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Original Scientific Article

Blockchain Adoption in Supply Chain in Industry 4.0

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Abstract—**In recent years, companies have been adopting new cutting-edge technologies into their supply chains. This paper aims to examine the possibilities and ways of adopting blockchain technology within the supply chain processes. The research methods include desk analysis, comparative analysis of literature and analysis of relevant case studies. The results reveal different ways in which blockchain can be utilized within supply chains and how the adoption of blockchain improves the performances of supply chains. Examples of supply chains from different industries that use blockchain are also given.**

Keywords - blockchain, supply chains, industry 4.0.

I. Introduction

The first association most people have about blockchain technology is most often associated with cryptocurrencies. The mass media often gives complex and not-so-well-defined explanations of what this technology is and how it can be adapted in different industries and companies. When simplified blockchain is just the next evolutionary step of the simple database, it represents a system of distributed databases. Blockchain is one of the main technologies of Industry 4.0, as well as being one of the catalyzers for digital transformation.

By analyzing data on the adoption of cutting-edge technologies into the supply chain, it was found that by 2021 blockchain was adopted by 10% of supply chains, with a trend of growth stating that by 2026 the adoption of this technology will reach 68% of supply chains [1]. In 2022 a survey about leading trends anticipated to impact supply chains by 2025, with 261 responses from experts from different industries, placed blockchain adoption in the twelfth position [2]. The prospect of adapting blockchain into supply chains is not something new, a survey from 2019, stated that 40% of supply chain leaders had responded that their companies are planning the adaptation of blockchain [3].

Nowadays, the development of industry 4.0 technologies, such as blockchain brings new challenges and opportunities for supply chains. The first implementation of blockchain technologies that weren't used for cryptocurrency was in retail. Company Walmart represents the pioneer among its peers when it comes to innovations and accepting new technologies, and thus was among the first retail companies to adopt blockchain into their supply chain. Following retail many other industries started adopting blockchain, such as agriculture, food, mining, pharmacy, logistics, automotive and others. Cross-examining and comparing the data from the most recent research studies that analyze different industry case studies about blockchain adoption in supply chains can be found in [4,5].

Thus, a new question arises: How did the adoption of blockchain affect the supply chains? To answer the research question, both the theoretical papers have to be analyzed but also the practical case studies of companies using blockchain in their supply chains need to be found and examined.

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Using Google Scholar's web portal as the main search engine with the combination of two primary keywords blockchain and supply chain, the first search resulted in a huge number of papers (232 00), that were sorted by publication date. The main limitation that had to be met in order for the research paper to be considered was that the observed paper must contain a DOI number. This was followed by additional scoping by adding keywords for each of eight supply chain processes determined by the Global Supply Chain Forum (customer relationship management, customer service management, demand management, order fulfillment, production process management, supplier relationship management, product development and commercialization, reverse flow management). Once again papers were sorted by date and checked for DOI numbers. The selection of papers was focused on quality, and having in mind the goal was to find credible sources to conclude how blockchain has been adopted in supply chain processes. On the other hand, the practical case studies used in the paper are selected from leading multinational companies that have proven their innovation and pioneered the digitization of supply chains in their industries.

The remainder of the paper is organized into four sections. Section 2 is designated for the theoretical background, while the possibilities and benefits of using blockchain within the supply chain processes are analyzed in Section 3. The examples of supply chains that use integrated blockchain in their supply chains are presented in Section 4. Finally, the conclusions and directions for further research are given in Section 5.

II. Theoretical Background

The first form of blockchain technology was firstly used as the foundation for the world's first cryptocurrency Bitcoin. A simple way to explain blockchain is that blockchain is a system of distributed databases that record all transactional data or other information. Its database security mechanism is ensured through cryptography, and access to the data is managed via a consensus mechanism [6].

The main characteristics of this technology are [7]:

- It is designed to be distributed and synchronized across the entire network;
- It relies on using "smart contracts"—pre-agreed arrangements stored on the blockchain, through which transactions can be conducted. These contracts represent protocols through which transactions are verified, validated, and executed as agreed in advance;
- Transparency—the network is built with a Peer-to-Peer (P2P) architecture, meaning that the agreement of all relevant participants is required for any transaction and its terms;
- Data immutability—it is impossible to delete a completed transaction from the network, and it remains stored permanently. Furthermore, no retroactive changes to any saved transaction content can be made.

Based on availability, there are four types of blockchain networks [8]: public, private, hybrid and consortium blockchain.

Public Blockchain suppose an open network, allowing anyone to participate in transactions without prior permission. It features a high level of decentralization, transparency, and strong security while ensuring data privacy and requiring cryptocurrency usage. Its main disadvantages are high energy consumption and slow transaction processing speed.

Private Blockchain suppose network that provides a high level of privacy, with closed access that requires permission from an existing member. It does not necessitate the use of cryptocurrency and features low decentralization. Its advantages include low energy consumption for maintenance, suitability for closed systems such as supply chains, high data security, and increased transparency in data exchange between members, such as in supply chains, along with faster transaction processing. A drawback of this type is the need for trust between participants and potential participants. Additionally, the low or centralized decentralization of this network poses a risk of third-party hacking. Companies typically use private blockchain networks in supply chains.

Hybrid Blockchain combines the previous two, allowing participants to choose whether parts of the data are publicly available or require authorization. It operates within both centralized and decentralized systems. Using this model can enhance the network's security and transparency.

Consortium Blockchain assume a semi-decentralized structure, enabling network activities to be conducted even by a single organization. This type is also known as a "federated blockchain". It is most commonly used in the banking industry or governmental organizations.

The introduction of blockchain technology into supply chains was explained and illustrated by Casado-Vara and his colleagues through an example of the traditional supply chain in the agricultural industry and its transformation following blockchain implementation [4]. The primary change observed is in the method of transmitting and storing information, where blockchain ensures that information from the product's origin to its retail placement is transmitted and stored within the blockchain network [9].

The promising advantages of applying blockchain technology in supply chains include [10-14]:

- Transparency and immutability of data and records.
- Blockchain application improves the operational efficiency of supply chains and helps reduce costs across the supply chain.
- Enhanced data and communication security.
- Increased collaboration between supply chain members.
- Enables accurate tracking of data and/or products and provides historical traceability by storing all records related to a specific product.
- Improves sustainability, by facilitating better compliances with environmental regulations and verification process of sustainable practices.
- Has a positive impact on adaptability to future technological advancements. This characteristic stems from the now-standardized documents and data sharing amongst supply chain members. Additionally, adapting future technologies will be easier because of the enhanced transparency, traceability, and higher levels of trust and safety that the blockchain provides.

The potential disadvantages of blockchain technology application in supply chains are [15-17]:

- High initial implementation costs.
- Technically complex introduction process.
- Scalability—the number of transactions that can be processed within a given time frame is limited.
- Regulatory challenges—varying laws may hinder the application of this technology in international supply chains.
- The technology is currently energy-inefficient—it requires powerful computers and consumes large amounts of electricity.

III. Application of Blockchain Technology in Supply Chain Processes

Using the Global Supply Chain Forum classification [18] of supply chain processes, this subchapter is meant to represent the use of blockchain in each of the eight processes, using the literature review method.

The use of blockchain was found to significantly improve and simplify the customer relationship management (CRM) process. After implementing blockchain, companies now have all the transactions with their customers recorded in the form of a transparent and immutable record. Having these transparent records, allows customers to track the origin and journey of the products they purchase. The introduction of this technology increases customer trust and satisfaction. Other key benefits of use from the company's perspective, besides the increased customer trust and satisfaction, is the greater security and efficiency of data transfers between supply chain members or company sectors [13].

The use of blockchain technology resulted in significantly enhanced and simplified customer service management. Blockchain provides customers with precise and up-to-date insights into the status of their orders and expected deliveries. Using blockchain, companies can quickly and efficiently resolve disputes or issues reported by customers by providing them with evidence of delivery and product quality. Key benefits of the use of blockchain are the reduction of the statistical possibility of fraud, the increase of customer satisfaction as well as trust, and also enhancement of the security of customer data [15].

The use of blockchain technology in demand management is currently mostly indirect. Blockchain is used to gain faster access to more accurate predictions, which helps employees manage demand. Since blockchain increases the transparency, traceability, and security of completed transactions, it ensures that data exchanged between supply chain participants is accurate and valid. This technology's undeniable impact is seen in the demand management process, where the delivered blockchain data allows for more precise forecasting and inventory management, aligning with real market needs [17].

The use of blockchain can result in an acceleration of the order fulfillment process. Due to its transparency and data security features, companies have precise and up-to-date information about inventory and shipment statuses. As a result, all supply chain participants have real-time insights into actual inventory levels. Additionally, blockchain reduces the likelihood of errors during order packing and the risk of theft [19].

The use of blockchain technology indirectly facilitates production process management. By forming a blockchain network and connecting with IoT (Internet of Things) devices in production facilities or on products, blockchain can store information about components, materials, and products throughout the production cycle and beyond. One advantage of using blockchain is the ability to identify quality issues with components, materials, or products, as well as production failures in real time [20,21].

The use of blockchain can significantly improve and simplify the supplier relationship management (SRM) process. By using blockchain, companies now have enchanted communication transparency, which results in easier and more transparent agreements established between the company and suppliers. The use of smart contracts increases the trust between the company and suppliers, leading to better and more open relationships, as well as greater supplier satisfaction [10].

The application of blockchain technology to product development and commercialization enhances data exchange and increases the security of sensitive data, such as product prototypes. It also ensures secure information exchange between stakeholders during the design and development phases. All modifications are stored within the blockchain, making it easier to identify and prevent data errors, thus improving the efficiency of new product development. Moreover, blockchain facilitates interaction and data exchange between suppliers and manufacturers, fostering innovation by sharing knowledge and ideas for developing new products. A key advantage is the transparent tracking and recording of intellectual property, as well as all contracts stored on the blockchain network [22].

One of the more interesting uses of blockchain can be seen in reverse flow management process. Blockchain enables in-depth product tracking, which reduces the likelihood of fraud during product returns, and simplifies cost transactions. This technology also increases the efficiency of the entire reverse flow management process. Furthermore, the return process becomes more secure and transparent compared to traditional methods of tracking returned items [16].

IV. EXAMPLES OF PRACTICAL APPLICATIONS

Theoretical literature review provides a deeper understanding of the connection between blockchain and supply chains, exploring concrete practical uses represents the final element to fully understand the connection and integration of blockchain into supply chains.

According to available literature, blogs, and interviews with notable CEOs of various companies, blockchain technology is considered one of the revolutionary drivers of digital transformation and a foundation for entering Industry 4.0. Its application in supply chains significantly enhances transparency, efficiency, and security, allowing companies to track product movements in real time and improve trust among supply chain participants [23,11].

World-renown company IBM known as one of the leading companies in digital transformation and software engineering, has numerous partnership projects for integrating blockchain into different industries' supply chains. The most known partnerships are with companies such as Walmart, Maersk, Ford and Unilever [24].

American food retailer company Walmart implemented the use of blockchain order to the origin and transportation route of all of food products they sell. The vision behind this transition was to apply blockchain throughout the whole supply chain from the field/farm to the store shelves. This allows faster and much more accurate tracing of products, meaning it makes identifying and recalling contaminated or faulty products easier and safer. Using the mango case study as an example the result of use is represented in decreased waste of uncontaminated food. The secondary result mentioned was the accelerated time needed to find food origin, for mangos it went from seven days to just 2.2 seconds [25].

One of the leaders in the automotive industry company Ford implemented the use of blockchain to track the origin of cobalt that they use in their electric vehicle batteries. One of the main reasons for use was to make the sourcing process of cobalt more transparent, know the company can track from which mine the cobalt came, and with such reassure their stakeholder that the metal was sourced ethically [24].

Global logistics company Maersk and IBM themed up to create a platform based on blockchain technology, to reduce trade frictions and promote and simplify global trade. The TradeLens platform was founded in 2018. with a vision of being a revolutionary push that will help the global supply chain digitalization, with its open and transparent flow of information, while providing high levels of security and traceability of data and information. Unfortunately, this platform was shut down in 2023., due to the lack of global support, and low ROI rate [26].

One of the world's global manufacturing giants company Unilever has implemented blockchain into its supply chain to enhance their sustainability and provide its stakeholders with more transparency when it comes to raw materials. The use of blockchain tracks the sourcing of all raw materials, meaning that the company can show data that proves their production and final products are made sustainably and ethically [27].

Similarly, to Unilever one of the world's largest food and beverage companies, Nestlé also implemented blockchain to enhance the sourcing of raw materials in their production lines. The implementation of blockchain into the supply chain, enchanted the sustainability of the final product, parallel helping prevent and reduce deforestation and promote responsible agriculture practices [25].

When it comes to the beverage industry company Coca-Cola used a different take when it came time to integrate blockchain into their business, they used the power of having a transparent, secure and trackable database, to form a secure registry of their worker working in the bottling plant in the Philippines. Coca-Cola uses the potential and power of blockchain to promote and ensure ethical labour practices [28].

One of the largest mining companies in the world, BHP uses blockchain for tracing the origins of their minerals, more precisely they implemented a blockchain-based platform called Prosperity. Prosperity's design uses blockchain to track and ensure accurate traceability within the mining supply chain. The key reason for using this platform, is to ensure sustainability and ethical practices are being implemented while mining, so that the miners are not exploited nor is the environment harmed [29,24].

Pharmaceutical giants Pfizer, Johnson & Johnson, and AstraZeneca use MediLedger which is a blockchain network. The primary functionality of this ledger is to help with the prevention of counterfeit medicine and increase the overall speed of medicine production in the supply chain, by eliminating unnecessary paperwork and increasing the processing time for analyzing and organizing product-related data between manufacturers, distributors and pharmacies [30]. The MediLedger uses blockchain in three distinct ways [31]:

- Synchronizes public data.
- Holds immutable records of all transactions with a high level of confidentiality.
- Utilizes smart contracts to enforce rules and the integrity of the system.

A common denominator for all of the mentioned companies when it comes to adapting blockchain is the strategic partnerships done with a large tech company most popular IBM. Logically and business-wise, a known fact is that larger companies have more resources, one of them being a dedicated budget for innovations and investment projects for integrating new technologies or partnering up and creating something new.

Considering the current global market there isn't a ready-made solution for just adding blockchain to an organization. An organization that wants to adopt blockchain and use all of its potentials, has to go through a detailed and expensive design and implementation period. This lack of cost-affordable solutions can be classified as one of the main reasons that SME companies aren't using blockchain as of now. A team of academics adapted blockchain technology in a small Italian bakery, in their simulation case study [32], they described the process of designing and implementing a blockchain network in tracking the origin of manufactured products from raw materials to the end customer. The paper [32] shows all of the steps they took to create a blockchain network for this bakery, in the main problem that occurred was the lack of space for all external data, and storing large amounts of data is expensive for any company let alone an SME. Different studies have been published regarding which factors are to be used in consideration when it comes to SME companies. Positive factors for adopting blockchain are: increased transparency, increased security, competitive pressure and advantage, improving operational efficiency [33,34]. The negative factors influencing blockchain adaptation are: high complexity, high initial investment high cost of development and maintenance, and lack of resources and support [33,34]. Adaptation of blockchain into SMEs is an interesting approach that with yield a lot of benefits if the SME has high funding and a proper support system with expert guidance, the adaptation can be done, but for the majority of SMEs is just not cost-effective for now.

V. CONCLUSION

The motivation behind this paper was to explore practical adoption and use of blockchain in supply chain processes. The paper highlights the various ways blockchain is used in supply chain processes as well as how different companies integrate blockchain into their business models and supply chains. It gives the main conclusions in how the adaptation of blockchain affects the supply chains. The use of blockchain establishes a more transparent, secure and traceable network. This technology can improve the relationship between not only customers and the companies but as well can enhance the collaboration between different supply chain parties.

This study is limited by the use of only a fraction of all the available materials that tackled the topic of rapidly increasing use of blockchain in the supply chain. A significant limitation of our research was the scarcity of studies that provide concrete data about the benefits and improvement results after adopting blockchain in supply chains. In the future, a more rigorous review should be conducted to provide in-depth insight into how blockchain adoption at different levels of implementation impacts the supply chain as a whole. One of the future research paths can be to conduct an in-depth cross-examination for the adoption process within different industries, as well as the differences in the adoption of blockchain between smaller and larger organizations.

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Original Scientific Article

Factors Affecting Adoption of Artificial Intelligence in SMEs and its Impact on Firm's Skills Needs

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Abstract—**The paper deals with the problem of artificial intelligence (AI) adoption in companies. It aims to empirically examine factors affecting the adoption of AI. It also identifies factors influencing the potential effects of AI adoption on future infirm skills needs. There is currently an absence of research focused on examining this topic based on empirical data. The research is based on the secondary data from Flash Eurobarometer 537 (2023). More than 19,000 companies from 27 EU countries and 9 non-EU countries have been included in the sample. By examining these data, substantial systematic differences were found between companies with different characteristics. Factors affecting AI adoption and consequences on skills needed have been identified by logistic regression. The results suggest that larger companies with older employees located in cities, as well as those hiring adequate skills without any problems, are often adopting AI. Similar characteristics are also typical for companies that reported a significant effect of AI on their skill needs. However, in this case, the effect of community size and difficulties with hiring skills are not significant. Significant differences were also identified among industries and types of specific skills that a company lacks.**

Keywords – artificial intelligence, shortage of skills, factors of AI adoption, skills needs, companies.

I. Introduction

Artificial intelligence (AI) is one of the very few technologies that have generated as much interest from professional and in the public. Despite the number of research papers focused on AI is growing there are still many specific areas where research is insufficiently covered. One of them is the issue of companies deciding on the introduction of AI and the subsequent consequences on the skills of the company. This paper aims to cover this gap based on empirical micro-level data. Its main goal is to identify factors affecting the adoption of AI and identify its anticipated effect on the skills needed. The results may help to better understand the decision-making process for AI introduction, provide evidence on factors affecting their choices, and predict its potential consequences for skills. The following three main research questions have been examined in the paper:

RQ1: What factors and firm characteristics are positively correlated with the choice to adopt AI in the company?

RQ2: What factors and firm characteristics are positively correlated with the expected significant effect of AI on skill needs (positive or negative)?

RQ3: Are there any significant differences between both sets of factors?

