities	3
Simple tasks	3
Combination of multiple languages or algorithms	5

3. 4. Sample Testing and Assessment

Currently, 2 samples have been selected for research purposes. All samples have been generated as results of a student project task, where they were required to create a terminal library application using the C++ programming language. The application should include features such as reading, deleting, adding, and more. The fundamental data storage methods are vectors and .txt files.

First Sample

The group consists of four students who have developed an application in the C++ programming language. All criteria required by the project documentation have been successfully fulfilled, and the application contains all necessary features. The alternative rating is defined using numbers from 1 to 10, where 1 represents the lowest score and 10 represents the highest score. Rating 1 indicates a high probability that artificial intelligence was used in project development, while rating 10 indicates a high probability that the project was done independently by students.

Criterion 1. Unusual Patterns and Styles

In the first sample, a part of the code was noticed that is used at an intermediate level of programming. Students encountering programming in their first years of study usually employ if-else conditions to check certain possibilities. In this example, we observe that students used a while loop with a condition that must be fulfilled.

Proof:

```
void setJMBG (string JMBGulaz)
  {
    while(JMBGulaz.size()!= 13)
 {
       cout<<”Pogresan unos, pokusajte ponovo: “<<endl;
       cin>>JMBGulaz;
    }
    JMBG = JMBGulaz;
  }
```

Grade: 3 (Three)

Criterion 2. Lack of Consistency

Lack of consistency has not been noted; there are minor differences, but it's taken into consideration that the project task was done by multiple students.

Grade: 7 (Seven)

Criterion 3. Changes in Code Writing Style

Changes in code writing style have been documented in the work, particularly noticeable in classes. Students used a different syntax and comments in the classes, while in the main method, they did not include comments nor maintained proper and consistent spacing between lines.

Proof:

```
// Main
string nule = "000";
cout<<" Posudjena knjiga : " + posudjenaKnjiga;
cout<<", Kategorija clanstva: " + kategorijaClanstva<<endl;

// Klasa
int brojSvihDodatihKnjiga=0;
#endif // KLASEVEKTORI_H_INCLUDED
```

Grade: 2 (Two)

Criterion 4. Use of Rare Functionalities

In this work, the use of rare functionalities has not been observed. There are a few anomalies, but they can be attributed to exploration on some of the platforms where developers share their code with the broader community of programmers.

Grade: 8 (Eight)

Criterion 5. Simple Tasks

Repetitive simple tasks have not been found, but we do have a few simple tasks that, due to their logic and syntax, raise suspicion that this portion of the code was generated using AI. Students used 'void' for printing surnames, which differs from other project tasks where students attempted to incorporate as much code as possible into if-else conditions or loops.

Proof:

```
 void printPrezime ()
 {cout<<prezime<<endl;}
```

Grade: 5 (Five)

Criterion 6. Combination of Multiple Languages or Algorithms

The combination of multiple programming languages and algorithms in this project task has not been identified.

Grade: 9 (Nine)

Second Sample

The group consists of four students who have developed an application in the C++ programming language. All criteria required by the project documentation are fulfilled, containing all necessary conditions for the work to be evaluated. The alternative grade is defined numerically from 1 to 10, where a grade of 1 represents the highest likelihood that the work is plagiarism or that artificial intelligence was used in completing the project task.

Criterion 1. Unusual Patterns and Styles

Unusual styles have been noted during the creation of the main.cpp file. The students' knowledge is limited to specific areas, so the appearance of these instances can be considered an unusual style.

Proof:

```
 void ukloniKnjigu(Biblioteka& biblioteka, string naslov) {
   biblioteka.ukloniKnjigu(naslov);
 }
```

Grade: 3 (Three)

Criterion 2. Lack of Consistency

A lack of consistency has not been observed in the mentioned project. There are certain exceptions, but they are not worth recording and analyzing.

Grade: 8 (Eight)

Criterion 3. Changes in Code Writing Style

Changes in code writing style are noticed in the main.cpp file, which contains certain anomalies in code writing. Based on the examples, there is a suspicion that artificial intelligence was used in the development of the mentioned methods.

Proof:

```
 // case 1
string naslov; getline(cin, naslov);

// case 2

cin >> police; cin.ignore();
```

Grade: 4 (Four)

Criterion 4. Use of Rare Functionalities

The use of rare functionalities is also present in the previous criterion, where students used the '*cin. ignore();*' part of the code, which is rarely used in academic studies at the fundamentals of programming or intermediate level.

Grade: 3 (Three)

Criterion 5. Simple Tasks

Simple tasks present in this project assignment have not been recognized as parts of artificial intelligence, as everything is already determined according to the syllabus.

Grade: 9 (Nine)

Criterion 6. Combination of Multiple Languages or Algorithms

The combination of multiple languages has not been recorded. Changes in algorithms are documented, particularly in the part where the input values in string form are controlled.

Proof:

```
if (knjige.size() == 0)
if (knjiga.naslov == "")
```

Grade: 3 (Three)

3. 5. Research Results

In the following table, the research results are presented with methods and alternative calculations.