Our findings attempt to cover the research gap in this field. As far as we are aware, there is no other study focused on examining a similar set of factors for AI adoption based on such extensive micro-level data. Most of the research examining micro-levels deals with the attitudes of individuals, such as, for example, customer perceptions of digitalization [1] or correlations with personal traits [2]. On the other hand, studies investigating firms' characteristics and factors are mostly based on much smaller samples (such as [3]) or focused on more general problems such as Industry 4.0 (such as [4]).

The following section briefly summarizes the results of previous research focused on similar research problems. However, there are currently only a limited number of studies dealing with the factors affecting AI adoption at companies. The next section describes the methodology and data used in the analysis. Key results are summarized in the fourth section. The final section contains an explanation of the main conclusions resulting from the results.

II. Literature Review

Adoption of artificial intelligence (AI) in company changes its business operations by optimizing existing processes. It enhances automation while interacting with humans [5]. Successful adoption of AI can increase a company's total turnover [6], improve the efficiency and accuracy of logistics [7], improve the safety and security of suppliers [8] and support economic growth [9]. Businesses can take advantage of AI adoption, regardless of their size. While large companies usually employ AI in robotics and resource management, SMEs mostly use it to improve the knowledge management and quality control [10].

The decision on AI adoption is affected by many factors, which we will further examine in more detail. However, the difference between the expected benefits and the costs associated with the adoption is an important criterion. The adoption of any new technology in firm can be theoretically explained by the Innovation diffusion theory [11]. Our research is also based on this theoretical approach, while the focus is on factors affecting AI adoption and role of skills needs.

A. Factors Affecting AI Adoption in Companies

There are many internal and external factors that could influence the willingness and actual decision to adopt AI in the company. Organizational factors such as digital skills, company size, and R&D intensity appear to have the most significant effect on the adoption of AI [3]. Some studies argue that larger companies are more likely to implement AI tools [10,12]. On the contrary, [4] found that firm size does not matter for Industry 4.0 and especially for the adoption of digital technologies. Our paper is trying to resolve this inconsistency and carefully examine this problem with a larger sample of companies. It is likely that SMEs could struggle with AI adoption due to a lack of sufficient data as well as problems with financial and human resources [13]. The smaller size of the company can be partly compensated by its membership in an industry cluster or any other similar business organization. Membership in the industry cluster provides a conducive environment that supports digitalization [14] and business transformation towards Industry 4.0 [15]. Our analysis takes into account the size of the company as well as its potential membership in an industry cluster or similar organization.

The financial situation of the company is also considered an important factor affecting AI adoption. Especially, the ability to generate significant turnover and profit are both positively related to the adoption of digital technologies [4,16]. Moreover, the growth in total turnover is positively associated with process and product innovation in companies [17].

Besides companies' internal factors, there are certain external factors that are also playing an important role. Country-specific factors such as regulations, labor market specifics, quality of institutions, and cultural differences are affecting the adoption of digital technology or innovation [18,19]. The geographical location of the company in a city or rural area seems to also be important. Considerable heterogeneity among SMEs with respect to the adoption of advanced digital technologies have been found based on their location. [20]. Rural and small-town SMEs are less frequently adopting digital technology in general. In line with these findings, we considered the size of the community where the company is located as an independent variable in regressions.

B. AI Adoption and Skill Needs

Despite several positive effects of AI adoption, there are also some crucial problems resulting from this rather major change. It can mostly lead to significant shifts in the workforce composition [9] and a rising need for highly qualified workers [21]. The usage of digital technologies requires trained professionals who have the competencies and skills to thrive in the new digital environment [22]. Adoption of AI in the company will likely lead to increased demand for soft skills such as critical thinking, problem-solving, communication skills, and creativity

[23,24]. AI can replace some technical skills but increases the need for soft skills in firms [23].

The effect of AI on skill needs after its adoption seems to be more evident. However, the availability of certain skills is also considered a prerequisite for the adoption of digital technology. Several previous studies found that human capital and skills are essential for the adoption of digital technologies [4]. Adoption of new digital technologies such as AI requires employees with specific digital skills [25,26]. Technical skills such as software development, IT design, and complex data analysis, along with the involvement of some soft skills (such as intercultural collaboration or customer handling), are essential for the ability to introduce digitally integrated solutions and technologies [3,27]. Shortages of such skills in the company represent a significant challenge for the process of digital technology adoption.

A firm's absorptive capacity, which is often proxied by R&D intensity, is considered one of the key determinants for the implementation of new technology [28]. This indicator shows how effectively a company can adopt and use new technology to gain certain benefits. The shortage of R&D skills can therefore represent a barrier to the adoption of AI. Firms with this problem may therefore be less likely to use AI. However, these hypotheses need to be further empirically tested.

It is evident that the relationship between skill needs, and adoption of AI is debatable and needs further empirical investigation based on larger samples of firms. Our paper covers this research gap and examines how shortages of different types of skills could affect AI adoption. Furthermore, the paper is also focused on examining factors affecting expectations related to the effect of AI on the skills needed.

III. METHODOLOGY AND DATA

The main aim of the paper is to identify factors affecting the adoption of AI in SMEs. Secondly, we also examine companies' characteristics and potential, affecting their expectations about the effect of AI adoption on future skills needed in their company. Factors affecting both mentioned problems have been compared. This comparison allows us to provide a better discussion and state the implications of our results. The analysis is based on secondary data collected by Flash Eurobarometer Survey No. 537. A questionnaire survey was conducted in Iceland, Norway, Switzerland, the United Kingdom, North Macedonia, Turkey, the United States, Canada, Japan, and all 27 EU countries between September 11 and October 13, 2023. More than 19,000 respondents' companies were interviewed. More information about the sample can be found in [29]. Fieldwork related to the questionnaire survey has been conducted by Ipsos European Public Affairs. Representative probability sampling methods have been used to select respondent firms- of businesses. The sample data was weighed to marginal population distributions, in terms of company size and NACE sector. We focused our attention on two main questions related to the usage of AI in the company and the expected effects of AI on future skills and needs in the company. These questions

TABLE I. DESCRIPTION OF DEPENDENT VARIABLES INCLUDED IN THE REGRESSIONS.

<table>
<tr><th>Name</th><th>Question</th><th>Coding</th></tr>
<tr><td>Use/Plan AI (using AI or have concrete plans to do so)</td><td rowspan="2">Which of the following statements best describes the deployment of Artificial Intelligence Technologies (AI) in your company over the next 5 years?
1. You use AI, or you have concrete plans to do so, and you expect a significant impact on your company's skill needs.
2. You use AI, or you have concrete plans to do so, but you do not expect a significant impact on your company's skill needs.
3.You have no concrete plans to use AI, but in case you would use it, you expect a significant impact on your company's skill needs.
4. You have no concrete plans to use AI and you expect no significant impact of AI on your company's skill needs.</td><td>Use AI, or have concrete plans to do so (answers 1 and 2) coded as 1; Otherwise = 0</td></tr>
<tr><td>AI impacts skills (Expect impact of AI on skills)</td><td>Expect a significant impact of AI on your company's skill needs (answers 1 and 3) coded as 1; Otherwise = 0</td></tr>
</table>

Source: Authors based on the data from Flash Eurobarometer 537 (2023).

were used as dependent variables in logistic regression. They are described in Table I.

Both dependent variables are binary variables created based on the answers of respondent companies. Descriptive statistics of the variables capturing the answers on the main question are shown in Table II.

More than 56% of companies in the sample reported that they have no concrete plans to use AI, and they also do not expect a significant impact of AI on a company's skill needs. More than 11% are either already using AI or at least have concrete plans to do so soon and expect a significant impact on company' skill needs. On the other hand, approximately 9.4% of the sample is using AI or plans to use it and does not expect an effect on skill needs. Hence, the subsample of those firms using AI or planning to use AI is divided into two almost equally represented groups concerning their expectations towards the effect of AI on skills needed. We will further examine factors affecting their attitudes, represented by independent variables shown in in Table III. They have been chosen based on the theoretical background and expected potential effects. The choice was also limited by data availability. Hence, only the variables capturing the questions in the questionnaire can be used in

TABLE II. DESCRIPTION OF INDEPENDENT VARIABLES INCLUDED IN THE REGRESSIONS.

Variables/Answers	Proportion/ Std. Error	95% Conf. Interval
Use AI, or have concrete plans to do so, and expect a significant impact on company's skill needs	0.1121/ 0.0023	0.108-0.117
Use AI, or have concrete plans to do so, and do not expect a significant impact on company's skill needs	0.0935/ 0.0022	0.089-0.098
You have no concrete plans to use AI, but in case you would use it, you expect a significant impact on your company's skill needs	0.1681/ 0.0028	0.163-0.174
You have no concrete plans to use AI and you expect no significant impact of AI on your company's skill needs	0.5648/ 0.0037	0.558-0.572
Dont know/No answer (excluded in regressions)	0.0615/ 0.0018	0.058-0.065

Source: Authors based on the data from Flash Eurobarometer 537 (2023).

TABLE III. DESCRIPTION OF INDEPENDENT VARIABLES INCLUDED IN THE REGRESSIONS.

Name	Question	Coding
Employees	What is the size of your company in terms of number of employees?	1 to 4 employees = 1; 5 to 9= 2; 10 to 49= 3; 50 to 249 = 4; 250 to 499 = 5; 500 or more = 6
Employees' age	What is the average age of your employees?	Under 20 years = 1; 20-29 = 2; 30-39 = 3; 40-49 = 4; 50 or above = 5
Increased annual turnover	Over the past 2years, has your company's annual turnover increased/decreased/ remained unchanged?	Increased = 1; Decreased/remain unchanged = 0
Community size	Which of the following best describes the area where your company is located	A rural area = 1; less than 20000 inhabitants = 2; 20000-100000 inhabitants = 3; 100000-500000 inhabitants = 4; Over 500000 = 5
Industry cluster	Are you a member of an industry cluster or another SME business support organisation?	Yes = 1; No = 0
Difficult to hire skills	Over the past 24 months, how difficult was it for your company to find and hire staff with the right skills?	Very difficult = 4; Slightly difficult = 3 Not difficult at all = 2; Not relevant. We did not need to hire anyone in the past 24 months = 1
IT shortage	Does your company face skill shortage for any of these job roles? …	Yes = 1 (IT experts skill shortage) No = 0
Administrative shortage		Yes = 1; No = 0
HR shortage		Yes = 1; No = 0
Technician shortage		Yes = 1; No = 0
Customer care shortage		Yes = 1; No = 0
R&D shortage		Yes = 1; No = 0
Marketing shortage		Yes = 1; No = 0
Other shortage		Yes = 1 (Other job roles skill shortage); No = 0
Industry (dummy)	What is the main activity of your company?	11 dummy variables created based on NACE categories.

Source: Authors based on the data from Flash Eurobarometer 537 (2023).

the regression. The company's size was represented by the number of employees in intervals, coded from 1 to 6. Variables such as employees' average age, recent changes in turnover, type of industry, community size, and membership in the industry cluster have also been used. Moreover, we introduced independent variables capturing the skills shortage for a specific type of job (IT, administrative jobs, HR, technician, customer care, R&D, marketing).

Specific types of skills that are missing in the company can potentially affect the decision on AI adoption. Some skills are more likely to be substituted by AI, while others are less replaceable. The overall difficulty of hiring adequate skills can also affect AI adoption. On one hand, companies with lower skill availability in the labor market could consider introducing AI more often. On the other hand, the adoption of AI itself also requires highly skilled employees.

The effects of factors represented by independent variables on both binary dependent variables have been identified by logistic regression. We used robust standard errors to avoid problems with heteroscedasticity. Standard errors are also clustered by countries to reduce potential problems with sampling design while interpreting the results. This method is widely used in economic and social research. However, there are certain limitations to our approach. Despite our best efforts to identify casual relationships, we are not able to rule out potential endogeneity problems. Hence, most of the relationships found in the regression can be interpreted more as correlations than causation.

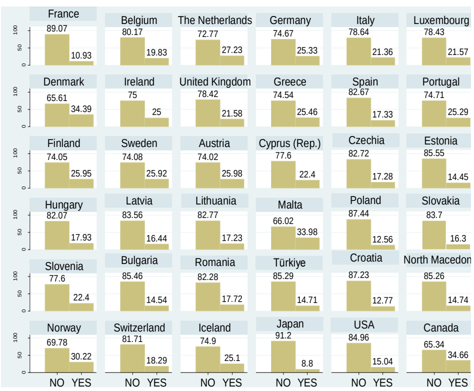

Figure 1. Share of companies using AI or have concrete plan to do so (YES – second column). Source: Authors based on the data from Flash Eurobarometer 537 (2023).

IV. RESULTS AND DISSCUSION

Firstly, we examine the share of companies that are using or planning to use AI soon. Fig. 1 explores differences among the countries where the respondent firms are located. This is one of the most interesting classifications from our perspective. The differences among countries are notable.

The proportion of firms that do not even plan to introduce AI appears to be highest in Japan, followed by France and Poland. On the other hand, companies from Canada, Denmark, and Malta are the leaders in AI adoption. Comparing the situation in EU countries, the differences between the top and bottom countries are more than 20 percentage points.

Turning to the potential impact of AI on a company's skill needs, we explore the differences in the firm's size. We assume that bigger companies with more employees will likely experience less impact on skill needs than smaller ones. Surprisingly, the results show us the opposite (Fig. 2). Companies with fewer employees are usually reported to perceive the effect of AI adoption on skills as irrelevant.

This could be since smaller companies are often not considering using AI, and even if they did, the extent of its application in day-to-day business would be smaller. However, these interesting findings need to be investigated in future research. The following part of research is focused on more detail examining the potential effect of individual factors on adoption of AI and its expected affects on skills need in company.

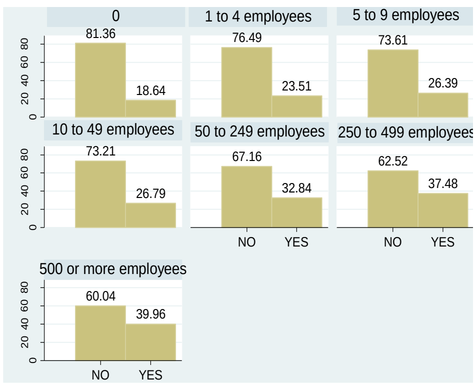

Figure 2. AI impacts skill needs in companies (YES we expect a significant impact on company's skill needs). Source: Authors based on the data from Flash Eurobarometer 537 (2023).

The results of logistic regression are shown in the Table IV. There are several companies' characteristics that appear to play a significant role. The probability that the company will introduce AI as well as this adoption will lead to changes in skills need increases with the number of employees and decreases with the average age of the employees. Hence, the results suggest that the size of the company is positively linked with the probability of AI adoption. Although this finding is contrary to the findings provided by[4], similar results were achieved by [10,12].

Furthermore, the increasing turnover of the company in recent years is positively correlated with the adoption of AI as well as with its effect on skill needs. This is in line with the results of previous studies such as [4], and [17] which found a similar positive correlation between turnover and innovation. However, the exact direction of this should be further examined. Difficulties with hiring staff are negatively correlated with AI usage, which can also be the cause as well as the result of AI adoption. Hence, companies with more problems acquiring adequate skills tend to use AI less. Interestingly, this variable has no significant effect on the expected effect of AI on skill needs.

Similarly, the community size where the company is located is affecting the usage of AI but not its potential effect on skills needs. This is fully in line with our expectations as well as the results of previous studies [20]. The agglomeration forces should play a role in the adoption of new digital technology and innovation in general. Nevertheless, the effect of AI on skills should not directly depend on the geographic location of the company.

On the other hand, membership in the industry cluster seems to be positively correlated with both dependent variables. This could be due to a suitable environment and better access to knowledge, as previously reported by [14,15].

Missing skills in the company and their exact type also appear to be linked with AI usage and its effects on skills. Companies that have a problem with the availability of IT skills are opting for AI usage more often. A similar correlation can be found for customer care skills, R&D job-related skills, and marketing-related skills. On the other hand, there is no evident link between the shortage of administrative and technician jobs' related skills.

TABLE IV. RESULTS OF LOGISTIC REGRESSION.

	(1)	**(2)**
VARIABLES	**USE or PLAN_AI**	**AI IMPACTS SKILLS**
Employees	0.0782***	0.122***
	(0.0281)	(0.0206)
Employees' age	-0.133***	-0.118***
	(0.0399)	(0.0272)
Increased annual turnover	0.265*** (0.0576)	0.180*** (0.0367)
Difficult to hire skills	-0.0537** (0.0241)	-0.00546 (0.0241)
Community size	0.0514**	0.0204
	(0.0228)	(0.0167)
Industry cluster	0.334***	0.219***
	(0.0607)	(0.0486)
IT shortage	0.439***	0.563***
	(0.0879)	(0.0775)
Administrative shortage	0.0454 (0.0792)	0.101 (0.0651)
HR shortage	-0.210* (0.113)	0.0786 (0.149)
Technician shortage	0.0262 (0.0628)	0.0780 (0.0479)
Customer care shortage	0.167** (0.0750)	0.238*** (0.0677)
R&D shortage	0.432*** (0.127)	0.0435 (0.129)
Marketing shortage	0.440*** (0.133)	0.396*** (0.0831)
Other shortage	-0.0759 (0.0577)	-0.0798 (0.0552)
Industry dummy variables (reference category ICT sector) – selected variables:		
Manufacturing	-1.090***	-0.547***
	(0.118)	(0.0873)
Energy	-1.156***	-0.471*
	(0.211)	(0.242)
Construction	-1.399***	-0.778***
	(0.166)	(0.106)
Financial	-0.367**	-0.191
	(0.143)	(0.128)
Constant	-0.399**	-0.593***
	(0.183)	(0.156)
Observations	15870	15870

Notes: Robust standard errors clustered by countries.
*** p<0.01, ** p<0.05, * p<0.1
Source: Authors based on the data from Flash Eurobarometer 537 (2023).

We also found some significant effects of industry on both dependent variables. All industries except for the ICT industry (as the baseline category), appear to have a negative correlation with AI adoption. These results are not surprising because the ICT sector is the one that is very closely linked with AI. Moreover, the construction sector appears to be significantly lagging. This is in line with previous findings such as [30], who argue that AI technology is gaining ground only very slowly in construction due to several industry-specific challenges. Adoption of digital technology is slower due to the specific nature of the construction industry as well as financial and managerial problems in the field [31].

However, the differences among industries should be examined in more detail in future research. There are also several external factors that could potentially influence the probability of AI adoption in companies. This includes financial and non-financial external support from the government or other institutions. Here we also see a potential path for future research.

Despite the best efforts to use relevant and sound methodology, it is also important to mention some limitations of this research. The results of regression cannot be directly interpreted as causal effects due to potential problems with endogeneity, which cannot be ruled out. However, the results are still valid for explaining associations. Problems related to omitted variables have been minimized by the inclusion of control variables. However, the research is not able to identify the possible effect of other potential factors that cannot be captured within the available data or through proxy variables.

V. CONCLUSIONS

Our findings shed light on factors potentially affecting AI adoption as well as those affecting its effect on skill needs in companies. The results achieved helped us answer the three research hypotheses stated in the introduction. Several significant factors related to AI adoption have been found. These factors include the size of the company, employees' ages, turnover growth, and community size. Moreover, problems with hiring skills and shortages of certain skills, such as IT skills and customer care skills, also play a crucial role in the adoption of AI.

To some extent, similar factors were found to be associated with the expected effect of AI on infirm skill needs. However, there are also some crucial differences. Community size and difficulties with hiring skills are not considered significant factors affecting the expected consequences of AI adoption on skills needed in companies.

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Original Scientific Article

Knowledge Management: A Basis for using Renewable Energy Sources

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Abstract—**The use of clean and sustainable technologies necessitates a high level of professional expertise, particularly during the installation phase. Importing foreign technologies in the field of sustainable energy sources is possible even with limited knowledge, but it is not always the best solution. Knowledge about contemporary technologies and energy efficiency is a must when it comes to the development of the energy sector. Strategic management is essential for avoiding problems. Knowledge is the key resource that provides a competitive advantage in the European market. For the duration of the intended use, financial benefits can be obtained from investments in modern solutions and increased energy efficiency; however, in the opposite case, it would be necessary to justify the losses. Strategic management plays an important role in the development of the energy sector because it can provide significant long-term benefits while requiring the same level of financial investment. Lack of knowledge results in minimal savings, technical problems, lower energy efficiency, and a shorter exploitation period. Effective knowledge management in the field of applying renewable energy sources is also crucial for the implementation phase, which involves maintaining installed equipment. The paper discusses the importance of having educated personnel who will perform tasks related to renewable energy installation and maintenance. One of the most crucial requirements for achieving the goals outlined in the Energy Sector Development Strategy of the Republic of Serbia up to 2025 with Projections up to 2030.**

Keywords - strategic knowledge management, intellectual capital, energy sector, safety, environment

I. Introduction

Strategic knowledge management, as an important factor in market survival, offers a number of benefits in terms of energy and technological development. The education of new employees is influenced by appealing educational programs and the already established cost of labour. Long-term competitive advantage can be achieved by identifying market needs and investing in knowledge. It is becoming more and more important to take intellectual capital into account, not just economic resources. A high level of knowledge leads to financial gains, and ensures environmental protection and safe working conditions at the same time. Therefore, it is necessary to create and adopt a knowledge management strategy at the national, regional, and local level. The process of knowledge management at the enterprise level indicates the fact that the employer is starting to recognize the value of key resources for business improvement. A basic case study that examines the operations of a wind park installation company can highlight the significance of this knowledge. In this case, importing obsolete equipment for wind energy applications has many shortcomings – it does not provide a 25-year use period, and it requires a huge space for storing propellers that have reached the end of their useful life. In this case, in a short period of time, the employer must plan the purchase of wind generator storage space, pay off the equipment, and invest significant funds in maintenance. Using knowledge to choose more modern and energy-efficient wind generators improves the financial benefit and reduces the payback period.

II. Managing the Development of Sustainable Energy Sector

The development of a sustainable energy sector should be based on the use of renewable energy sources, as well as the possibility of saving fossil fuel reserves. Improving the technology for converting raw materials into electricity in its final form also implies opening new vacancies. It is unrealistic to expect that new technologies will be implemented through retraining processes. In specific cases, miners should be given the option to continue with their regular jobs, but not to be authorised to install and maintain solar power plants or wind generators.

Opening job vacancies for performing installation of modern energy plants requires the education and training of workers for suitable positions. Educating workers is a requirement by which all operations must be carried out with the proper application of safety measures and workplace health and safety legal requirements.

The Energy Sector Development Strategy [1] looks to replace the use of coal with renewable energy sources while considering the possibility of ceasing operations for coal-fired thermal power plants. The goal of new strategic solutions must be based entirely on intellectual capital. Otherwise, Serbia expects to import not only modern energy technologies but also investments in foreign intellectual capital.

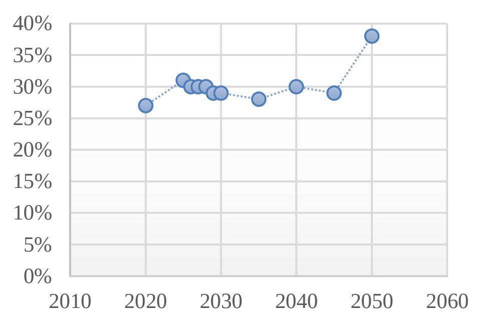

Figure 1. The share of renewable energy sources in the production of electricity in the 2020-2050 period [2]

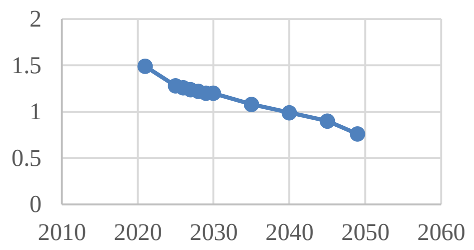

Figure 2. Intensity of CO_2 emissions per unit of GDP (kg CO_2 from energy sources/ € GDP), in the 2020-2050 period [2]

Fig. 1 depicts the planned share of renewable energy sources in Serbian electricity production until 2050.

Fig. 2 shows the intensity of CO_2 reduction per gross domestic product (GDP) [2].

Based on Fig. 2, which depicts the projected development of the renewable energy sector, it is concluded that the period after 2040, when a significant need for professional staff is anticipated, should be prepared. However, the process of redirecting intellectual capital to renewable energy sources should begin as soon as possible, as there are real needs even earlier. Although the picture shows a consistent trend in the share of clean technologies, it should be noted that a reduction in the use of fossil fuels is expected even sooner due to obligations to the European Union.

Fig. 2 clearly shows that CO_2 emissions per unit of gross social product are expected to decrease beginning in 2030. Based on this, it is concluded that, in addition to training personnel for the use of renewable energy sources, it is necessary to invest in the retraining of workers who will be responsible for the maintenance of the air purification system.

Table I shows the estimated number of workers needed for the installation, operation, and maintenance of solar power plants, wind farms, and biomass processing plants.

The data from Table I show that the number of qualified workers depends on the installed capacities.

Planning should be completed during the first knowledge management phase, taking into account the projected modern installed capacities. The phase of organizing educational

TABLE I. EMPLOYMENT FACTORS DEPENDING ON TECHNOLOGY [2].

Technology	Installation		Work and maintenance	
	(Person-year/MW)		*(Jobs/MW)*	
Solar power plants	10	15	0,2	0,4
Wind turbines on land	10	15	0,2	0,4
Plants for biomass	15	20	0,2	0,4

activities in the energy sector should not be delayed, as training personnel for the tasks of installing and maintaining power plants is a complex process. Relying on international staff has a significant impact on the decision-making process in the implementation and control phases, but also on the use of electricity.

III. KNOWLEDGE MANAGEMENT IN THE FIELD OF RENEWABLE ENERGY SOURCES

Knowledge management planning in the field of renewable energy sources requires the implementation of development plans for wind, solar, and biomass energy. Assessments are primarily based on studies about existing experiences. Many studies have been conducted to assess the number of new jobs in EU countries. Appropriate data should be obtained from countries with similar characteristics to the Serbian energy sector and available energy resources.

Figure 3. Estimation of the number of new jobs resulting from the introduction of new wind energy capacities (installation – left, maintain - right) [2]

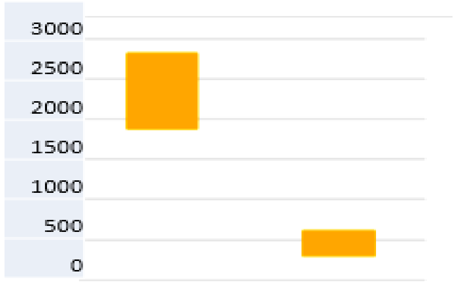

Figure 4. Estimation of the number of new jobs resulting from the introduction of new solar energy capacities (installation – left, maintain - right) [2]

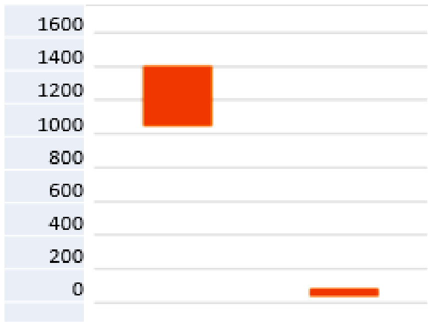

Figure 5. Estimation of the number of new jobs resulting from the introduction of new biomass energy capacities (installation – left, maintain - right) [2]

Based on experience in EU countries, the construction time for energy plants is estimated to be one year for solar power plants and two years for wind and biomass power plants [2].

Fig. 3, 4, and 5 show job estimates resulting from the introduction of new energy capacities based on renewable energy sources such as wind, solar, and biomass.

Fig. 3, 4, and 5 show that the required number of workers was assessed for the period up to 2030 and that it encompasses the maintenance and installation of additional capacity.

Fig. 3 shows that 1,900 to 2,800 new workers will be hired to complete the wind power plant installation, as well as 600 to 1,200 workers to maintain the wind energy transformation system.

Fig. 4 shows that a similar number of workers should be provided for solar power plant installation, but fewer workers are required for maintenance (from 300 to 600).

The installation of a power plant for biomass processing is expected to secure employment for 1,050–1,400 additional workers, as seen in Fig.5. In this case, approximately 100 workers will be assigned to the maintenance of the biomass processing plant, which is the smallest number of workers among the analysed power plants.

Assessments show that there is an urgent need for highly qualified employees, so it is critical to begin the process of knowledge management in the field of renewable energy sources immediately. The required number of workers for the expansion of the electricity distribution network should be considered in addition to the estimated number of workers; however, Serbia is thought to have the necessary personnel.

IV. Knowledge Management Model in the Field of Sustainable Energy Resources

Knowledge management in the field of renewable energy sources largely depends on national energy policies, the adopted energy development strategy, assumed international obligations [3], and financial resources. Apart from the aforementioned variables, the execution of energy-related plans also depends on the preparedness of potential students to acquire knowledge and recognize the perspective of the developments in the energy sector. It is necessary to inform the public about national plans so that potential candidates can adopt modern knowledge. Implementing study programs related to the use of renewable energy sources is also a significant challenge, especially in conditions where faculties, despite students' lack of interest, continue to implement programs that do not provide a competitive advantage in the labour market. Teaching programs that have no real application and are not innovated in accordance with the development of new technologies pose a unique challenge in the knowledge management process. Information that is currently available remains an unused strategic resource unless people apply specific skills and knowledge in the fields of innovation, design, installation of new technologies, and maintenance of modern energy systems. The interval between the introduction of contemporary technology and the time it takes to carry out plans and make decisions presents a unique challenge, because the lack of readiness slows down technological development. The use of advanced technologies, grounded in

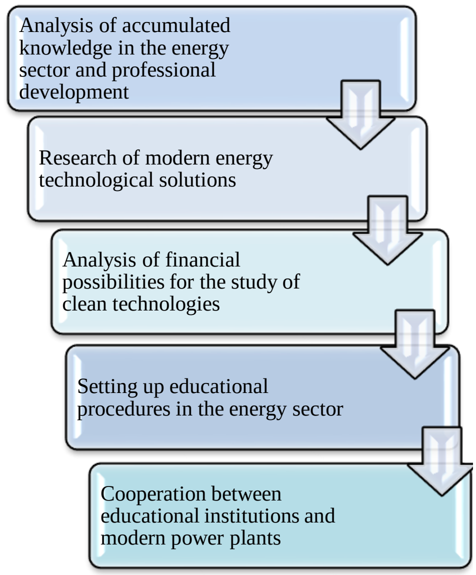

Figure 6. Model of knowledge management in the field of renewable energy sources

professional expertise, necessitates continuous learning and the timely application of acquired skills. Energy managers have a significant responsibility to support the development of energy because, since in the process of obtaining the necessary licenses, they learn about legal norms, energy transformations, and management.

Participation in decision-making should require the application of useful knowledge.

V. Knowledge Management and Renewable Energy Sources

Specific technological achievements, in the field of renewable sources, affect sustainable energy development. A wind system with a 20-year life expectancy results in an average of 40.7 g CO_2/kWh, and 30-years reduces it to 25.3 g CO_2/kWh [4].

The life expectancy of solar and wind energy systems has a significant impact on greenhouse gas emissions. The majority of greenhouse gasses for PV and wind are generated during the extraction and manufacturing and installation process. Thus the longer life expectancy the lower greenhouse gas emissions through the whole life of the system [5].

Effective knowledge and strategic management are key to realizing the needs of stakeholders, over a longer period of time.

Community engagement and awareness are emphasized as crucial factors in renewable energy education [6].

Organizations in the energy sector can implement and improve practical knowledge management systems. The advantage of applying intellectual capital is the use of the latest technologies.

The Build Up initiative was launched at the European level, which includes 30 projects in 30 European countries financed within the CIP Intelligent Energy Europe program [6]. The goal of the initiative is to bring together relevant people to work on achieving the necessary skills of workers.

Concrete examples of the application of knowledge management strategies in the field of energy still represent a corporate advantage. Fossil fuel reserves are low, and renewable resource technology is improving. Competitive advantage is achieved by applying more energy efficient systems. Knowledge sharing is not at a high level in the energy industry. The problem can be solved by creating knowledge management tools. It is necessary to integrate knowledge management software into existing management systems. In this way, the objectives of the application of renewable energy sources can be harmonized with the development of technology. Using feedback and a systemic approach to problem solving contributes to sustainable energy development.

The energy sector in Serbia, based on renewable energy sources, is developing. Strategic knowledge management includes the accreditation of new educational programs in the field of energy. In Serbia, engineers of renewable energy sources are educated in Novi Sad. Schools in Nis, Pirot, Kula and Sombor educate technicians of renewable energy sources. The number of pupils and students is small compared to the plans foreseen in the Energy Sector Development Strategy. Advanced countries invest more in training workers to solve specific problems, in the area of safety, risk, energy efficiency and the environment.

Comparative analysis can contribute to the comparison of the results of the work of different energy sectors. It is necessary to create a set of clear, relevant and measurable indicators. Before that, the area of application and the type of renewable source should be defined. Key indicators in the field of wind and solar energy use should be based on fire indicators and knowledge management indicators. The comparative analysis provides the necessary data for the development of the energy sector.

The causes of fires at PVPP sites vary and the most common causes include the faulty installation of quick couplers or the selection of incorrect quick couplers, inadequate cable routing, failure to use shields on them, or the use of inadequate adapters, which can lead to electric arc formation that directly causes fires. Sometimes, there are design errors, including too many parallel connections that have affected several installations. Occasionally, fires are caused by animals that damage the installations. This means that fires are started by the panels and then proceed to the soil surface and vice versa [7].

The analysis further explores pedagogical approaches, learning tools and the training required for educators and trainers in the field of renewable energy [6]. Organizations can conduct joint research and solve problems together. Development of a strategic plan includes: development of a training program, selection of quality lecturers, creation of knowledge management indicators and consideration of specific problems.

VI. CONCLUSION

Knowledge management, whether in the energy sector or elsewhere, is essential for improving technological processes, preserving environmental quality, and increasing worker safety. If the knowledge management process yields positive results, the acquired intellectual capital should be considered a national asset that should be retained in the country rather than transferred to other countries that understand how to value it.

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Original Scientific Article

Scientific Illusions in Psychological Practice

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Abstract—**The article briefly examines the issue of the emergence of scientific illusions using two cases from psychological practice as an example. They are formed when the behavior of a complex system has to be placed in the Procrustean bed of a simplified model that corresponds to current scientific ideas and assumptions. It is shown that the so-called "Conjunction Fallacy" and the product-based experimental approach, which is inappropriate for generative processes in adiaphoric systems, presented in the book "Ways of Worldmaking", can be considered as scientific illusions. The presence of scientific illusions can be seen on the basis of the approach of transcendental psychology. It leads to a significant shift in scientific views, including ideas about the design and interpretation of experiments related to perception and cognition. On this basis, the concept of adiaphoric systems is presented and the possibilities of studying the generative processes in adiaphoric systems are shown.**

Keywords - probability, conjunction fallacy, apparent motion, scientific illusion, transcendental psychology

I. Introduction

Many scientific theories and mathematical methods have an attractive precision and a familiar obviousness. In practice, this can lead to errors and scientific illusions when the applicability of a theory or method to a given problem is insufficiently substantiated and verified. The basis of errors here are the initial explicit and often implicit propositional attitudes present in the original scientific paradigms.

This is especially true for sciences associated with complex systems and, in particular, for psychology, when relatively simple scientific concepts and norms are used to explain complex behavior. If this behavior does not fit into the existing norm, then perhaps it is not worth looking for a problem in this behavior. It would be more reasonable to start checking the limits of the real applicability of the scientific model used to form the corresponding norm of behavior. A simplified model may not correspond to a more complex system that is trying to fit into the Procrustean bed of this model. At the same time, changing the research model used is often difficult to implement, since understanding the illusion requires a transition to another paradigm, which presupposes a significant change in the accepted way of thinking.

This paper presents two examples of scientific illusions concerning the study of perception and decision-making processes in psychology [1,2]. The transition to a new scientific paradigm of transcendental psychology of perception [2,3] allows us to reveal both the peculiar fallacy of a number of well-known psychological studies and to outline ways of more adequately examining the corresponding psychological phenomena related to generative processes in so-called adiaphoric systems.

II. Conjunction Fallacy

The first example of a scientific illusion involves applying simple rules of probability theory to random events in psychology. According to probability theory, the probability of two or more random events combining is always less than the probability of a single event. However, experiments show that psychologically people tend to make mistakes and believe that the probability of two events is higher than the probability of a single event [4].

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The reasons why such inappropriate behavior occurs and why violations of the probability pooling rule are so common are generally unclear and poorly explained [5,6]. Attempts to explain the systematic nature of unification rule violations have even led to the idea that cognitive processes are akin to quantum phenomena [7].