Tabel 3. View ratings

Criterion	Criterion assessment	Sample 1	Sample 2
Unusual Patterns and Styles	5	3	3
Lack of Consistency	4	7	8
Changes in Code Writing Style	5	2	4
Use of Rare Functionalities	3	8	3
Simple Tasks	3	5	9
Combination of Multiple Languages or Algorithms	5	9	3

Calculation of the First Sample:

$$5(3)+4(7)+5(2)+3(8)+3(5)+5(9) = \mathbf{137}$$

Calculation of the Second Sample:

$$5(3)+4(8)+5(4)+3(3)+3(9)+5(3) = \mathbf{118}$$

In the research results using the Scoring method, we can observe that the second sample has a high likelihood of plagiarism based on the specified and defined evaluation criteria. The second part includes verification using AI tools to check the generated code. If the results align with the research findings, it can be concluded that AI verification tools perform their task successfully.

Testing AI Tools

All tools used are free and enable verification of text, images, or code if there are elements of artificial intelligence in their creation. The first tool is *content-detector.ai*. After inputting the samples into the testing application, the following results were obtained:

The first sample (AI generated at a rate of 50%),

The second sample (AI generated at a rate of 77%).

The second tool for verification is *copyleaks.com*, which returned the following results based on the samples:

The first sample (AI generated at a rate of 46%),

The second sample (AI generated at a rate of 71%).

The research results show a correlation between the data obtained from the manual evaluation of criteria and verification using AI tools. It is important to note that currently, we do not have tools that can definitively confirm whether a document, image, or code is 100% generated using AI. There are some possibilities that companies could add a hidden signature to their AI generators, which could be identified after a user copies or downloads the content.

4. Conclusion

In conclusion, the use of artificial intelligence (AI) in reviewing student projects presents significant opportunities for improving the evaluation process in education. The advancements in AI technologies, such as natural language processing, machine learning, and computer vision, have the potential to enhance scalability, objectivity, and efficiency in assessing student work.

By automating and augmenting the reviewing process with AI, instructors can provide timely and comprehensive feedback to students, fostering a more engaging and personalized learning experience. The objectivity of AI algorithms helps mitigate subjective biases, ensuring fair and consistent evaluations for

all students. Furthermore, AI techniques can analyse diverse project types and provide insights into content quality, organization, creativity, and technical proficiency.

However, the adoption of AI in reviewing student projects comes with its own set of challenges and considerations. Privacy concerns regarding student data and ethical implications surrounding automated assessments need to be carefully addressed. Additionally, maintaining a balance between AI-driven evaluation and human involvement is essential to preserve the pedagogical aspects of education.

Moving forward, it is crucial to conduct further research, validation, and refinement of AI systems for reviewing student projects. The responsible integration of AI technologies in educational practices requires ongoing evaluation, ethical guidelines, and professional development for educators. Collaboration between researchers, educators, and policymakers is necessary to address these challenges and harness the full potential of AI in improving the evaluation process.

By embracing the benefits of AI and addressing the associated challenges, educational institutions can unlock new possibilities for enhancing the assessment of student projects. The future of reviewing student work using AI holds promise for providing more effective and personalized feedback, promoting student growth, and facilitating continuous improvement in education.

In summary, the integration of AI in reviewing student projects represents a transformative shift in the evaluation process. Leveraging AI techniques offers opportunities to overcome the limitations of manual assessment, enhance objectivity, and provide meaningful feedback to students. As we navigate the evolving landscape of educational technology, the responsible and thoughtful adoption of AI has the potential to revolutionize the way we evaluate student work, fostering a more engaging and effective learning environment.

References

1. Aminzadeh, F., Temizel, C., & Hajizadeh, Y. (2022). *Artificial Intelligence and Data Analytics for Energy Exploration and Production*. John Wiley & Sons.
2. Cambria, E., White, B. (2019). *Artificial Intelligence in Education: Promises and Implications for Teaching and Learning*. United States.
3. contentdetector.ai. AI Content Detector - Detect ChatGPT Plagiarism. https://contentdetector.ai (01.08.2023).
4. copyleaks.com. Copyleaks: AI & Machine Learning Powered Plagiarism Checker. https://copyleaks.com (01.08.2023).
5. Dehghani, M., & Boyd, R. L. (Eds.). (2022). *Handbook of language analysis in psychology*. Guilford Publications.
6. Dimitrova, V., Mizoguchi, R., & du Boulay, B. (Eds.). (2009). *Artificial Intelligence in Education: Building Learning Systems that Care: From Knowledge Representation to Affective Modelling* (Vol. 200). IOS Press.

7. Maybury, M. T. (1998). *Intelligent Tutoring Systems: Lessons Learned*. United States.

8. McNamara, D. S., Graesser, A. C., McCarthy, P. M., & Cai, Z. (2014). *Automated evaluation of text and discourse with Coh-Metrix*. Cambridge University Press.

9. Nkambou, R., Mizoguchi, R., and Bourdeau, J. (2010). *Artificial Intelligence in Education*. United States.

10. Romero, C., Ventura, S., Pechenizkiy, M., & Baker, R. S. (Eds.). (2010). *Handbook of educational data mining*. CRC press.

11. Rosé, C.P., Martínez-Maldonado, R., Hoppe, H.U., Luckin, R., Mavrikis, M., Porayska-Pomsta, K., McLaren, B. and Du Boulay, B. eds., (2018). *Artificial Intelligence in Education: 19th International Conference, AIED 2018, London, UK, June 27–30, 2018, Proceedings, Part I* (Vol. 10947). Springer.