The nature of the processes of perception differs from the logic of probabilistic processes and has a generative co-presented character. In the reality of perception, an object with many simultaneously present and mutually related (co-presented) properties is much more probable than an abstract object with no or only a small number of properties. Events co-presented in perception are interconnected, have a common origin and are related to the individual representing them.

Without changing the theory of probability itself, it is advisable to use models of events that ensure the presence of this co-representation for modeling psychological phenomena. A simple example of interrelated events is the fall of a double coin, which can suddenly split into two parts, like the opening of a medallion (Fig. 1).

More complex is the model of a dice in the form of a rhombicuboctahedron, which is a three-dimensional figure consisting of 8 triangles and 18 squares (Fig. 2).

When observing perpendicular to the plane of the dropped face, the probability of seeing a particular combination of several cubic faces (colored dark red in the figure) is generally more than twice as high as the probability of seeing only one of these faces [8].

Figure 1. Example of a medallion

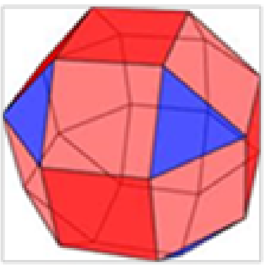

Figure 2. Type of rhombicuboctahedron

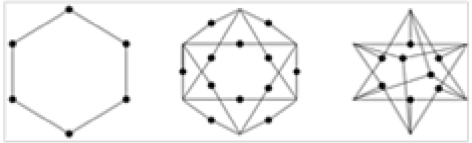

Figure 3. Test states of the rhombicuboctahedron

To analyze states and the probability of their occurrence, it is convenient to use the concept of a test space [9]. We have: 6 states of seeing one face of the primary cube; 12 states of seeing two faces of the primary cube; 8 states of seeing three faces of the primary cube (Fig. 3).

Based on the developed model of co-presented events, the conjunction fallacy can be overcome and it can be shown that human heuristic behavior in assessing the probabilities of random events should not be considered erroneous. In fact, when applying the scientific norms of probability theory, it is necessary to build new models that take into account the complex nature of human perception. As a result, it can be stated that the "Conjunction fallacy" is a scientific illusion.

It is known that an illusion usually means some deception of the senses, leading to a distorted perception of existing objects or phenomena. In science, they appear before us in the form of ideal and, moreover, idealized (non-existent in reality) abstract ideas and models of the world, accepted in the learning process. Illusions in science are connected with the problem of scientists' vision of these objects or phenomena through the prism of these models, as corresponding to the scientific picture of the world. A scientific illusion in this sense turns out to be a situation when the accepted model is not subject to doubt and turns out to be a measure of the truth of the fragment of the world being studied. The possibility of different initial foundations accepted in a specific science naturally leads to the construction of different models of the world being studied and to ambiguous resulting interpretations that have different degrees of validity in relation to truth.

III. WAYS OF WORLDMAKING

The second example of a scientific illusion is more difficult to directly understand. Let us consider it based on the description of P. Kolers' experiments in N. Goodman's book "Ways of Worldmaking" [10]. It is known that this phenomenon of apparent movement was a dramatic violation of the idea of a direct correspondence between physical stimulus and psychological experience [10]. P. Kolers demonstrated experimentally that if the first stimulus spot is round and the second is square, then the moving spot seen is smoothly transformed from a circle into a square; transformations between two-dimensional and three-dimensional forms often occur smoothly without any problems.

And here the question arises: how great a difference is required to interrupt the smooth transition and separate the visible events in the same way as physical ones? Using a variety of shapes, perhaps in this experiment one can discover the degree of similarity of different shapes. It can be assumed that two figures are more similar to each other, the more easily and smoothly they are transformed into each other. Forms with individual features can transform into each other in different ways (with different smoothness) during visible movement.

If so, these features may be decisive in the formation (development) of forms. Thus, it is possible, apparently, to find the "bricks" from which visual perception is built. With the traditional approach, this task seems tempting and it is impossible to predict a negative result of experiments in advance. However, the result is negative and the visible change does not represent a sensitive instrument for measuring the similarity of forms [10]. Such a result can be predicted in advance using the approach of transcendental psychology, based on the idea of form-generation in the process of direct perception [10].

In this case, the form and its properties are generated in the process of perception, and properties that have not yet been generated cannot determine the mechanism of the process of their own generation. Processes whose mechanisms (regardless of their complexity) are not determined by the properties of their products and do not depend on them can be called generative. These mechanisms are a kind of adiaphora in relation to their products. Adiaphora in the philosophical sense is a term representing the indifference of that which has no immediate relation to the moral good or evil that is significant for life. Systems with such generative mechanisms can be called adiaphoric systems.

The use of the concept of "adiaphora" in a new context allows us to reveal an important hidden meaning of the term "generation", often used in psychology, which indicates the complex and often incomprehensible nature of the processes taking place. In particular, perceptual processes are adiaphoric in the sense that they seem to specifically generate new structures and forms by mechanisms that are indifferent to the products involved and their properties. As a result, these properties then do not contain any adequate information for knowing the corresponding mechanisms.

Figure 4. A metaphorical representation of the functional (over water) and transcendental (under water) views on aquatic vegetation, related to different approaches to the study of perceptual processes

Metaphorically, one can distinguish between product-based (functional) and transcendental views (Fig. 4). The properties of vegetation on the water surface have nothing in common with the processes of underwater life and plant growth.

In the experiments of P. Kolers, in fact, the product-based approach [2] is used in the study of the adiaphoric system. It is initially accepted that some of the forms or properties of perceived objects can become an adequate measure and serve to create an explanation of the process of perception. It turns out that P. Kolers' experiment could not have been done, since its negative result can be predicted in advance [3]. In fact, the source of the scientific illusion about the possible positive result of the experiment in this case is the product approach itself, which resembles the inevitable cognitive illusion associated with accepting obvious data as satisfactory grounds for further reasoning without properly analyzing the adequacy of the chosen grounds [11].

The product approach has a natural justification and is associated with the implementation of the identification of the characteristics of the mental process with its subject-content result. Historically, the adequacy of the relationship between the object and the result of its perception has had great functional and practical significance for the successful activity of a person. At the same time, the directly procedural side of the perception process did not have such a great significance for the activity.

IV. Study of Adiaphoric Systems

Adiaphoric systems are characteristic not only of the psyche, but, apparently, often occur in structures at the junction between different sciences [12]. It is important to note that adiaphoric systems, in fact, require a different experimental approach to find the mechanisms of their processes, since in this case it makes no sense to use the product-based approach. The researcher must look for a way to penetrate the process being studied, which requires a change in the way of thinking and a change in the researcher's point of view, taking into account the possibility of its becoming dynamic [2].

If, as often happens in psychology, it is difficult or practically impossible to penetrate the process, then the way out is to expand the context of the research by creating on a scientific basis some more general new philosophy with a broader axiomatics of hypothetical natural scientific procedural principles. The approach of transcendental psychology of perception, founded by A. Mirakyan, represents precisely such an opportunity for conducting research [2,3]. Experimental research here is aimed at identifying the action of these fundamental process features and the corresponding verification of the initial procedural principles. In particular, the development of new process models on the basis of these principles allows us to predict new phenomena, which can then possibly be discovered experimentally.

In the practice of studying perception, the fact that it is essentially impossible to understand the procedural mechanism of an adiaphoric system based on the properties of the initial and resulting parts and products of a normally functioning process means that within the functional range of the process of direct sensory perception, its mechanisms do not in any way manifest their features in real phenomena of perception and, therefore, their real characteristics cannot be identified or experimentally studied in this way [2,3]. In this case, one should abandon the traditional principle of ecological validity and keep in mind such, in essence, a conflict situation in perception, which can occur when going beyond the boundaries of the functional range of perception, that is, when stimulating at the edge or beyond the boundaries of this range. In particular, this can occur in the case of critical spatiotemporal conditions of perception, for example, in various conditions of limiting the time of perception of objects [2,13]. In this case, one can expect the appearance of such phenomena of perception, which in one way or another can manifest the supposed internal mechanisms of the process of perception and in this connection make these mechanisms experimentally observable. The idea of an experimental approach to the verification of models of form generation in the transcendental psychology of perception is based on this assumption.

A specific experimental study of one of the models of transcendental psychology, conducted in work [13], made it possible to demonstrate the presence of the so-called reversed Fröhlich effect in visual perception. Another interesting phenomenon we discovered is related to the socio-psychological effect of perceptual-semantic blindness [14].

V. Conclusion

Since the method of simplifying phenomena in one way or another is one of the foundations of science, the possibility of scientific illusions appearing in scientific practice is not something fundamentally out of the ordinary. The two scientific illusions considered in the article are connected with the use by researchers of precisely such simplified models of more complex processes or phenomena.

In the first case, a simplified model of human behavior is used from the probability theory model developed when considering relatively simple random events, for example, those related to actions with inanimate objects such as a coin or a dice. The proposed extension of the model involves considering events that occur with objects that have a wider range of possible states, including the joint observation of random events. This situation is not rare and constantly arises in cases of different projection geometries or in the presence of a hierarchy. It should be noted that models with the joint occurrence of random events do not correspond to the standard axiomatics of elementary probability theory and necessarily require an expansion of the boundaries of this theory. It is known that another related request for an expansion of probability theory comes from the field of quantum mechanics and is associated with the implementation of the complementarity principle using the concept of a test space [9]. At the same time, this principle itself also has psychological origins [15].

In the second case, the naturally formed approach of finding the characteristic qualities of a mental process based on the properties of the products of this process serves as an experimental model basis. Such a product approach, in principle, works well for the case of considering information systems and is currently receiving further expansion of its use given the development of modern information technologies. Going beyond the use of the product approach is difficult even at the philosophical level, since the entire arsenal of scientific capabilities available to humans is based on mental products. Strategies related to the transition from psychology to the level of psycho or neurophysiology, although they can lead to successful solutions, are unlikely to be decisive in the study of mental processes. In this regard, the approach proposed by transcendental psychology, although not simple and obviously successful, may be of interest to a wider area of psychological research and, in general, research into the mechanisms of generative processes in so-called adiaphoric systems.

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Original Scientific Article

The Importance of Knowledge Management in the Field of Occupational Safety and Health in Supply Chains

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Abstract—**Modern working conditions increasingly impose the need for employee efficiency and productivity, but not at the expense of their occupational safety and health. Literature and international law are continually seeking ways to protect employees' rights as effectively as possible. In achieving this goal, the concept of corporate due diligence in supply chains and the legal instruments it encompasses, particularly the internal grievance mechanism, play a significant role. The paper analyzes the connection between three concepts – knowledge management, corporate due diligence in supply chains and occupational safety and health. Even though their interdependence may not be immediately apparent, the paper highlights this connection and the special importance that knowledge management has in protecting employee rights in supply chains.**

Keywords - knowlegde management, due diligence, supply chains, occupational safety and health

I. INTRODUCTION

Occupational safety and health is one of the fundamental human rights proclaimed by numerous international documents [1,2]. It is well known in literature and practice that safe and healthy employees are the foundation of productivity in any organization [3-5]. Occupational safety and health is a key strategic goal for our country, as well as for all relevant international organizations [6]. One of the most important factors in increasing employees' efficiency and productivity is the employers' ability to develop a work environment in which employees perceive the organization's goals as their own and take responsibility, without the need for constant supervision. In order to achieve this goal, employers are required to respect employees' needs and ensure their sense of safety and workplace dignity.

One of the important prerequisites for the prevention of workplace injuries and occupational diseases, as well as for establishing an effective occupational safety and health system in a business organization, is knowledge management. It involves the identification, optimization, and active management of intellectual capabilities, either in the form of explicit knowledge contained in artificial sources or in the form of implicit knowledge held by individuals or communities [7]. The literature increasingly emphasizes the human factor in knowledge management, asserting that people are a crucial part of the management process, while information and communication technologies provide support to these processes. In practice, the aim of knowledge management is to train employees to perform their work tasks, as well as to provide broader education by accessing knowledge bases and interacting with other individuals and groups through information and communication technologies. Knowledge management serves to increase the amount of implicit knowledge that an individual possesses and applies to solving specific problems, as well as to create new knowledge [8].

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One relatively new area where knowledge can be effectively managed is occupational safety and health of employees in supply chains. The idea behind the concept of corporate due diligence in supply chains is the protection of human rights [9], which includes the rights of employees and the prevention of forced labor in global supply chains. The goal of this concept is to ensure that companies take appropriate steps to establish and implement due diligence measures concerning their own operations and those of their suppliers. This involves the obligations of companies regarding actual and potential negative impacts on human rights (including the right to occupational safety and health) and the environment, considering their operations, the operations of their subsidiaries, and activities in the supply chain conducted by entities with which the company has a business relationship. The idea is that every company in the supply chain should define conditions and procedures that enable the protection of human rights and the environment, which includes the right to safe and healthy working conditions.

This paper analyzes the possibilities that knowledge management offers in the field of employee protection in supply chains. It establishes a connection between knowledge management, corporate due diligence in supply chains and occupational safety and health, emphasizing the special importance of knowledge management in protecting employee rights in supply chains.

II. The Concept of Knowledge Management in Occupational Safety and Health

The concept of knowledge management has been known for a long time, but towards the end of the 20th century, educational and scientific institutions, as well as employers, began to pay more attention to this issue, gradually recognizing its role and importance. In the literature, there are several definitions of knowledge management. There is no single and universally accepted one, but the basic starting point is finding an answer to the question 'how can knowledge contribute to the organization' [10].

Knowledge management deals with making the right knowledge available to the right people. It involves creating an environment where an organization can learn and effectively retrieve and use its knowledge base as needed in current situations [11]. Knowledge management is every process or practice of creating, acquiring, understanding, sharing, and using knowledge, regardless of its location, in order to improve performance and work within organizations [12]. It is the process of creating, gathering, and utilizing knowledge to enhance organizational performance [10]. Knowledge management encompasses all methods, tools, and mechanisms that contribute to the promotion of the core values of the knowledge process through a holistic approach [13]. It is a modern interdisciplinary business concept that includes people, technology, and all processes that enable the creation, dissemination, and use of knowledge to achieve organizational goals. Various opportunities for the optimal use of knowledge, its distribution, transfer, and application in accordance with safety requirements and the needs for promoting and protecting occupational health are of particular importance [8].

With regard to the relationship between the concept of knowledge management and occupational safety and health, knowledge management is observed as the formation and enhancement of knowledge systems and the incorporation of safety systems into the framework of knowledge systems. Knowledge management in occupational safety involves the development and management of integrated, well-structured knowledge systems tailored to the safety and health needs of the organization [8]. It enables the organization to effectively identify issues in the field of occupational safety and health and to assess the data, information, and knowledge needed to address these issues. The significance of knowledge management in work organizations is evident both in the onboarding and training of new employees and in job changes, requalification, upskilling, production planning, introduction of new work procedures and technologies, innovation in production processes, implementation of occupational safety management standards, environmental standards, and quality systems, as well as new regulations, provisions, and obligations related to risk assessment and management in the workplace and the environment, etc.

The concept of knowledge management can be placed in the context of occupational safety and health in supply chains. This represents an innovative approach to occupational safety from the perspective of connecting a larger number of employers and their employees, especially considering that they often operate in different countries, which implies varying legal systems and legal solutions in the field of occupational safety and health.

III. Due Diligence in Supply Chains

In modern working conditions, with rapid communication, increasing business demands, and market globalization, the concept of due diligence represents one of the foundations of successful business operations [14]. Business strategies of organizations should operate with due care, and this concept should underpin their work, creation, and implementation of business policies.

Like knowledge management, due diligence is also a concept which requires numerous definitions. In law, it is the level of caution that a reasonable person exercises to avoid harm to other persons or their property; in business, it is research and analysis of a company or organization done in preparation for a business transaction [15]. Considering the role of due diligence in international law, two important facts should be taken into consideration. Due diligence may be a constituent part of a primary rule of international law, but this can only be determined by referring back to the primary rule in question. There is no "general principle of due diligence" in international law; rather, this principle must be implemented in some international legal act. States undertake what could be characterised as 'due diligence' activity, some elements of which may be a result of a legal requirement and some of which may not [16].

European Commission adopted the Directive on Corporate Sustainability Due Diligence in July 2024 [17] with the aim of fostering sustainable and responsible corporate behavior and anchoring human rights and environmental considerations in companies' operations and corporate governance. The new rules are to ensure that organizations address adverse impacts of their actions, including in their value chains inside and outside Europe [18]. This Directive establishes a corporate due diligence duty. This duty consists of identifying, completing, preventing, mitigating and accounting for negative human rights and environmental impacts in the company's own operations, their subsidiaries and their value chains.

Several European Union member states have enacted due diligence laws, some are in the process of enacting them, and others are considering the possibilities of enacting them. In the spirit of introducing corporate due diligence obligations, Germany adopted the Act on Corporate Due Diligence Obligations in Supply Chains in 2021, which came into effect in 2023 [19]. This act imposes an obligation on German companies to take responsibility not only for their own activities but also for the activities of their partners that endanger human rights (including occupational safety and health) and the environment, whether it involves the procurement of input components that German companies further process or the sale of their final products. This means that the law also applies to all Serbian companies that have business relationships with German companies. According to this law, companies must establish an appropriate and effective risk management system to comply with due diligence obligations. Risk management must be integrated into all relevant business processes through appropriate measures. Effective measures are those that allow for the identification and minimization of human rights and environment-related risks and to prevent, end, or minimize the extent of human rights-related (which includes occupational safety and health) or environment-related obligations if the company has caused or contributed to these risks or violations within the supply chain. The company is obliged to determine who is responsible for monitoring risk management in the company, for example, by appointing a human rights officer. Senior management must seek information on a regular basis, at least once a year, about the work of the responsible person or persons. In establishing and implementing the risk management system, the company must consider the interests of its employees, employees within supply chains, and those who may otherwise be directly affected in a protected legal position by the economic activities of the enterprise or by the economic activities of an enterprise in its supply chains [19]. All this enables a significant expansion of the scope of this law beyond Germany.

IV. Knowledge Management, Corporate Due Diligence and Occupational Safety and Health

Considering the nature and characteristics of knowledge management, corporate due diligence, and occupational safety and health, a connection and mutual interdependence among these concepts can be identified. Occupational safety and health itself represents one of the fundamental human rights and belongs to economic rights [1,2]. The Directive on Corporate Sustainability Due Diligence and the German Act on Corporate Due Diligence Obligations in Supply Chains require companies to take responsibility for their own activities as well as the activities conducted by their partners that may violate human rights, which includes rights related to occupational safety and health. Therefore, the connection between occupational safety and health and corporate due diligence in supply chains has only been established relatively recently. This is confirmed by the fact that the Directive on Corporate Sustainability Due Diligence was only adopted in July this year.

Although the role of knowledge management in the relationship between corporate due diligence and occupational safety and health might not be immediately apparent, these two concepts are actually based on knowledge management. To effectively implement corporate due diligence in supply chains and develop mechanisms to protect employee rights in the field of occupational safety and health within supply chains, it is essential to possess and efficiently manage knowledge.

An internal grievance mechanism is a legal instrument provided by these documents. It requires employers in supply chains to establish grievance procedures for employees. These procedures should be available for situations where employees believe that their human rights have been violated, including rights related to occupational safety and health. Such a mechanism would enable employees to effectively communicate with their employer about instances of rights violations in the workplace, while being protected from retaliation for reporting these violations. Such information can be highly beneficial for employers, as it avoids initiating arbitration or legal proceedings, or involving inspection services. It allows employers to address and rectify the situation of rights violations based on the reported issue, potentially preventing further legal actions that would require time, costs, and other resources.

V. Conclusion

One of the instruments for achieving a high level of occupational safety and health is the concept of corporate due diligence in supply chains. It plays an important role in international human rights law by defining the extent of a state's obligations to prevent and respond to infringements of human rights by private actors within its territory or jurisdiction. Large companies have been increasingly adopting due diligence processes because they can offer a competitive advantage. This approach also addresses growing market pressure for companies to operate sustainably, helping them avoid reputational risks with consumers and investors who are becoming more aware of sustainability issues [17].

There are numerous benefits and opportunities provided by the concept of corporate due diligence in protecting employees. First and foremost, special attention should be given to internal grievance mechanisms. The creation of an internal remediation mechanism should be the responsibility of a specialized expert team that considers the needs of the company and the necessity for protecting human rights of all individuals working for the company in any capacity. When developing a grievance mechanism, it is important to ensure that it includes multiple tiers, meaning that a grievance can be reviewed at various levels within the company. Additionally, the remediation mechanism should be developed within large companies operating in specific sectors and then extended to their subsidiaries, subcontractors, and all entities within the supply chain. Since internal remediation mechanisms are not recognized in our Labor law, they are established through general company documents, such as a work rule or collective agreement. Finally, and most importantly, for the internal remediation mechanism to achieve its intended effects, it is crucial that the people it is designed for are aware of it, trust it, and know how to use it. To achieve this, email addresses for complains should be transparent, all information about the process should be publicly available on the company's website, and procedures should be clear. Employees will also be encouraged to use internal grievance mechanisms if a clear timeframe for the process is provided, if procedures are clear and simple, and if results are made available. All the mentioned advantages should contribute to raising the awareness of employees about the mechanisms of protection of their rights and provide them with a simple mechanism of communication with decision makers. In perspective, this should lead to a reduction in the number of work injuries and occupational diseases of all employees at all employers in supply chains.

Despite all these advantages, corporate due diligence has one “downside”- these processes are based on voluntary standards and do not provide legal certainty for either companies or victims in case harm occurs. However, corporate due diligence and internal remediation mechanisms are not the end of employee rights protection. If a disputed issue is not resolved successfully through the internal grievance mechanism, employees have access to labor inspections, arbitration, or legal proceedings, among other options. It should also be borne in mind that corporate due diligence and internal remediation mechanisms should be applied to employers and employees in a large number of countries that are interconnected in the supply chain. All of them are subject to numerous national regulations in the field of occupational safety and health. Therefore, the voluntariness of this concept can be seen as providing the opportunity to successfully implement it while respecting the specificity and diversity of the legal systems of the countries to which it refers. In addition to respecting the diversity of legal systems, when introducing internal remediation mechanisms, the specificity of the employers themselves should be taken into account. This means that one should look at the branch of the economy in which they perform their activity, the work operations themselves that are undertaken and their risks for safety and health at work, the number of employees, means and equipment for work that are used, preventive measures that have been taken, etc.

All of the above indicates that knowledge management is an essential factor in connecting employers, employees, their rights, obligations, and opportunities. It is a key element through which employee rights can be protected within supply chains while simultaneously highlighting deficiencies in occupational safety and health. This forms the basis for successful protection of employee rights under the concept of due diligence in supply chains.

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AI-human Collaboration: Redefining Roles in the Modern Workplace

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Abstract—**This review paper examines the evolving dynamics of contemporary work environments, with a focus on the collaborative relationship between artificial intelligence (AI) systems and human workers. As AI technologies increasingly permeate various industries, they are reshaping traditional roles and processes in knowledge production. The review synthesizes recent research and real-world examples to provide insights into how organizations can effectively leverage AI-human synergies to enhance knowledge production and innovation in the modern workplace. It analyzes the current state of AI-human collaboration and investigates how AI is transforming job roles, skills requirements, and workflow processes. The paper also explores some successful AI-human partnerships in knowledge-intensive fields, discussing both the challenges and opportunities presented by this new paradigm. Additionally, the review considers the implications for organizational structure, management practices, and employee development. By examining potential future trajectories of AI-human collaboration, this paper contributes to the ongoing dialogue about the future of work in an AI-augmented world.**

Keywords - AI-human collaboration, AI integrated workplace, future of work

I. Introduction

A. Background

Artificial Intelligence (AI) has emerged as a transformative force in the modern workplace, reshaping traditional paradigms of work and collaboration. The integration of AI technologies into various industries has led to significant changes in how knowledge is created, shared, and utilized within organizations. Initially used for task automation, focusing on repetitive and rule-based activities, AI technologies have advanced to include more complex cognitive tasks. Recent developments in machine learning, natural language processing, and computer vision have further accelerated the adoption of AI across various sectors. For instance, in healthcare, AI systems are being used to assist in diagnosis and treatment planning [1] and AI algorithms are employed for fraud detection and risk assessment in finance [2].

The impact of AI on the workplace is fundamentally altering the nature of work itself, leading to the emergence of new roles and the evolution of existing ones. [3] estimated that nearly 47% of total US employment is at risk of computerization, although many researchers argue that replacing the knowledge work with AI is problematic and is more likely to augment human capabilities, reconfiguring work tasks and creating new job categories [4].

As AI systems become sophisticated, the human and AI are expected to evolve into a more collaborative partnership of “hybrid intelligence”, where both parties work together to achieve outcomes that neither could accomplish alone [5]. This collaborative approach is particularly evident in knowledge-intensive industries, where the combination of human expertise and AI capabilities can lead to enhanced problem-solving and innovation.

B. *Knowledge Co-Production*

In the context of AI-human collaboration, the concept of knowledge co-production, the joint process of generating, integrating, and applying knowledge through the collective efforts of various stakeholders [6], has garnered significant importance. In AI-human partnerships, this entails combining human expertise, imagination, and contextual comprehension with AI's data processing capabilities, pattern recognition, and predictive analytics.

The importance of knowledge co-production in the AI era can be attributed to several factors. (1) Complexity of modern challenges - many organizational problems are complex and multifaceted, and the human-AI co-production of knowledge can address these challenges by merging diverse perspectives and capacities. (2) Rapid pace of information generation – while humans provide the necessary context and interpretation, AI can sift through and analyse the high volume of generated data. (3) Need for continuous innovation - continuous innovation is vital for organizational success, and human-AI knowledge co-production can promote creativity and innovative solutions. (4) Adaptability to change - the co-production of knowledge enables organizations to be more adaptable to changing circumstances by leveraging both AI's rapid processing of new information and humans' ability to navigate ambiguity and uncertainty.

C. *Objectives and Scope of the Review*

The review aims to analyse the current state, challenges, and future directions of AI-human collaboration in knowledge co-production work. It examines how AI is transforming job roles, skills requirements, and workflow processes in knowledge-intensive fields and explores effective AI-human partnerships. It also discusses the challenges and opportunities of this new paradigm and briefly considers its implications for organizational structure, management practices, and employee development. Additionally, it examines potential future trajectories of AI-human collaboration in knowledge work and their implications for the workforce and organizations across various knowledge-intensive industries.

II. AI-HUMAN COLLABORATION

A. *Research and Recent Trends*

Recent research has emphasized key trends in the rapid integration of Artificial Intelligence (AI) into knowledge work, reshaping human-machine collaboration. Contrary to popular belief, studies suggest that AI is more likely to augment human capabilities rather than entirely replace workers. [4] argue that the most significant impact of AI will be in creating new forms of human-machine collaboration, which they term “the missing middle”.

There is a significant shift towards developing and deploying AI systems capable of performing cognitive tasks such as natural language processing, machine learning, and computer vision applications that can assist in complex decision-making processes. For example, in the legal sector, AI-powered tools are being used for contract analysis and legal research, augmenting the capabilities of human lawyers [7].

As AI systems evolve, there is a growing emphasis on developing explainable AI models, driven by the need for transparency and accountability in AI-assisted decision-making, particularly in critical sectors such as healthcare and finance [8]. The development of AI systems that incorporate human feedback and oversight, known as “human-in-the-loop” AI, is also gaining momentum [9]. With AI's increasing prevalence in knowledge work, research is addressing the ethical implications of these technologies, including bias, fairness, privacy, and societal impact [10].

B. *Job Roles and Skill Requirements*

The integration of AI into knowledge work is greatly transforming job roles and the skills required in the modern workplace. Hybrid roles, such as “AI translators” or “AI-business integration specialists”, combine domain expertise with AI literacy and can bridge the gap between technical and business needs [4]. With AI handling more routine and analytical tasks, there's an emphasis on the growing importance of human capabilities such as creativity, emotional intelligence [11].

Alongside a growing need for technical upskilling, an understanding of AI capabilities, limitations, and ethical considerations is crucial for everyone. There is a significant need for continuous learning and adaptation, requiring organizations to invest in employee reskilling and upskilling in an AI-augmented workplace [12]. As AI systems become more prevalent in decision-making processes, workers must be able to navigate the ethical implications, identify and mitigate AI bias, ensuring fairness, and privacy [13].

C. Workflow and Hybrid Work Models

AI has brought about significant changes in the structure and implementation of knowledge work. It is increasingly assuming responsibility for mundane, repetitive tasks, thereby enabling knowledge workers to dedicate their attention to more valuable activities, such as supporting journalists by freeing them from routine tasks and allowing them to focus on more complex investigative work [14]. In decision-making, AI-powered diagnostic tools are aiding doctors in interpreting medical images and providing suggestions for treatment plans [1]. Moreover, AI facilitates the customization of products and services such as the adaptive learning systems that can tailor educational content to meet the specific individual needs [15].

As AI and human workers increasingly collaborate, new work models are emerging such as (1) Centaur Intelligence, particularly evident in fields like chess, where human-AI teams have been shown to outperform both human experts and AI systems working alone [16]. (2) Collaborative and augmented Intelligence where AI work together with humans for collaborative outcomes [4] and where AI enhance the human capabilities rather than replace them. (3) Human-Guided Machine Learning that involves humans actively guiding the learning process of AI systems such as content moderation on social media platforms [17]. As AI technologies continue to advance, we can expect further refinement and development of these changes while the key challenge will be the effecting balancing of AI and human capabilities.

III. Real-World Applications of AI-Human Partnerships collaboration

A. AI-Human Partnerships Across Various Industries

Healthcare is a promising area for AI-human collaboration. IBM Watson for Oncology, trained by oncologists at Memorial Sloan Kettering Cancer Centre, analyses a patient's medical information and suggests treatment options. Watson's treatment recommendations concurred with human oncologists in 93% of lung cancer cases [18]. The healthcare sector is rapidly embracing AI technology in certain areas, but its adoption is slower in other areas due to regulatory concerns and the critical nature of medical judgments.

The finance industry typically demonstrates agility in embracing new technologies. Nevertheless, the rate of AI adoption varies across different subsectors. Major Banks and fintech startups are at the forefront, whereas smaller institutions and regulatory bodies may exhibit a slower pace of adoption. The sector’s AI-human partnerships enhance fraud detection, risk assessment, and customer service. JPMorgan Chase's COiN reviews commercial loan agreements in seconds, saving 360,000 hours annually. However, human experts still play a crucial role in interpreting complex clauses and making final decisions [19].

The integration of AI and automation in the manufacturing sector exhibits considerable variation. Prominent automotive and electronics manufacturers are leading the way, whereas smaller enterprises and those situated in developing nations may experience more gradual adoption due to financial constraints. The manufacturing has seen improved efficiency and quality control through AI-human partnerships. Siemens' Senseye Predictive Maintenance uses AI and machine learning to generate machine and maintenance worker behaviour models. This facilitates communication between users, AI, and maintenance experts [20].

In the creative fields, the Georgia Institute of Technology's AI system, Shimon, collaborates with human musicians, generating novel melodies and harmonies while human musicians provide emotional interpretation and context [21]. However, the creative industry's partnership with AI technology is heterogeneous. Certain domains, such as digital advertising, demonstrate rapid uptake of AI tools, whereas others, like traditional art or music composition, may exhibit more reluctance, stemming from apprehensions regarding authenticity and artistic integrity.

B. Factors Contributing to Effective Collaboration and Challenges

Several essential factors have been recognized as vital for successful AI-human partnerships. (1) Role Definition - AI is proficient at tasks such as data processing, pattern recognition, and rapid analysis, while humans contribute by providing context, interpreting results, and making complex decisions. (2) Transparency and Explainability - AI systems that offer clear explanations for their recommendations or decisions build trust and enable human partners to comprehend and validate the AI's reasoning. (3) Continuous Learning and Adaptation – while AI systems are regularly updated, humans receive training for effective partnership. (4) Human-centred Design - AI tools designed with human users in mind, considering their workflow and cognitive processes, tend to be more successful. (4) Ethical Considerations - ensuring that AI systems are fair, unbiased, and align with human values and legal requirements.

Despite potential benefits, AI-human partnerships encounter obstacles. Humans naturally resist change, fearing AI will replace their jobs. Organizations can address this challenge by highlighting AI's role as a tool that enhances, not replaces, human capabilities. One study found that overcoming this obstacle depends on the organizational environment and careful observation of various stages of organizational AI maturity [22]. Many professionals lack skills to effectively work with AI systems, so organizations need to upskill their workforce. Microsoft's AI Business School provides free online courses to help business leaders understand how to integrate AI into their organizations and develop AI strategies [23].

AI systems' effectiveness heavily depends on the quality of the training data. Biased or poor-quality datasets can result in inaccurate and unfair outcomes. Implementing strong data governance practices and promoting diversity within data collection and development teams are crucial strategic measures. According to a study [24], a widely used algorithm in US healthcare systems exhibited racial bias, leading to unequal allocation of resources between Black and White patients of equal illness severity. The rapid advancement of AI raises intricate regulatory and ethical concerns that organizations must actively address with regulators and ethics experts to formulate guidelines. The European Union's General Data Protection Regulation (GDPR) incorporates provisions for "the right to explanation" for decisions made by AI systems, compelling companies to create more transparent and explainable AI models [25].

IV. IMPLICATIONS AND FUTURE DIRECTIONS

A. Impact on Organizational Structure and Management Practices

AI's capacity to process and analyse large volumes of data is diminishing the necessity for multiple layers of middle management typically responsible for information synthesis and reporting. A study revealed that AI could automate up to 54% of managers' time spent on administrative coordination and control tasks [26]. Organizations are increasingly embracing more flexible, project-based team structures, which AI tools can facilitate by enabling easier knowledge sharing and collaboration. ING Bank's "Agile" transformation incorporates AI tools to facilitate real-time data analysis and rapid decision-making [27].

Further, AI is enabling more data-driven decision-making, shifting management practices to evidence-based approaches. Amazon's utilization of AI for inventory management and demand forecasting has reduced costs and improved efficiency [28].

B. Employee Development and Training Needs

The increased use of AI in knowledge work is driving the need for employees to acquire new skills and competencies. There is a growing necessity for a fundamental understanding of AI capabilities, limitations, and implications. For instance, Finland introduced a no-cost online course designed to teach the fundamentals of AI [29]. As highlighted by [18], employees must acquire expertise in effectively collaborating with AI systems, interpreting AI outputs, discerning the level of reliance, and offering feedback. With AI assuming more routine cognitive tasks, there is a heightened focus on uniquely human skills. The World Economic Forum projected that by 2025, critical thinking and problem-solving will be the most sought-after skills by employers [30]. Moreover, the swift advancement of AI calls for continual learning, making it imperative for organizations to facilitate these changes. For instance, AT&T initiated a large-scale reskilling program, investing $1 billion to retrain almost half of its workforce for new roles in the AI era [31].

C. Ethical Considerations and Potential Risks

The incorporation of AI into workplace raises numerous ethical concerns and potential risks. (1) Algorithmic Bias and Fairness - An example of this is Amazon's discontinuation of an AI recruiting tool that exhibited bias against women, indicating the fact that AI systems can perpetuate or exacerbate existing biases if not carefully designed and monitored [32]. (2) Privacy and Data Protection - The utilization of AI often necessitates vast amounts of data, prompting apprehensions regarding the privacy of employees and customers. The implementation of AI monitoring in work-from-home scenarios has notably escalated privacy concerns [33]. (3) Job Displacement and Economic Inequality - Although AI has the potential to generate new jobs, it also has the capacity to displace existing roles, thereby exacerbating economic inequality. A report suggested that by 2030, up to 14% of the global workforce may be required to transition to different occupational categories due to AI [34]. (4) Accountability and Transparency - As AI systems play a more significant role in decision-making, questions arise about accountability and the need for explainable AI. The utilization of AI in criminal justice systems, such as the COMPAS recidivism prediction tool, has given rise to concerns that have led to legal challenges [35].

D. *Future Scenarios for AI-Human Collaboration in Knowledge Work*

The future of AI-human collaboration in knowledge work holds the promise of significant transformations in our work, learning, and organizational methods. (1) Hyper-Personalized Work Environments - AI assistants could tailor various elements, such as office temperature, lighting, and task scheduling, based on individual biorhythms and productivity patterns. (2) Fluid Global Team - Real-time AI translation and cultural context providers could enable ad-hoc teams to form and collaborate seamlessly across continents and languages. (3) AI as Team Members - Increasingly sophisticated AI systems may be considered less as tools and more as team members, leading to project teams regularly including multiple AI entities working alongside humans. (4) Cognitive Augmentation - humans could utilize non-invasive brain-computer interfaces to directly access AI-powered information and cognitive support, boosting their problem-solving abilities.