Prof. dr. Hadžib Salkić[1]
Mr. sc. Marija Kvasina[2]
Dr. sc. Almira Salkić[3]
Mr. Sc. Aldijana Omerović[4]

Original scientific paper

MULTIMEDIA INFORMATION SYSTEMS IN CLASS

Abstract

The success of information systems in class, or multimedia, depends on teachers so their attitude on the use of technology in class has a very important role in accepting and real use of it. They are the key factor in acceptance of multimedia as a teaching tool. So, the subject of this research is teachers` attitude on multimedia tools in class. The goal is to find out if teachers believe that multimedia has a positive impact on class content, the result of teaching, the knowledge of the students, and teachers` efficiency. The research was done online in the Central Bosnia Canton area and all the teachers in elementary schools took part in it. The result shows that teachers` opinions are that multimedia has a positive impact on the results of teaching, class content, and teachers` efficiency and that there is a correlation between maximizing students` knowledge and teachers` skills. The general opinion on the use of multimedia is positive, but with improved conditions, their usage would be even higher.

Key words: *Teachers, Information System, Multimedia, Students.*

1. Introduction

We have been witnessing an unseen growth of multimedia data in digital form. It is easy for a user of a personal computer or mobile phone to create multimedia content thanks to relatively cheap and available hardware. Efficient and long-term data storage is possible thanks to magnetic and optical media but also thanks to developed algorithms for compression. Computer networks with growing permeable power thanks to efficient algorithms for digital processing of signals and protocols that manage the flow of data through communication channels are in charge of the transition of data.

1 Visoka škola „CEPS-centar za poslovne studije“, Josipa bana Jelačića 18, Kiseljak, hadzib.salkic0911@gmail.com
2 Sveučilište „Vitez“, Školska 23, Travnik, marijasantic0@gmail.com
3 Visokoškolska ustanova Visoka škola za financije i računovodstvo FINra Tuzla, almira.salkic@hotmail.com
4 Visokoškolska ustanova Visoka škola za financije i računovodstvo FINra Tuzla, aldijana.finra@gmail.com

The expansion of multimedia content is also helped by standard formats which help transition of data between different hardware platforms and operational systems. Probably, the most obvious example in which all the mentioned factors work together is the web. So, we can say that there is a trend of comprehensive entry of multimedia data in today's computer science. And even though multimedia is very present in today's life and multimedia content is rising, we cannot certainly define multimedia. One of the reasons is that multimedia can be defined differently in different aspects of life. So, for an artist, a teacher, a hardware or a software programmer multimedia will mean different things. In this work we were focused on multimedia in class. We carried out a survey in Central Bosnia Canton and analyzed teachers' attitudes on the impact of multimedia on teaching, class content, students' knowledge, and the effectiveness of teachers.

1. 1. Problem, subject, and object of the research

The fact is that in BiH there is a lack of innovative ways of teaching, so the problem of this research can be defined as insufficient use of information systems in teaching process. The success of using information systems, or multimedia, depends on teachers. Their attitude towards the use of technology in class can play a big role in accepting its usage. So, there is the subject of this research, to investigate teachers' attitudes towards the usage of multimedia tools. The object of research – teachers, multimedia, class.

1. 2. Working hypothesis and backup hypothesis

Based on the problem, subject, and object of the research, we make the following hypothesis:

WH – Use of multimedia tools has a positive impact on students in elementary school, compared with the use of traditional tools.

BH1 – Use of multimedia tools has a positive impact on teachers.

BH2 – There is a strong correlation between the improvement of students' knowledge and the skill growth of elementary school teachers.

1. 3. Purpose and the goal of the research

The main goal of this research is to explore and establish teachers' attitudes towards the use of multimedia in class. We will explore if teachers think that the use of multimedia has a positive impact on class content, teaching process, students' knowledge, and teachers' efficiency. Besides that, we will explore which software teachers use most commonly.

1. 4. Scientific methods

Scientific methods appropriate for the subject of the research, established methods, and the goal of the research will be used in this work:

- The inductive method supports inductive ways of conclusion in which based on individual or special facts one can conclude the general cause.
- The mathematical method used for the calculation of the percentage of results.
- Proofing method which will determine the accuracy of improving the teaching process.
- Statistic method which will numerically show the attitudes of teachers on stated statements.

2. Multimedia learning system

A Multimedia system is a system that integrates multimedia content and applications. This system can generate, process, memorize, exchange, manipulate, and show or reproduce multimedia content and control multimedia applications. Multimedia system includes multiple types of content which are independent but integrated within the system. Considering the inseparability of multimedia from the computer, the multimedia system must be controlled by the computer. Also, the interface, by the last presented media or media can be interactive (Risojević, 2018).

MMLS (Multimedia Learning System) is a network tool for learning which is approached by the web browser. The purpose of MMLS is to offer students multimedia resources so they can learn concepts of diagram of entity correlation (ERD) as a part of an undergraduate course on managing information systems and making ERD in interactive media. MMLS uses the correlation between entities and symbols of diagram flows, so it logically presents relations of entities in the database. MMLS system is similar to CASE tools (Computer-Aided Software Engineering) (Cohen,2005).