V. CONCLUSION

A. *Summary of Key Findings and Insights*

Our examination of AI-human collaboration in knowledge work has uncovered significant findings and insights. Successful AI-human partnerships in various industries have leveraged the strengths of both AI (data processing, pattern recognition, rapid analysis) and humans (context understanding, complex decision-making, creativity). The integration of AI is restructuring organizational structures and management practices, leading to flatter hierarchies, more agile team structures, data-driven decision-making, and continuous performance management.

Additionally, there is a growing demand for new skills among knowledge workers, including AI literacy, human-AI interaction skills, enhanced soft skills, and a capacity for lifelong learning and adaptability. We also addressed the ethical considerations and risks, including algorithmic bias, privacy concerns, potential job displacement, and questions of accountability and transparency. Furthermore, we identified several emerging trends and technologies that are shaping the future of AI-human collaboration and potential future scenarios.

B. *Implications for Theory and Practice*

Our findings have significant implications for both theoretical understanding and practical application of AI-human collaboration. (1) Socio-technical Systems Theory - The incorporation of AI into knowledge work demands an evolution of socio-technical systems theory to perceive AI as a collaborator rather than just a tool. (2) Organizational Behaviour - Theories of organizational behaviour and management must be revisited to accommodate the changing nature of work, team dynamics, and decision-making processes. (3) Human Capital Theory - The evolving skill requirements and the necessity for continuous learning warrant a re-evaluation of human capital theory, particularly in terms of skill acquisition, valuation, and obsolescence. (4) Ethical Framework Development - There is a pressing need for the development of robust ethical frameworks that can guide the responsible development and deployment.

Furthermore, organizations need to adapt their management practices to effectively leverage AI-human collaboration, reconsidering performance evaluation, team composition, and leadership approaches. HR practices need to evolve to accommodate continuous learning and development, and the nature of jobs needs to be reconsidered to optimally combine human and AI capabilities.

C. *Recommendations for Future Research*

Long-term Impact Studies such as longitudinal studies are essential to comprehend AI-human collaboration's effects on job roles, skill requirements, and career trajectories. Research on cognitive load, stress levels, and overall well-being of humans within AI-human collaborations, as well as identifying effective methods for developing AI literacy across various contexts, are important research premises.

Further research is necessary to develop methodologies for designing and implementing ethical AI systems and to understand how cultural differences impact AI-human collaboration. Studies should explore the factors that influence trust between humans and AI systems in collaborative knowledge work settings. Assessing the economic impact and informing the development of appropriate regulatory frameworks for AI use are crucially important research areas.

D. Final Thoughts on the Future of AI-Human Collaboration

As we contemplate the future of AI-human collaboration in knowledge co-production, it is evident that we stand at the brink of a transformative era. The opportunities for augmenting human capabilities, increasing productivity, and addressing intricate problems are substantial. However, realizing these opportunities will necessitate cautious navigation of the challenges and ethical considerations that have been deliberated upon. The forthcoming landscape of knowledge work is expected to feature a mutually beneficial relationship between humans and AI, leading to a progressively indistinct boundary between human and machine contributions. This collaboration holds the potential to unlock unprecedented levels of creativity and innovation, expanding the limits of what we perceive as achievable in knowledge generation and complex-problem resolution.

Nonetheless, it is imperative that we proactively and responsibly shape this future. This involves (1) prioritizing human-centred AI development that enhances human capabilities instead of replacing them, (2) investing in education and training to ensure that the workforce can adapt to and thrive in this new paradigm, (3) establishing robust ethical frameworks and regulatory systems to guide the responsible use of AI in knowledge work, (4) promoting a culture of continuous learning and adaptability in organizations and individuals, and (5) fostering interdisciplinary collaboration to address the complex challenges that emerge at the intersection of technology, human behavior, and societal impact.

Ultimately, the success of AI-human collaboration in knowledge co-production depend on our ability to leverage the unique strengths of both human intelligence and artificial intelligence, creating synergies that propel progress and innovation. By fostering effective collaboration between human and artificial intelligence, we have the opportunity to usher in a new era, one that holds the potential to address some of the most pressing challenges facing our world.

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Original Scientific Article

Innovative Knowledge Management in Modern Supply Chains

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Abstract—**This research explores the role of innovative knowledge management in enhancing the performance, resilience, and sustainability of modern supply chains. It examines how advanced digital tools such as artificial intelligence, blockchain, and machine learning facilitate real-time data analysis, improve transparency, and support decision-making processes. The study develops a theoretical model outlining the key elements of knowledge management—creation and acquisition, sharing and dissemination, and utilization and application—alongside their sub-elements, such as data analytics, collaborative networks, and training programs. The relationships among these elements reveal how innovative knowledge practices drive process optimization, risk management, and sustainability initiatives. The research identifies several challenges, including data security, resistance to change, and integration complexities, and suggests strategies for governments, enterprises, and individuals to foster effective knowledge management. Emphasizing the need for collaboration and continuous learning, the study provides actionable insights for developing more adaptive, resilient, and sustainable supply chains in a rapidly evolving global environment.**

Keywords - knowledge management, supply chain innovation, digital tools, resilience, sustainability.

I. Introduction

Knowledge management (KM) is a crucial component in the efficient functioning of modern supply chains. It involves the systematic handling of knowledge resources within an organization, encompassing the creation, sharing, use, and management of knowledge to achieve strategic objectives. In supply chains, knowledge includes a deep understanding of processes, relationships, market conditions, and best practices that influence supply chain operations. Traditionally, KM in supply chains has relied on methods such as documentation, databases, and formalized training programs. However, these methods often fail to keep pace with the dynamic and complex nature of global supply chains, where rapid decision-making and responsiveness are essential [1]. This has created a need for innovative KM approaches that leverage modern technologies and foster more effective knowledge sharing among stakeholders.

Recent years have seen a surge in innovative practices and technologies that are reshaping the landscape of KM in supply chains. Digital tools, such as artificial intelligence (AI) and machine learning, are increasingly being integrated to enhance knowledge discovery, sharing, and utilization [2]. AI-powered systems can analyze vast amounts of supply chain data in real-time, providing insights that help organizations anticipate demand, optimize inventory, and manage risks more effectively. Machine learning algorithms can identify patterns and trends from past data, enabling proactive decision-making. Blockchain technology has also emerged as a revolutionary approach to KM in supply chains. Blockchain's decentralized ledger system enhances transparency and trust among participants by ensuring all parties have access to accurate and immutable data, reducing the risk of fraud and discrepancies.

Alongside these digital tools, there is a shift toward more collaborative and decentralized approaches to knowledge sharing in supply chains. Traditional hierarchical models, where knowledge flows from top management downwards, are increasingly giving way to networked models that emphasize peer-to-peer learning and real-time communication [3]. Digital platforms and social media tools are central to this transformation, enabling employees and partners to share insights, ideas, and best practices across organizational boundaries. These platforms facilitate the creation of knowledge-sharing networks where stakeholders collaborate to solve problems and innovate, enhancing the agility and responsiveness of the supply chain. These approaches are particularly valuable in environments characterized by high volatility, where the ability to quickly share and act on knowledge can be a decisive competitive advantage.

The impact of innovative KM practices on supply chain performance is significant. Effective KM enables supply chains to operate more efficiently by reducing lead times, minimizing waste, and optimizing resource allocation [4]. For instance, predictive analytics powered by AI can help organizations foresee potential disruptions, allowing them to take preemptive action and mitigate risks. Improved knowledge sharing fosters better collaboration between suppliers, manufacturers, and distributors, leading to more synchronized supply chain activities. This coordination is crucial for just-in-time production and delivery, reducing inventory costs and improving customer satisfaction.

Innovative KM practices also strengthen the resilience and adaptability of supply chains. In an era marked by frequent disruptions—such as natural disasters, geopolitical tensions, and pandemics—supply chains that can quickly adapt to changing conditions are more likely to sustain their competitive edge [5]. This culture helps build resilient supply chains capable of withstanding shocks and bouncing back from setbacks quickly. Additionally, the ability to efficiently manage knowledge contributes to sustainable practices by promoting transparency and accountability, encouraging ethical sourcing, and reducing environmental impact through better resource management.

However, the adoption of innovative KM practices is not without challenges. Organizations often face significant hurdles, such as data security concerns, high costs of technology adoption, and resistance to change from employees accustomed to traditional methods. Data security is particularly critical as the increased use of digital tools for knowledge sharing also exposes organizations to cyberattacks and data breaches. Effective KM requires cultural alignment and collaboration among diverse supply chain participants, which can be difficult due to differences in organizational cultures, languages, and management styles. Overcoming these barriers involves fostering a culture of openness, trust, and collaboration, supported by appropriate incentives and governance mechanisms.

II. Innovative Knowledge Creation, Acquisition, and Sharing in Modern Supply Chains

Innovative knowledge management is essential for modern supply chains, where efficient knowledge creation, acquisition, and sharing play a vital role in enhancing operational performance and competitiveness. Knowledge management (KM) in this context involves the systematic processes of generating new knowledge, acquiring valuable external insights, and disseminating this knowledge effectively across the supply chain. Traditional methods such as databases, documentation, and formal training programs have served as the foundation of KM in supply chains. However, these methods often fall short in today's rapidly changing global environment, where speed, adaptability, and real-time decision-making are crucial [6]. To address these challenges, organizations are increasingly adopting innovative practices that leverage digital tools and foster a more collaborative approach to knowledge management.

A critical component of innovative KM in supply chains is the use of advanced digital technologies for knowledge creation and acquisition. Artificial intelligence (AI) and machine learning are pivotal tools that enable the extraction of actionable insights from vast amounts of supply chain data. AI-driven systems can process data in real-time to identify patterns, forecast demand, and optimize inventory management. Machine learning algorithms can learn from historical data to predict future trends, enhancing the organization's ability to make proactive and informed decisions. For example, predictive analytics tools can help organizations anticipate disruptions, such as supplier delays or shifts in consumer demand, and prepare contingency plans accordingly [7]. This capability not only improves efficiency but also minimizes risks by allowing supply chain managers to respond swiftly to emerging challenges.

Blockchain technology also plays a significant role in innovative knowledge creation and sharing within supply chains. As a decentralized digital ledger, blockchain ensures secure and transparent transactions, which is particularly valuable for maintaining trust and data integrity among supply chain partners. Blockchain technology enables all stakeholders to access accurate, immutable data, reducing the risk of discrepancies and fraud. For instance, blockchain can be used to trace the origin of raw materials or products, ensuring ethical sourcing and compliance with regulatory standards. This transparency fosters a more collaborative environment where knowledge is shared openly and efficiently across the entire supply chain network [8].

Beyond these digital tools, there is a growing emphasis on more collaborative and decentralized approaches to knowledge creation and sharing. Traditional hierarchical models, where knowledge flows top-down from senior management, are increasingly being replaced by networked models that emphasize peer-to-peer learning and real-time communication. These platforms support the development of knowledge-sharing networks where supply chain stakeholders can collaborate to solve problems and innovate. This more open and collaborative approach to knowledge management helps organizations adapt more quickly to changes in the market or operational environment, providing a significant competitive advantage in volatile conditions. A collaborative knowledge development is another key aspect of innovative KM, where multiple stakeholders within the supply chain work together to generate new knowledge. This collaboration can take various forms, such as co-development projects, joint research initiatives, and innovation partnerships. By leveraging the diverse expertise of suppliers, manufacturers, distributors, and customers, supply chain networks can create new products, processes, and solutions that would be difficult to achieve in isolation. For example, a manufacturer and a supplier might collaborate on developing a new, sustainable packaging material that reduces environmental impact and costs. The knowledge generated from such collaboration is then disseminated throughout the supply chain, leading to broader adoption and enhanced performance [9].

Digital platforms and tools for communication are fundamental to the process of knowledge sharing and dissemination. Cloud-based systems, social media, and collaborative software enable real-time information exchange, fostering a more dynamic and responsive supply chain. These platforms not only facilitate the quick sharing of knowledge but also ensure that it is available to all stakeholders, regardless of their location. This is particularly important in global supply chains, where partners may be spread across different geographies and time zones [10]. The ability to access and share information in real-time helps reduce bottlenecks, improve coordination, and enhance decision-making, ultimately leading to greater supply chain agility and resilience.

Decentralized knowledge networks complement these digital tools by promoting a more inclusive and participatory approach to knowledge sharing. In these networks, knowledge is not confined to a few key individuals or departments; instead, it flows freely across the entire organization. This approach fosters a culture of trust, openness, and continuous learning, where employees at all levels are encouraged to share their insights and expertise. Decentralized networks also enable organizations to tap into the collective intelligence of their entire supply chain, leading to more innovative solutions and a greater ability to adapt to changing conditions. For example, a decentralized knowledge network might include suppliers, customers, and other external partners, creating a more integrated and collaborative supply chain ecosystem [11].

Training and development programs are essential for building the capacity of employees and stakeholders to effectively create, acquire, and share knowledge. These programs help ensure that all participants in the supply chain are equipped with the necessary skills and knowledge to use new tools, technologies, and practices. For instance, training on advanced data analytics or blockchain technologies can enhance the ability of supply chain managers to interpret data, identify trends, and make more informed decisions. Ongoing training initiatives also support a culture of continuous improvement, where employees are encouraged to learn from both successes and failures and apply those lessons to future challenges [12].

III. Impact of Innovative Knowledge Management on Supply Chain Performance and Future Challenges

Innovative knowledge management (KM) practices have a profound impact on the overall performance of supply chains, enhancing efficiency, agility, resilience, and sustainability. In an increasingly interconnected and complex global environment, the ability to effectively manage knowledge across the supply chain has become a key factor for maintaining competitiveness. Effective KM practices enable organizations to optimize processes, reduce costs, improve collaboration, and respond rapidly to changes in the market. At the same time, these practices present new challenges that organizations must address to fully realize their benefits [13].

One of the primary impacts of innovative KM practices is the enhancement of supply chain efficiency. Advanced digital tools, such as artificial intelligence (AI), machine learning, and blockchain technology, facilitate real-time data analysis, enabling organizations to make quicker and more informed decisions. Predictive analytics powered by AI can help anticipate demand fluctuations, optimize inventory levels, and prevent stockouts or overstock situations [14]. For example, AI can analyze historical sales data and market trends to forecast future demand with greater accuracy, allowing organizations to align their supply chain activities accordingly. This reduces waste and operational costs while improving customer satisfaction through timely product availability.

Knowledge sharing and dissemination practices also contribute significantly to improving supply chain agility. Agility in supply chains refers to the ability to respond swiftly to changes in demand, supply, or external conditions, such as natural disasters or geopolitical events. Digital platforms and communication tools enable real-time information sharing among supply chain partners, fostering a more collaborative environment where rapid decision-making and problem-solving can occur. For instance, during a disruption such as a supplier failure or a logistics delay, a well-integrated knowledge management system can quickly relay critical information across the network, allowing stakeholders to coordinate their actions and mitigate potential risks. This capability to adapt rapidly to unforeseen events helps maintain supply chain continuity and reduces downtime, which is essential for sustaining competitive advantage in a volatile market [15].

Innovative KM practices also play a vital role in building supply chain resilience. In today's global supply chains, which often span multiple countries and involve numerous partners, managing risks effectively is crucial. Effective KM enables organizations to identify potential risks, share risk-related information with relevant stakeholders, and develop contingency plans. For example, blockchain technology provides greater visibility and traceability throughout the supply chain, allowing companies to detect vulnerabilities or points of failure more quickly and take corrective action. Additionally, the use of digital twins—virtual models of physical supply chain processes—enables organizations to simulate different scenarios and assess the potential impact of various risks, thereby improving preparedness and resilience [16].

The implementation of KM strategies varies significantly between developed and developing markets. In regions like the U.S. or Europe, the presence of advanced infrastructure, high digital literacy, and regulatory support facilitate the smooth adoption of AI and blockchain technologies. For instance, developed markets often have the capital to invest in cutting-edge KM tools, such as predictive analytics and blockchain, providing a competitive advantage in efficiency and sustainability. In contrast, developing markets may face barriers such as limited access to technology and poor infrastructure. To address this, companies can focus on simpler KM solutions, such as mobile-based knowledge sharing platforms or decentralized communication networks, which require less investment but still enhance transparency and collaboration.

Amazon and machine learning for inventory management is great example of successful integration of advanced technologies. Amazon uses machine learning models to predict customer demand, optimize warehouse storage, and automate stock replenishment. Their algorithms analyze historical sales data, seasonality trends, and customer behavior to make real-time decisions on inventory management. These models have enabled Amazon to streamline its just-in-time inventory system, reducing storage costs and improving delivery times, while maintaining high customer satisfaction. Machine learning plays a pivotal role in managing inventory complexity, helping large companies like Amazon maintain efficiency at scale.

Another great example is Walmart with their implementation of blockchain. Using IBM's Food Trust blockchain platform, Walmart created a decentralized ledger that records every transaction related to a product, from farm to shelf. Blockchain allowed Walmart to reduce the time it took to trace the origin of food from 7 days to just 2.2 seconds, significantly improving the response to food safety issues. The system also helped reduce food waste and improved compliance with safety standards. This case illustrates how blockchain can enhance trust, data accuracy, and traceability in complex supply chains, which is particularly valuable in industries where safety and quality control are critical.

Sustainability is another area where innovative KM practices have a significant impact. Organizations are under increasing pressure from consumers, regulators, and investors to minimize their environmental footprint and adopt sustainable practices. KM practices that promote transparency, traceability, and accountability are essential in achieving these sustainability goals. Blockchain technology, for example, can be used to track the provenance of raw materials and ensure ethical sourcing, while digital platforms can disseminate best practices for reducing waste, conserving energy, and minimizing carbon emissions. By embedding sustainability knowledge into supply chain operations, organizations not only comply with regulatory requirements but also enhance their reputation and build trust with stakeholders.

KM practices such as blockchain and predictive analytics contribute to reducing the environmental footprint by optimizing resource use, minimizing waste, and ensuring ethical sourcing. For instance, a blockchain-powered traceability system can verify that raw materials are sourced from sustainable suppliers, ensuring compliance with environmental standards. KM tools can promote social sustainability by enhancing transparency and fairness across the supply chain. Companies can use KM to ensure labor practices meet ethical standards, improving brand reputation and trust.

Despite these benefits, the adoption of innovative KM practices comes with its own set of challenges. Organizations must ensure that sensitive information is protected while remaining accessible to authorized users. This requires robust cybersecurity measures, such as encryption, access controls, and continuous monitoring, to maintain trust and cooperation among supply chain partners.