The Interactive Multimedia Learning Systems (IMLS) have been used in the developed countries and they are shown as very successful in helping students to learn in much more efficient way (Zeqiri, Luma, 2007).

The use of multimedia enriches the process of learning because it provides multi-perception. It represents the integration of more than one media (text, sound, video, pictures, animations, etc.) which complement each other. It is scientifically proven that a student of average capabilities can memorize 10% of what he reads, 20% of what he heard, 30% of what he saw, 50% of what he heard and saw, 70% of what can be dramatized and written and almost 90% of what he imagines, realizes, and does. Because of that, it is necessary to use multimedia systems, so that the content we teach stays permanently. But no element is perfect for the transfer of content, for all ages, different capabilities,

and ways of learning. So, it is important to choose good didactic models when teaching certain content (Papić, Aleksić, 2012).

3. Research analysis

There were 137 research participants, all of whom are teachers in Central Bosnia Canton. The questionnaire was answered online and made through Google Forms. The first part of the questionnaire refers to demographic questions, the second part includes questions about teachers' agreement about the same, and in the third part participants graded classroom equipment, students' knowledge, and teachers' efficiency.

3. 1. Participants sample

The participants' sample is shown in the next table.

Table 1. Sample of respondents

GENDER	M	101
	F	33
AGE	20-25	12
	25-30	26
	30-35	23
	35-40	20
	40-45	30
	45-50	8
	50+	18
PLACE OF RESIDENCE	Bugojno	12
	Busovača	5
	Dobretići	1
	Donji Vakuf	6
	Fojnica	9
	Gornji Vakuf	9
	Jajce	12
	Kiseljak	13
	Kreševo	7
	Novi Travnik	10
	Travnik	21
	Vitez	32

SCHOOL MUNICIPALITY	Bugojno	6
	Busovača	5
	Dobretići	1
	Donji Vakuf	8
	Fojnica	14
	Gornji Vakuf	9
	Jajce	12
	Kiseljak	10
	Kreševo	8
	Novi Travnik	4
	Travnik	28
	Vitez	32

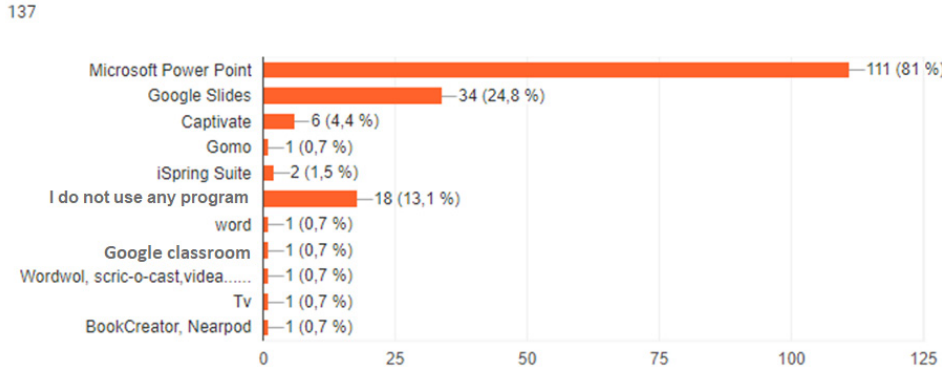
In the table, we can see that out of the total number of participants, they are 73,2% female, or 101. The highest number of participants (30) is between 40 and 45 years old, and the lowest (8) is between 45 and 50 years old. We can say that all the age groups are similarly presented, except the one between 45 and 50 years. The majority of participants is from Municipality of Vitez (32) and Travnik (21), and also those are the municipalities of schools where participants work, Vitez (32), and Travnik (28). Only one participant was from Municipality of Dobretici.

3. 2. Answers analysis

Descriptive statistics

The first question in the second part of the questionnaire is about the use of the programs for showing the class content. Besides the offered answers the participants could write down their own answers and choose multiple answers.

Which program do you use for showing the class content?



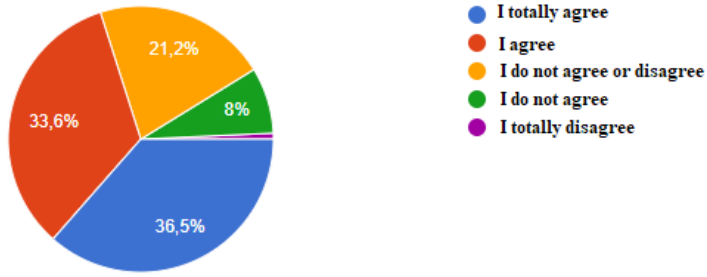
Graph 1. Content creation programs

We can see, from the graph, that the highest number of participants use Microsoft Power Point (81% of participants). After that, they use Google Slides (24,8%), then Captivate, 6 users. 13,1% or 18 respondents do not use any program. Other programs are used by one or two respondents – Word, Google Classroom, Worldwol, scric-o-cast, BookCreator, and Nearpod.

The next six questions are claims where respondents gave their agreement or disagreement with the statement. According to the Likert scale we assigned points to answers – I totally agree 5, I agree 4, I do not agree or disagree 3, I do not agree 2, and I totally disagree 1. We will show the attitudes of the participants through the sum of the points; the higher the sum, the more positive teachers' attitude.

Claim 1 – The result of learning is better when the content is shown through multimedia than when it is taught traditionally.

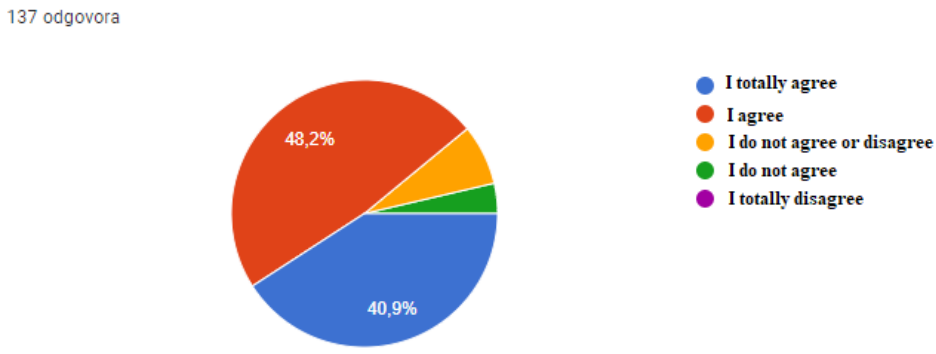
137



Graph 2. Participants' answers to the first claim

From Graph 2 we can see that the highest number of participants totally agree, or agrees with the claim, 70,1% or 96 participants. Twenty-nine participants do not agree or disagree, and 12 participants do not agree or totally disagree. The total sum with the assigned points is 544.

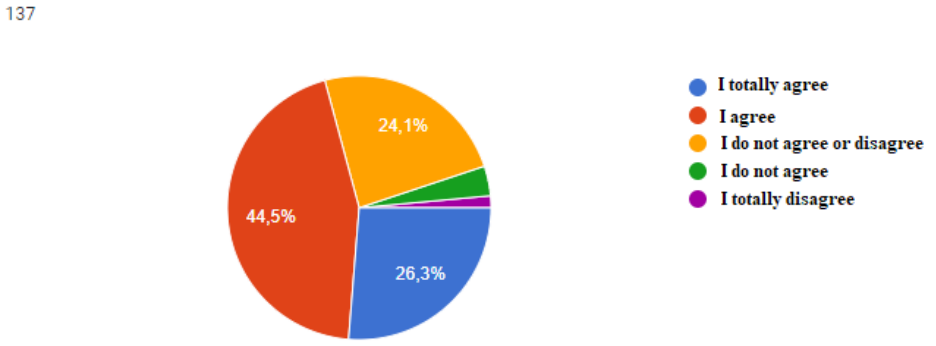
The next claim is – The use of multimedia has a positive impact on showing class content.



Graph 3. Participants' answers to the second claim

From Graph 3 we can see that the highest number of participants totally agrees or agrees with the second claim, 81,9% or 122 respondents. Nine participants do not agree or disagree, and 6 of them disagree or totally disagree. The total sum of this claim is 581.

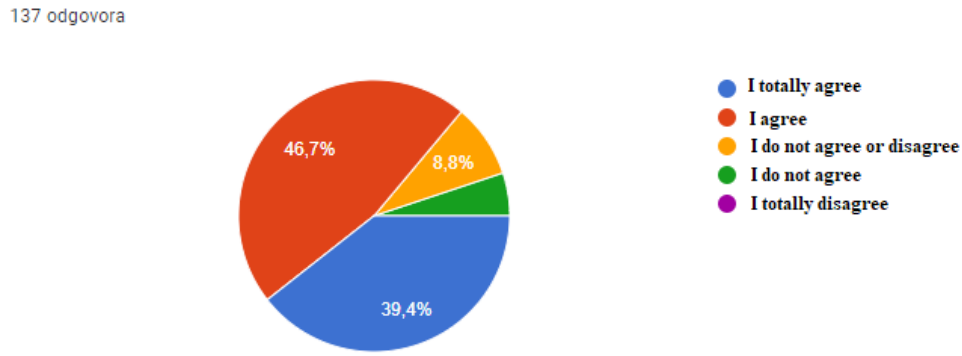
Next claim – Software used in class has a positive impact on the learning process.



Graph 4. Participants' answers to the third claim

In graph 4 we can see that majority of the participants totally agrees or agrees with the claim, 70,8% or 97 participants. There are almost forth of those who do not agree or disagree, 33 of them, 5 respondents do not agree, and 2 of them totally disagree. The total sum of this claim is 535.

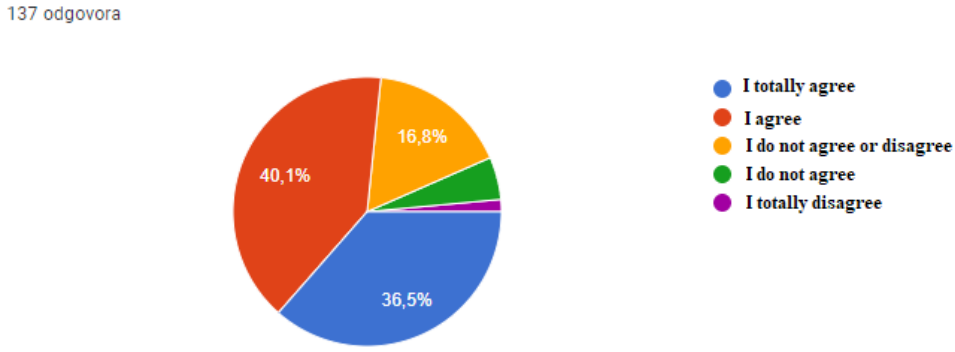
The next claim is – The usage of multimedia is connected with the technology skills of a teacher.