Blockchain, AI, and machine learning have revolutionized data management in supply chains, but they also introduce vulnerabilities, such as exposure to cyberattacks. To address this, organizations must adopt stringent encryption, continuous monitoring, and access control mechanisms to secure sensitive data.

The integration of new KM tools with legacy systems often results in operational disruptions. Organizations should consider phased implementation approaches, starting with pilot programs that ensure smooth integration without compromising daily operations.

Another significant challenge is overcoming resistance to change. Implementing innovative KM practices often requires a cultural shift within organizations, where employees accustomed to traditional methods may resist adopting new technologies or embracing more collaborative approaches to knowledge sharing. Organizations must foster a culture of openness, trust, and continuous learning to overcome this resistance. This can be achieved by investing in training and development programs that equip employees with the skills and knowledge needed to use new tools and technologies effectively.

In manufacturing, AI-powered predictive analytics can optimize production schedules and inventory levels. KM tools help in anticipating machine downtime, reducing waste, and improving process efficiency. In contrast, service-based industries benefit from real-time knowledge sharing through digital platforms. For example, service providers use KM tools to track customer interactions and feedback, improving service delivery and client satisfaction.

Companies can measure the impact of knowledge management (KM) practices on environmental and social sustainability by implementing specific metrics and tools that evaluate the effectiveness of these practices. Below are ways companies can measure the impact on both environmental and social sustainability:

- Companies can track greenhouse gas emissions across the supply chain, particularly in areas like logistics, production, and raw material sourcing. Use carbon accounting tools (e.g., the GHG Protocol) to calculate emissions before and after implementing KM practices such as blockchain for traceability and AI for optimization. Reduction in emissions can indicate better resource utilization and more efficient transportation routes, directly influenced by predictive analytics and real-time data sharing.
- Monitoring energy usage in manufacturing processes, warehouses, and distribution centers. Energy management systems and sensors that track energy consumption at various points in the supply chain. Lower energy usage after adopting AI-driven predictive maintenance or optimization algorithms reflects a direct environmental benefit from KM practices.
- Auditing labor practices throughout the supply chain to ensure compliance with labor laws, fair wages, and safe working conditions. Blockchain and real-time monitoring platforms can track the working conditions at various points of the supply chain. Improvements in labor standards, such as reducing forced labor or providing better working conditions, can be tracked through third-party audits and supplier transparency.
- The level of employee engagement in KM practices and sustainability initiatives can be measured through surveys, participation rates in training programs, and feedback loops. Use learning management systems (LMS) and internal surveys to gauge the effectiveness of training on KM tools and sustainability initiatives. Higher levels of employee participation in continuous learning and sustainability efforts can be indicative of a positive social impact.

IV. Theoretical Model

External knowledge acquisition, collaborative knowledge development, and internal research and development directly contribute to knowledge creation and acquisition. These activities involve gathering insights from external partnerships, joint ventures, and internal expertise, all of which feed into data analytics and insight generation. The knowledge capture and documentation process ensure that newly acquired information is systematically organized for future use.

Knowledge creation leads to knowledge sharing and dissemination through decentralized networks and knowledge repositories. These platforms enable the transfer of information across departments and teams. Training and development programs facilitate the practical sharing of knowledge, helping individuals understand and apply what has been acquired. Feedback loops and continuous improvement processes strengthen this flow, ensuring that shared knowledge is continuously refined and updated.

The next phase, knowledge utilization and application, draws directly from shared knowledge. Decision support systems and performance analytics rely on these insights to guide strategic choices. Knowledge repositories and feedback from the dissemination stage ensure that decision-makers are working with up-to-date information. These tools also support process optimization and innovation by applying learned knowledge to enhance operational efficiency.

Knowledge application then influences risk management and resilience-building practices, as organizations adapt their strategies to mitigate potential disruptions. Through this interplay between knowledge utilization and operational improvements, competitive advantage is achieved in the supply chain. Finally, the feedback mechanism ensures that knowledge derived from practical applications informs future acquisitions and dissemination, creating a continuous cycle of learning and improvement (Fig. 1).

V. Guidelines and Recommendations

The following guidelines provide actionable recommendations for stakeholders to optimize knowledge management practices, address challenges, and drive sustainable supply chain performance.

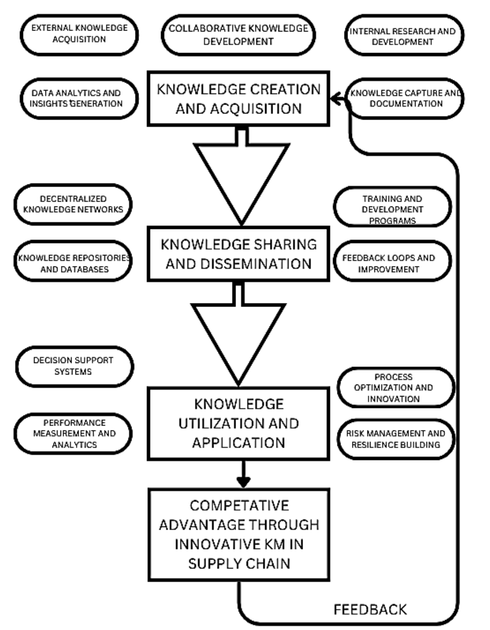

Figure 1. Model for improving supply chain through knowledge management.

- **Enterprises should invest in advanced digital tools and technologies for knowledge management.** Implementing AI, blockchain, and machine learning can enhance data analysis, transparency, and decision-making.

- **Organizations should establish decentralized knowledge networks to encourage peer-to-peer learning.** Using digital platforms can break down silos and facilitate real-time communication and collaboration.

- **Governments can incentivize sustainable and ethical supply chain practices through regulations and guidelines.** Offering tax benefits or subsidies can encourage organizations to adopt effective knowledge management strategies.

- **Individuals should engage in continuous learning and development programs to enhance their skills.** Participating in training and sharing expertise contributes to the collective knowledge base.

- **Organizations should create feedback loops to capture insights and drive continuous improvement.** Regular reviews and feedback sessions can identify gaps and optimize practices.

- **Organizations should prioritize sustainability in knowledge management strategies.** Integrating sustainable practices and partnering with stakeholders can improve compliance and corporate reputation.

VI. Conclusion

Innovative knowledge management plays a crucial role in enhancing the performance, resilience, and sustainability of modern supply chains. As supply chains become more complex and interconnected, the ability to effectively create, share, and utilize knowledge becomes a key differentiator for organizations aiming to maintain a competitive edge. This research has highlighted the significance of integrating advanced digital tools, such as artificial intelligence, blockchain, and machine learning, to facilitate real-time data analysis, transparency, and decision-making. Additionally, fostering decentralized knowledge networks and collaborative environments can help break down silos, promote peer-to-peer learning, and enable dynamic problem-solving across the supply chain.

However, the adoption of these innovative practices is not without challenges. Issues such as data security, resistance to change, system integration complexities, and the management of knowledge across diverse global networks require concerted efforts from all stakeholders. Governments, enterprises, and individuals must work together to create an enabling environment for knowledge management by investing in digital infrastructures, fostering public-private partnerships, and promoting a culture of continuous learning and openness. Incentivizing sustainable and ethical practices, enhancing training and development, and building secure platforms for data sharing are among the strategies that can support the effective implementation of innovative knowledge management in supply chains.

As the global supply chain landscape continues to evolve, the importance of innovative knowledge management will only increase. Organizations that are able to adapt to new technologies, collaborate effectively, and manage knowledge dynamically will be better positioned to navigate uncertainties, capitalize on opportunities, and achieve long-term success. This research contributes to the understanding of how innovative knowledge management can be leveraged to create more adaptive, resilient, and sustainable supply chain networks, offering practical insights and strategies for organizations and policymakers alike.

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Original Scientific Article

PSI-AROMAN Assessment of the WB6 Countries Innovation Performance

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Abstract—**This paper will examine the performance of West Balkan countries (WB6) in the research and innovation field (R&I). Their performance is assessed according to 12 main R&I aspects. The procedure is based on the Multiple-Criteria Decision-Making methods. The Preference Selection Index (PSI) was applied to define the weighting coefficients. At the same time, the Alternative Ranking Order Method Accounting for Two-Step Normalization (AROMAN) was used to assess the R&I performance of the selected countries. The results revealed Serbia as the best performer in the R&D field in this part of the world.**

Keywords – R&D, WB6, PSI, AROMAN.

I. Introduction

An organization's development and endurance strongly depend on research and innovation (R&I) activities because permanent technological change and limited resources make the environment severely competitive. Managers and governments have a difficult task to find the adequate ways to support these activities because the economic development and growth are under the influence of R&I [1]. Besides, encouraging innovation is the 9th goal of the 2030 Agenda for Sustainable Development [2-4]. Unsurprisingly, the authors have shown significant interest in the topics that deal with the innovation activities conducted within the organizations and countries [5-10]. The European Commission introduced the European Innovation Scoreboard (EIS) to respond to the rising need to measure the degree of innovativeness of a country [11]. Proposed innovation indicators represent metrics that assess innovation achievements in a wider context [12]. The authors have proposed combining the EIS indicators with the Multiple-Criteria Decision-Making (MCDM) techniques to elicit adequate scientific results.

MCDM techniques facilitate decision-making in complex environments characterized by numerous alternatives and conflicting evaluation criteria [13]. Various MCDM approaches have been proposed until now (for example [14-18]), and each has pros and cons. Additionally, different combinations of MCDM methods and models have been proposed for analyzing the R&I performance of selected countries [19-24].

For the need of this research, we assessed Western Balkan′s countries (WB6) using the MCDM model that consists of the Preference Selection Index (PSI) [25] and the Alternative Ranking Order Method Accounting for Two-Step Normalization (AROMAN) [26]. The PSI method was used to define the weighting coefficients. The reason for applying this method is that its computation procedure is based on input data that exclude the possibility of obtaining biased weightings. The AROMAN method was applied to the final assessment of the WG6 country's innovation performance. It is a newly introduced method whose potential has yet to be fully observed in different scientific cases, so we decided to base our analysis on it. The assessment was performed regarding 12 main R&I aspects presented in the EIS report for 2024 [27]. To present the conducted research and obtained results, the remainder of the paper is

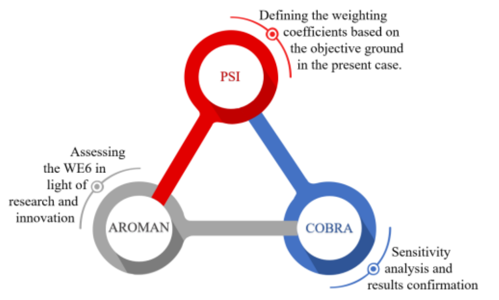

Figure 1. Employed MCDM methods.

organized as follows: Section 2 presents the methodology used; Section 3 involves the case study; and the conclusion is presented at the end of the article.

II. METHODOLOGY

This paper employed three MCDM methods, as presented in Fig.1.

Because the COBRA method is used only for sensitivity analysis, its computation procedure is omitted from the methodology section.

A. *The PSI Method*

The PSI method [25] defined the weighting coefficients based on the objective ground in the present case. Namely, the PSI method uses the initial data in the weighting coefficients computing, which excludes the possibility of decision-maker interference in the case when the data is quantitative. The positive side of the PSI method is not only the determination of objective weights but also the possibility of ranking the considered alternatives. The whole assessment procedure could be based solely on this method. It revealed the potential to resolve many decision-making problems, which proves the following articles [28-32].

The computation procedure of the PSI method contains the following series of steps.

Step 1. Select the evaluation criteria and alternatives.

Step 2. Evaluate the alternatives against the selected criteria and construct the primary decision matrix *X*:

$$x=\left[x_{ij}\right]_{n\times m}, \tag{1}$$

where x_{ij} is the performance ratings of the alternative *i* regarding the criterion *j*, *n* is the number of alternatives, and *m* is the number of criteria.

Step 3. Define the normalized decision matrix using the following equations:

$$r_{ij}=\frac{x_{ij}}{x_{ij}} \text{ for maximization criteria,} \tag{2}$$

$$r_{ij}=\frac{x_{ij}}{x_{ij}} \text{ for minimization criteria.} \tag{3}$$

Step 4. Calculate the preference variation value regarding each criterion in the following way:

$$\chi_j=\sum\nolimits_{i=1}^{m}\left(r_{ij}-\bar{r}_j\right)^2, \tag{4}$$

where $\bar{r}_j$ represents the mean value of normalized ratings of criterion *j* defined as follows:

$$\bar{r}_j=\frac{1}{m}\sum\nolimits_{i=1}^{m}r_{ij}. \tag{5}$$

Step 5. Calculate the deviation in the preference variation value as follows:

$$\Omega_j=1-X_j. \tag{6}$$

Step 6. Determine the criteria weights w_j using the following equation:

$$w_j=\frac{\Omega}{\sum\nolimits_{i=1}^{n}\Omega_j}. \tag{7}$$

Step 7. Compute the preference selection index of alternatives in the following way:

$$S_i=\sum\nolimits_{j=1}^{n}r_{ij}w_j. \tag{8}$$

The highest preference selection index value signifies the best option alternative.

B. *The AROMAN Method*

The AROMAN method [26] is used to assess the WE6 in light of research and innovation. Although it was introduced recently, the authors used it and its extensions in a significant number of research studies. The following articles [33-43] prove this constatation.

The computation procedure of the AROMAN method could be illustrated by the following series of steps.

Step 1. Form the initial decision matrix X as in the procedure for the PSI method.

Step 2. Normalize the decision matrix. In this case, the normalization procedure involves the linear, the vector normalization, and finally, the aggregated averaged normalization.

Linear normalization is performed in the following way:

$$t_{ij} = \frac{x_{ij} - \min_i x_{ij}}{\max_i x_{ij} - \min_i x_{ij}}, \quad (9)$$

$$i = 1, 2, \ldots, n, j = 1, 2, \ldots m. \quad (10)$$

Vector normalization is performed as follows:

$$t_{ij}^{*} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^{2}}}, \quad (11)$$

$$i = 1, 2, \ldots, n, \; j = 1, 2, \ldots, m. \quad (12)$$

Aggregated averaged normalization is done to achieve the final normalized values, and it is performed in the following manner:

$$t_{ij}^{norm} = \frac{\beta t_{ij} + (1-\beta) t_{ij}^{*}}{2}, \quad (13)$$

$$i = 1, 2, \ldots, n, \; j = 1, 2, \ldots, m, \quad (14)$$

where t_{ij}^{norm} represents the aggregated averaged normalization, and β is the weighting coefficient that varies from 0 1 to and usually is set on 0.5.

Step 3. Define the weighted decision matrix. This matrix is defined using (15):

$$\hat{t}_{ij} = w_{ij} \times t_{ij}^{norm}. \quad (15)$$

Step 4. Calculate the sum of the normalized weighted values for the cost and the benefit criteria separately as follows:

$$L_i = \sum_{j=1}^{m} \hat{t}_{ij}^{(\min)}, \quad (16)$$

$$i = 1, 2, \ldots, n; \; j = 1, 2, \ldots, m., \quad (17)$$

$$A_i = \sum_{j=1}^{m} \hat{t}_{ij}^{(\max)}, \quad (18)$$

$$i = 1, 2, \ldots, n; \; j = 1, 2, \ldots, m, \quad (19)$$

where L_i stands for cost, and A_i for benefit type of criteria.

Step 5. Rank the alternatives. The final ranking of the alternatives is obtained in the following way:

$$R_i = L_i^{\lambda} + A_i^{(1-\lambda)}, \; i = 1, 2, \ldots, n, \quad (20)$$

where R_i represents the value for ranking the alternatives, and λ is the coefficient level of the criterion type. If both criterion types are involved in the procedure, λ is set to 0.5. The alternatives ranking is performed in descending order.

III. CASE STUDY

A. Data

The evaluation is done against the 12 main aspects presented in Table I. The R&I performance of the EU-member countries, neighboring countries and selected global competitors are measured against 12 aspects and 32 indicators. The findings are published annually in the EIS since 2001. For this research, we evaluated the WG6 country's R&I performance using the MCDM model (Table II).

TABLE I. R&D ASPECTS [27].

Abbr.	Aspect	Optim.
HR	Human resources	max
AS	Attractive research systems	max
DI	Digitalization	max
FS	Finance and support	max
FI	Firm investments	max
IT	Use of information technologies	max
IN	Innovators	max
LI	Linkages	max
IA	Intellectual assets	max
EI	Employment impacts	max
SI	Sales impacts	max
ES	Environmental sustainability	max

TABLE II. WB6[*] [44].

Abbr.	Country
AL	Albania
BA	Bosnia and Herzegovina
ME	Montenegro
MK	North Macedonia
RS	Serbia

The initial decision matrix is based on data retrieved from the European Innovation Scoreboard for 2024 [27], and it is presented in Table III. There was a missing value for the FS – Finance support aspect, which we fulfilled with the data for the previous year [45].The further analysis was based on initial data presented in Table III.

B. Results

The weighting coefficients were determined using the PSI method. Table IV presents the obtained results.

The results emphasized the aspect IN – Innovators as the most significant. Surprisingly, the aspect FS – Finance and support has the slightest influence on the R&I performance of the countries.

After defining the weighting coefficients, we used the AROMAN method to perform the final analysis and determine the ranking order of the selected countries regarding their R&I achievements. The procedure is performed using (2)-(8), and the final score and ranking order are shown in Table V.

TABLE IV. ASPECTS′ WEIGHTING COEFFICIENTS.

Abbr.	Aspect	w_j
HR	Human resources	0.0842
AS	Attractive research systems	0.0985
DI	Digitalization	0.0874
FS	Finance and support	0.0454
FI	Firm investments	0.0536
IT	Use of information technologies	0.0967
IN	Innovators	0.1003
LI	Linkages	0.0770
IA	Intellectual assets	0.0771
EI	Employment impacts	0.0942
SI	Sales impacts	0.0902
ES	Environmental sustainability	0.0954

TABLE V. RESULTS

Abbr.	Country	R_i	Rank
RS	Serbia	0.3284	1
ME	Montenegro	0.2505	2
MK	North Macedonia	0.2319	3
AL	Albania	0.1524	4
BA	Bosnia and Herzegovina	0.1439	5

The final ranking order highlights Serbia as the best innovation performer within the WB6 countries group. Serbia expressed very satisfying

TABLE III. INITIAL DECISION MATRIX [27,45].