Graph 5. Participants' answers to the fourth claim

In graph 5 we can see that 86,1% of participants totally agree or agrees with this claim, 118 of them. 12 respondents do not agree or disagree, and 7 of them do not agree. The total sum of this claim is 576.

Next claim – There is a connection between students' knowledge and teachers' skills.

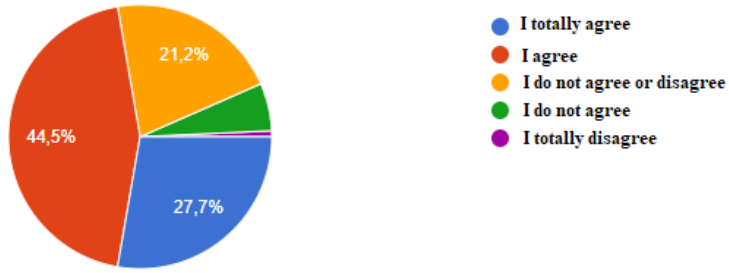


Graph 6. Participants' answers to the fifth claim

In graph 6 we can see that most of the participants totally agree or agree with this claim, 76,6% of participants or 105 of them. 23 participants do not agree or disagree, and 9 of them totally disagree or disagree. The total sum of this claim is 555.

The last claim is – The usage of multimedia has a positive impact on teachers' efficiency, unlike traditional ways of teaching.

137



Graph 7. Participants' answers to the sixth claim

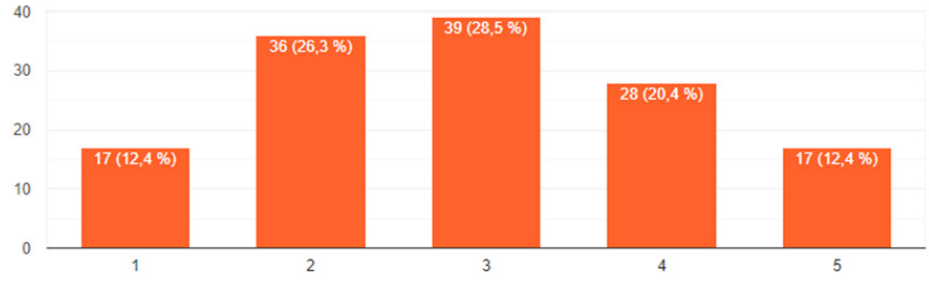
In graph 7 we can see that most of the participants totally agree or agree with this claim, 72,2 %, or 99 of them. 29 of them do not agree or disagree, 8 do not agree, and 1 totally disagrees. The total sum of this claim is 538.

Observing the total sums of the claims, we can see that the second claim has the highest total sum which means that participants' attitude on this claim is the most positive. Max total sum is 686, the minimum is 137, and the average is 411. Every claim with a total sum that is higher than the average one is considered a positive one. The total sums of our claim are: C1 – 544, C2 – 581, C3 – 535, C4 – 576, C5 – 555, and C6 – 538, therefore we can say that every claim has a positive attitude among participants.

The next 3 questions are the grades of the users on classroom equipment, results of learning, and teachers' skills. We will use grades to establish a correlation between grades for teachers' skills and results of learning, and classroom equipment and teachers' skills.

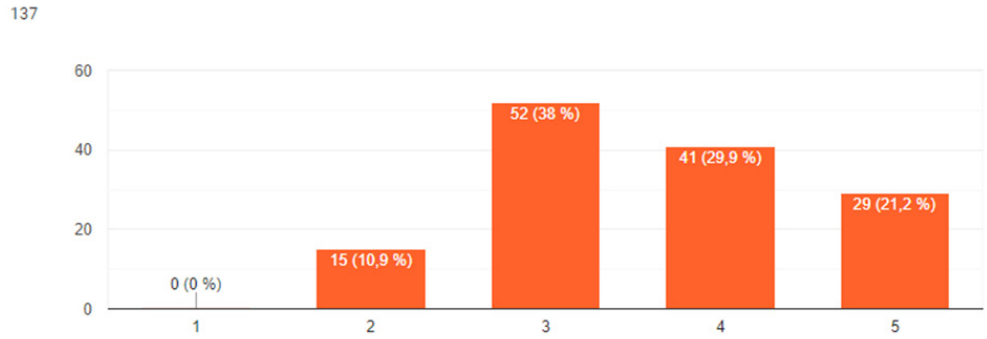
Question 1: How would you grade classroom equipment in your school?

137



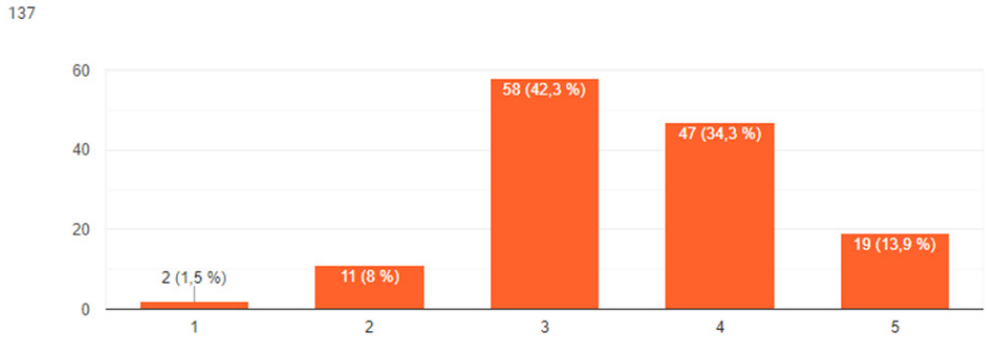
Graph 8. Respondents participants' answers to the first question

Question 2: How would you grade teachers' skills in your school?



Graph 9. Participants' answers to the second question

Question 3: How would you grade the results of students learning in your school?



Graph 10. Participants' answers to the third question

Inferential statistic

Before we start with inferential statistics, as methodology orders, first we have to check if the use of parametric statistics is justified, in other words, if the distribution of the results matches normal distribution or significantly deviates from it. We will calculate that (through SPSS) with measures of skewness and kurtosis of distribution.

Table 2. Skewness and kurtosis of distribution

	N	M	s.d	Skewness		Kurtosis	
				Stat	Std. Err	Stat	Std. Err
How do you agree with the claim - the result of learning is better when the content is shown through multimedia than when it is taught through traditional ways.	136	3.97	.988	-.641	.208	-.426	.413
How do you agree with the claim - the use of multimedia has a positive impact on showing class content.	136	4.26	.750	-.997	.208	.913	.413
How do you agree with the claim - software used in class has a positive impact on the learning process.	136	3.90	.885	-.657	.208	.491	.413
How do you agree with the claim – the usage of multimedia is connected with the technological skills of a teacher?	136	4.21	.808	-.991	.208	.788	.413
How do you agree with this claim – there is a connection between students' knowledge and teachers' skills?	136	4.04	.934	-.919	.208	.620	.413
How do you agree with this claim - the usage of multimedia has a positive impact on teachers' efficiency, unlike traditional ways of teaching?	136	3.93	.891	-.619	.208	.065	.413
How would you grade classroom equipment in your school?	136	2.95	1.21	.100	.208	-.891	.413
How would you grade teachers' skills in your school?	136	3.62	.943	.030	.208	-.946	.413
How would you grade the results of students learning in your school?)	136	3.51	.886	-.110	.208	-.090	.413
Valid N (listwise)	136						

As it can be seen in the previous table, the measures of skewness and kurtosis do not go over 1 for any of the variables which means that distributions do not deviate from the normal, in other words, we meet the criteria for the usage of parametric statistics.

By using interferential statistics, we will check the preset hypothesis of the research. We will use Excell and SPSS 26 to calculate coefficients needed for correlation, or simple linear regression (beta ponders), to establish significant predictors for variable criterium.

Questioning of significance for multimedia usage (predictor) on the results of the learning (criterium)

To check the main hypothesis which was – the usage of multimedia has a positive impact on learning results, we will apply simple regression analysis in which the usage of multimedia is a predictor of variable and learning results criterium of variable. The results are shown in tables.

Table 3. Model summary

Model Summary						
Model	R	R Square	Adjusted R Square	Std. The error in the Estimate	F	Sig.
1	.094[a]	.009	.002	.885	1.206	.274[b]
Predictors: (Constant), Do you use any program to show class content? Dependent Variable: How would you grade the results of learning in your school?						

As can be seen in the previous table, the determination coefficient is 0,09, (R=0,094) and it is not statistically significant. This shows that the usage of some sort of technology to show class content is not significant. Even though, methodologically, considering that it is statistically irrelevant, beta ponders do not have to be shown, we will show the table of coefficients. Beta ponder is 0,094 and it is not statistically significant. If the model was statistically significant, the equation of the linear regression line would be y'=3.042+0.252*x, but considering that the model is not statistically significant, we cannot discuss this or have a longer interpretation.

Table 4. Model summary – coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.042	.437		6.961	.000
	Do you use any program to show class content?	.252	.230	.094	1.098	.274
a. Dependent Variable: How would you grade learning results in your school?						

Questioning the significance of the multimedia tools usage (predictor) on teachers' efficiency (criterium)

To check if the usage of multimedia tools is a (predictor) operationally defined as a usage of some tool in practice and a significant predictor of teachers' efficiency, we used simple linear regression. The results are shown in tables.

Table 5. Model summary

Model Summary						
Model	R	R Square	Adjusted R Square	Std. The error in the Estimate	F	Sig.
1	.130[a]	.017	.010	.939	2.308	.131[b]
a. Dependent Variable: How would you grade teachers' efficiency in your school?						
b. Predictors: (Constant), Do you use any tool to show class content?						

As it can be seen, this model is not significant either, so we can conclude that the usage of multimedia tools, operationally defined as the usage of visual tools (Microsoft PowerPoint, Google Slides, Captivate, Gomo, iSpring Suite…) is not significant predictor to evaluate teachers' skills (operationally defined as an evaluation of teachers on their skills).

Considering that the model is not significant statistically, methodologically it is not necessary to show beta ponders because beta ponders cannot be statistically significant if the model is not statistically significant, but we will show the table with coefficients, which we hypothetically present.

Table 6. Model summary – coefficients

Coefficients						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.924	.463		6.310	.000
	Do you use any program to show class content?	.370	.243	.130	1.519	.131
a. Dependent Variable: How would you grade teachers' skills in your school?						

Beta ponder is 0.13 and it is not statistically significant. The model in which the predictor is the usage of multimedia tools, and the criterium of teachers' skills is not statistically significant, but if it was then the equation of the linear regression line would be y=2,924+0.37*x.

a) Questioning of correlation between students' knowledge and teachers' skills

To establish a correlation between students' knowledge and teachers' skills we will use Person's coefficient of correlation. It is important to mention that we calculated the correlation between two variables, which are teachers' evaluation of teachers' skills in school and teachers' evaluation of the results of students learning in their school. Person's coefficient of correlation is shown in the table.

The table that we will use for the degree of correlation strength is shown in the table 7.

Table 7. Degree of correlation strength

| r |	Strength of correlation
0	No correlation
0-0,5	Weak correlation
0,5-0,8	Medium strong correlation
0,8-1	Strong correlation
1	Total correlation

Table 8. Degree of correlation strength

Correlations			
		How would you grade teachers' skills in your school?	How would you grade learning results in your school?
How would you grade teachers' skills in your school?	Pearson Correlation	1	.645**
	Sig. (2-tailed)		.000
	N	136	136
How would you grade learning results in your school?	Pearson Correlation	.645**	1
	Sig. (2-tailed)	.000	
	N	136	136
**. Correlation is significant at the 0.01 level (2-tailed).			

As it can be seen in the previous table, the correlation coefficient between teachers' evaluation of teachers' skills in their school and the learning results of their students is r(134)=0.645 and is statistically significant for 0.01, and which shows that there is a medium, positive, and statistically significant correlation

between teachers skills and learning results according to teachers evaluation, and also showing that better the teachers skills are, better the learning will be and vice versa.

4. Conclusion

Through this work, we presented media tools for the classroom usage. We examined teachers' opinions and attitudes to confirm the descriptive method of research. First, we will interpret descriptive statistics related to the hypothesis.

Working hypothesis – Usage of multimedia tools in class has a positive impact on the learning results of students in elementary schools, compared to traditional ways of learning. This is reflected in the first claim – the learning result is better with the usage of multimedia content. Attitude toward this claim is positive, the sum is 544. 70,1% of participants totally agree or agree with this claim, and 9% of them do not agree or totally disagree.

BH1 – The usage of multimedia tools has a positive impact on teachers' efficiency and it is the same as the sixth claim which is agreed by 72,7% of participants, 21,2% of them do not agree or disagree, and 6,6% disagree or totally disagree.

BH2 – There is a strong correlation between students' knowledge and increasing teachers' skills. Looking at the fifth claim – There is a correlation between students' knowledge and teachers' skills, we saw that teachers have a positive attitude toward this claim, 76,6 of them totally agree or agree with this claim.

With descriptive statistics, we described teachers' attitudes on the usage of multimedia, and with interferential statistics, we will accept or discard the hypothesis.

WH – usage of multimedia tools in class is not a statistically significant predictor of students learning results. The model has presented itself as statistically not significant, so we conclude that the usage of multimedia tools does not contribute to the evaluation of learning results. The working hypothesis is declined.

BH1 – the usage of multimedia tools has a positive impact on a teacher's efficiency, operationally defined as an evaluation of teachers' efficiency, and this is also a hypothesis that we decline because the model is not statistically significant, so we conclude that the usage of multimedia tools is not a statistically significant predictor for evaluation of teachers' skills.

BH2 – there is a statistically significant relation between the evaluation of students' learning results and teachers' skills. With this, we confirmed the second backup hypothesis. The correlation coefficient is 0,645 and is statistically significant at the level of 0,01.

Classroom tools are important for the modernization and improvement of class and extracurricular work. With that, there are a lot of questions and prob-

lems that need to be solved so its effects could be recognized. Difficulties are shown regularly, starting with getting the equipment to a methodically operational class. Advanced scientific and technological development, as much as it provides new technical and methodological ground to advance the class, makes it difficult for schools to timely and adequately use the potential of class tools. So, modern classroom tools will represent a constant challenge for class, from the point of scientific and technological point of view. We can conclude that the teachers' final attitude about multimedia tools in class is positive, and with good conditions, the teacher is the key to success.

References

1. Cohen, E.B. (2005). Issues in informing science and information technology, California: Informing Science Press
2. Papić, T., Aleksić V. (2012). Metodika nastave tehničkog i informatičkog obrazovanja, Čačak: Tehnički fakultet.
3. Risojević, V. (2018). Multimedijalni sistemi, Banja Luka: Art Print d.o.o.
4. Zeqiri, N., & Luma, A. (2007). Multimedia learning systems and its implementation for the subject advanced it skills. In 30th Jubilee International Convention MIPRO.


DIEC
Book of Proceedings