Aspect / Country	HR	AS	DI	FS	FI	IT	IN	LI	IA	EI	SI	ES
	%	%	%	%	%	%	%	%	%	%	%	%
AL	59.3	36.1	14.2	0.0	12.7	45.6	75.3	40.1	5.9	38	47.5	66.4
BA	10.3	23.2	35.8	0.0	0.8	39.8	117.6	15	14.9	50.8	29.6	89
ME	34.4	49.6	54.7	12.5	23.8	69.4	170.3	73.5	8.9	100.5	20.9	52.3
MK	36	79.7	37.1	14.5	42.1	30.9	63.2	49.4	21.5	31.6	59.6	87.4
RS	48.6	43.4	64.1	42.7	102.4	92	135.7	77.8	21.9	71.7	64.8	31.1

[*] Kosovo* is excluded from the assessment because Serbia does not recognize it as an independent state.

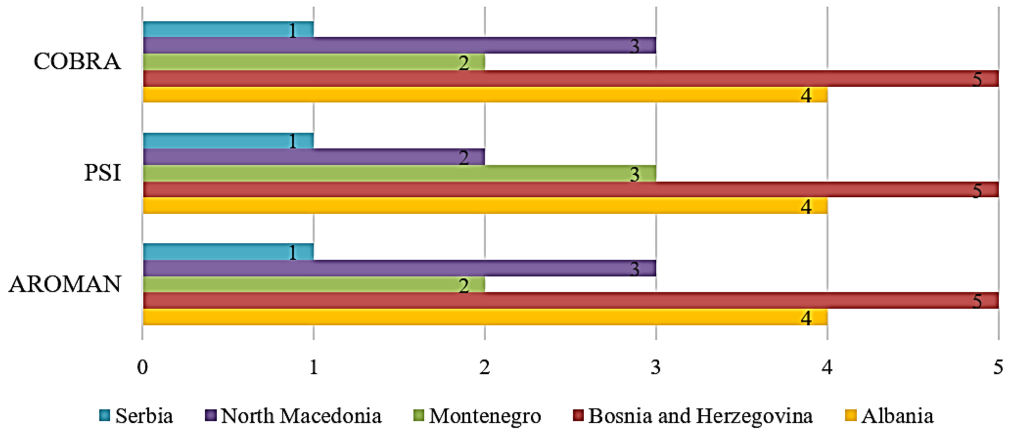

Figure 2. Sensitivity analysis.

parameters regarding all the R&I aspects. Although some performances of Serbia were not so good, overall ranking results put it in first place as the most perspective R&I performer among the WB6 countries group.

C. Sensitivity Analysis

The results obtained with the help of the AROMAN method were compared with those defined by using the PSI and the COBRA methods. The main reason for this was to check the reliability of the defined ranking order. Fig. 2 illustrates the comparison performed.

Although the rankings of the AROMAN and PSI methods differ slightly, the reliability of the proposed MCDM model is proved.

IV. Conclusion

The goal of this article was to address the possibilities of the MCDM model in evaluating the performance of the WB6 countries in the R&I landscape. The PSI method successfully and objectively determined the weighting coefficients, while the AROMAN method enabled an easy and reliable definition of the country's ranking order. The robustness and reliability of the model are proved using the COBRA and PSI methods.

The results outlined Serbia as a country that has made the best progress regarding R&I, while Bosnia and Herzegovina have the worst performance in the considered field. Fedajev et al.'s article confirms that Serbia is the best performer among WB6 countries observed through the R&I prism [23].

The benefits of the research include the comprehensiveness and ease of use of the proposed MCDM model. The proposed approach enabled the defining of adequate objective weighting coefficients and adequate ranking order, which is in accordance with similar research. The MCDM model could be successfully used to analyze any kind of decision problem, not only issues regarding R&I.

The essential limitation of the presented work is that it is based only on the EIS indicator set. It would be more satisfying if more relevant sources regarding the innovation indicators were used (e.g., the Global Innovation Index report). In that case the same problem would be observed from different perspectives, which would enable us to look at the WB6 countries' R&I achievements from different angles. Nevertheless, enhancing the methodological approach and involving MCDM methods with different methodology backgrounds would be desirable to elicit more objective results.

The proposition for further research includes comparing the WB6 countries with the achievements of the EU-27 countries regarding the R&I. The comparison with developed countries would bring good insight into what fields the WB6 countries should improve to reach the R&I level of developed countries. Furthermore, it would be advisable to incorporate the standpoints of experts, especially considering the aspects against which the R&I performance is measured. The standpoints of the experts could be included in the analysis by employing the subjective MCDM weighting methods, such as some from the PIPRECIA family. Everything said would lead to the creation of a more relevant and robust model that will enable drawing more robust and relevant scientific conclusions that respect the objective as well as the subjective aspects of the decision process.

Finally, it could be concluded that the proposed MCDM model facilitates the assessment process, resulting in quite adequate results. The approach is very understandable, which makes it convenient even for users unfamiliar with the MCDM field. Furthermore, this model could be used to improve the decision-making process in various scientific and business fields.

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Original Scientific Article

The Role of Organizational Culture and Organizational Learning in Organizational Change

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Abstract—**We live in an increasingly globalized world where change is the order of the day. Organizational change is a strategy that is progressively present in companies. Through this strategy, firms try to adapt to new environments, trying to improve in those aspects in which they previously showed weaknesses that threatened business progress. By accepting the limitations and characteristics of the outdated culture and defining the desired culture, the organization identifies the "culture gap" that must be overcome in order to implement the necessary change. Organizational changes are a wider concept than organizational learning, because every learning includes change, but every change does not automatically include learning. Thus, the purpose of this study is to investigate the role of organizational culture and learning in organizational change processes. The current study contributes to the existing body of literature in the field of interest.**

Keywords - organizational culture, organizational learning, organizational change

I. INTRODUCTION

This paper analyzes existing research on organizational learning and culture in the context of organizational change processes.

Why is it necessary for the organization to change its way of functioning? Globalization of the world economy and rapid changes in the needs and demands of the world market supported by the development of new technologies, democratization, economic liberalization, the expansion of communication technologies accompanied by significant migrations of the working population, are processes that affect changes in the organizational environment. High volatility, uncertainty and changing environment require an adequate organizational response, but also the people in them. Readiness for changes, flexible use of knowledge and creativity, become for this reason, the core qualities of people in organizations in the knowledge society [1].

Kotter [2] concludes that organization is changing or disappearing. This means that in order for organizations to survive in today's business environment, they must initiate changes or adapt to the existing environment. In order to do this, an appropriate supportive organizational culture must exist.

Change itself is one of the ways that organizations learn. The purpose of learning is to acquire new, necessary knowledge and to use it effectively in practice, so that the organization has a competitive advantage over other organizations. That is why it is very important that the organization learns as quickly as possible and that it applies new knowledge as quickly as possible through the processes and methods of its work. The ultimate goal is to implement one organized knowledge acquisition system and to quickly apply acquired knowledge through changes, innovations, more effective teamwork, more effective management system, etc. It is also important that the organization has an open approach in relation to the environment

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and is able to accept other people's knowledge and experience.

II. ORGANIZATIONAL CHANGE

Change is critical to the survival and success of organizations. In order to successfully implement change, organizations must consider several key factors. Organizations that fail to adapt to new circumstances lose their competitive advantages. Change is unavoidable and it can only be managed, otherwise organizations may cease to exist. Knowing what changes need to be made and how to make them appear to be key aspects for the organizational change process.

However, many projects and new initiatives in organizations often fail, despite the investment of resources. The key secret to successful change implementation lies in the human factor. Individuals are the ones who must accept and introduce changes, and it is important to focus on their awareness, desire, knowledge, ability and maintenance of change.

The term organizational change refers to changes an organization implements to improve efficiency [3]. According to Castel and Friedberg [4], organizational change is a complex, dialectic process, where the old and new ways of linkage result in a dynamic world.

Organizational change involves going from known to unknown and often goes with a sense of insecurity, fear and stressful situation for employees, because, organizational change leads to the transformation of organizational goals, processes, structure, work tasks and technology [5]. On the other hand, the implementation of organizational changes can provide employees the opportunity to achieve valued outcomes at work. For example, implementation of a new technology may require employees to learn new processes, which will increase their effectiveness.

The results of several studies concerning the key success factors of organizations with an international reputation show that they can be classified into two categories: those that exploit one approach that has been proven successful and those who explore new possibilities, ready to change not only the structure but also the processes [6]. These are the organizations that demonstrate willingness for change by continuously exploring and testing new ways of doing things. The first type of organization managed to achieve results significant on a global scale, two or three decades ago. In today's changing market conditions, another type of organization succeeds, that is, those organizations that are ready for change.

III. THE LINK BETWEEN ORGANIZATIONAL CULTURE AND CHANGE

Organizational culture has been identified as an influential factor affecting the successes and failures of organizational change efforts. The success of introducing changes in the organization depends to a great extent on the organizational culture that exists in the given organization. Sometimes it is necessary first to change the organizational culture in the organization, in order to create the conditions for the application of change management methods and techniques.

There is a dominant culture and subcultures. If all or most members of the organization accept the culture, then it is the dominant culture. A subculture is a set of only those values, beliefs and attitudes accepted by a part, that is, a group of employees. However, a strong, dominant culture is not always good in conditions of change, because it is rigid and closed to new attitudes.

There is no universal and unique definition of organizational culture, since it is something that is perceived, sensed and felt. However, all authors agree that it represents an important subsystem of an organization, a determinant of organizational effectiveness and the quality of work life of organizational members. According to Schein [7], organizational culture represents a set of values, norms, beliefs and attitudes adopted by the members of an organization and which influence how they will behave, think and feel. Cultural assumptions and values shared by the members of an organization affect the way in which employees and managers will understand the organization and thereby the appropriate way to change it. What will be determined as a suitable, efficient, or useful way of changing the organization will depend significantly on the shared assumptions and values of employees and managers built in their interpretative schemes [8]. Table I shows direct causal relations between certain organizational culture types, and suitable change management strategies.

TABLE I. THE DIFFERENTIATION OF ORGANIZATIONAL CHANGE STRATEGIES AND ORGANIZATIONAL CULTURE TYPES [8].

Assumptions about form of collective action/change tool / **Assumptions about power distribution/direction of change**	**Work structure, tasks**	**Social structure, relations**
Authoritarian, hierarchical cultures Directive changes	Role culture (H) “Eiffel Tower” culture (T) Rational empirical change strategy	Power culture (H) Family culture (T) Power coercive change strategy
Egalitarian cultures Participative changes	Task culture (H) “Guided missile” culture (T) Creative change strategy	People culture (H) Incubator culture (T) Normative reeducative change strategy

As can be seen from Table I, directive changes are prevalent in organizations with an authoritarian, hierarchical culture. Authoritarian culture supposes that an unequal distribution of power within a social system is inevitable, useful, and necessary for realizing the organization's goals and purposes. The hierarchy culture indicates a formalized and structured work environment, focusing on procedures and regulations, with formal rules. Directive changes are characterized by top-down leadership and minimal employee involvement [9]. Shein [7] suggested that leadership plays a significant role in shaping organizational culture. In hierarchical culture subordinates will be given specific tasks to complete in a specific way, which reduces their autonomy and satisfaction [10,11]. In such cultures, changes are led from the top down, the leader is the visionary and the planner, and the employees are only task-oriented executors. However, although directive changes can cause great resistance and dissatisfaction among employees, some authors suggest that a directive change management strategy can lead to positive organizational outcomes, if it is combined with effective communication, strategic management and the ability to effectively adapt to new situations [9]. Thus, while the directive change management method may be useful, eluding employee involvement may lead to accidental consequences, such as reduced morale, reinforced job insecurity, and feeling unappreciated at work. In addition, in power and role organizational cultures [12], as well as “Eiffel Tower” and family cultures [13], we may expect implementation of rational empirical and power coercive change strategies [8]. Power and family culture relies on a central figure that holds power. Lines of communication not only extend from that center, but also connect laterally along the organization. The dominant influence of the center results in a structure that is able to rapidly change and respond to changes and external threats. This ability was not achieved through formal methods, but by selecting individuals in key positions who would be able to “guess what the boss would do”. Communication is mostly intensive and informal. This is a culture with autocratic leadership. The role as well as “Eiffel Tower” culture is often labeled as bureaucratic because there are clearly defined behavioral procedures, authorities and role descriptions. Coordination is done from the top. Power derives from position, and to a lesser extent depends on a person's expertise. Change is difficult to implement. Change is very slow and often brings only fear. Power coercive strategy are used by change agents who operate under the assumption that people with less power will comply with the changes brought about by those with more power in the organizations. Rational empirical change strategy supposes that people are rational beings and will follow their self-interest – once it is revealed to them.

On the other hand, participative changes are prevalent in organizations with egalitarian cultures. Egalitarian culture assumed the need for more equal distribution of power. In this culture employees are more involved in the organization change process. Leaders as well as management must provide resources for changes and to manage change. In task and people organizational cultures, as well as in incubator and "guided missile" cultures, we may expect the implementation of normative re-educative and creative change strategies [8]. Task and "guided missile" cultures are characterized by the belief that organizations exist to solve tasks. The emphasis is on results and getting the job done. Individuals have freedom of decision, and control over their work. These cultures are flexible and adaptive and teamwork is highly valued. People or "incubator" culture is personal and egalitarian. The purpose of the organization is to free individuals from routine to more creative activities and to minimize time spent on self-maintenance. According to normative re-educative strategy people are social beings and they will follow the cultural norms and values. Successful change is based on redefining and reinterpreting existing norms and values, and developing commitments to new ones [14]. Creative change strategy is built on the premise that people are creative and that all processes in organization, including the process of change, are happening as a consequence of the free will, actions, and ideas of employees [8].

Many studies have found a positive influence of organizational culture on the process of change. For example, according to the reference [15], organizational culture has an indirect positive influence on changes through leadership styles. This research highlighted the significance of constructive culture and transformational leadership for a successful change process. On the other hand, according to reference [16], hierarchical culture was found to positively and significantly impact directly on planned and emergent change management in the public-sector service organization.

Organizational culture exists in parallel and together with national culture. We can say that organizational culture is a part of national culture. Since we live and work in the era of globalization, a big challenge for managers of multinational companies is to find a way to harmonize different national cultures and organizational culture. In the context of change, for example, in countries with a high degree of uncertainty avoidance (Latin America, Latin Europe, Mediterranean countries, Japan, Korea), employees will not be as open to change and risk acceptance as employees in countries with a low degree of uncertainty avoidance (Asia and Africa).

IV. Organizational Learning and its Role in Organizational Change

In the era of knowledge economy, the key strategic resource of competitive advantage is no longer based on material resources but rather the accumulation and utilization of knowledge within an organization. Rapid development of new technologies, methods and ways of working, introduction of new products, constant innovation in many fields, create great and constant pressure on many organizations and their employees. These organizations and all individuals in them are forced to constantly learn in order to acquire new knowledge with which they can successfully adapt to the ever-changing conditions in which they operate, i.e. so that they can successfully manage the changes required by this dynamic of rapid development in all fields in which they operate.

Organizational learning represents a complex process that is constantly repeated, that is, it represents a closed circle. Namely, learning is the process of creating new knowledge, and new knowledge creates new ideas and innovations, which ultimately cause changes. Changes create new knowledge, which in turn creates new ideas and innovations and which again lead to new changes. This cycle represents a continuous process through which the organization and its employees constantly progress in order to successfully survive in the market.

Organizational learning is a process that, through the acquisition of new information and knowledge, changes people, their way of thinking, their attitudes and representations, and they become capable of creating new ideas, taking new actions and making changes. Through the process of learning, people develop new approaches and strategies, new ideas, as well as ways of finding solutions to many problems. However, people only learn if they are motivated and have clear goals they want to achieve.

Studies about organizational learning have developed since the 1970s, and during the 1980s and 1990s, the interest grew significantly [17]. Organizational learning is a type of organizational change process in which a difference in the state of the organization occurs due to the generation and use of new knowledge. It includes changes of both cognitive structures and behaviors of organizational members. Organizational learning is often defined as a change in the cognitive structures and behavior of the organization's members, which ensures an increase in the organization's ability to adapt to its environment. Most researchers describe organizational learning as a change in the organization's knowledge that happens as a function of experience and gives a theoretical framework for analyzing organizational learning [18]. References [19-21] state that organizational learning happens when organization institutionalized new routines, creates and transfers new knowledge.

There are two concepts of organizational learning: single-loop and double-loop learning [22]. Adaptive learning or learning in one circle (single loop learning) represents a basic form of learning in which knowledge is acquired and changes are made only within the framework of a previously defined set of assumptions that remain beyond any questioning. With adaptive learning, the organization corrects its activities if they deviate from the previously defined course. This type of learning is carried out in the form of measuring the company's functioning and performance in relation to previously defined standards and results in an action aimed at removing deviations from the standards. There is no review of the standard itself. The result of adaptive learning is incremental changes or adaptations of existing routines within the framework set by the basic assumptions on which they are based. Generative learning or learning in a double loop (double loop learning) represents the acquisition of knowledge that questions and changes the basic assumptions on which existing routines are built. Therefore, generative learning does not improve existing routines, but creates completely new ones, based on new assumptions about sources of competitive advantage and suitable ways to realize that advantage. The changes generated by learning in the double circle are radical because the fundamental assumptions and definitions on which the functioning of the organization is based have changed.

In order to create organizational knowledge, it is necessary to convert one form of knowledge into another. That process of conversion of one form of knowledge into another through which individual knowledge is transformed into organizational is the process of organizational learning and is represented by the spiral of knowledge developed by Nonaka and Takeuchi [23].

Research results suggest that managers are required to have the necessary knowledge to facilitate ongoing change and support employees at all organizational levels [24].

Learning organizations should establish an innovative culture, which underlines employee development and learning, encourages the creation of new knowledge and modifies the knowledge in order to enhance the innovation capability. Establishing a learning culture is not an easy task considering the numerous obstacles that can be found on this way. According to the reference [25], the main obstacles to implementing e- learning culture in Kuwait are: lack of managerial support, language barriers, IT problems, workload and lack of time. Company processes can be also a barriers to learning. For example, due to the high volume of work, employees do not have time to devote to training and development. Another example is where employees are only permitted to complete training courses on company-owned devices.

V. Conclusion

The aim of the research was to summarize the recent literature about organizational changes, organizational culture and organizational learning, as well as to emphasize the link between culture and change and learning and change. It can be concluded that managers should strive to adapt their policies according to the national and organizational culture. Knowledge and creativity are becoming the most important economic resource of modern societies, and change management is a key process in developed economies. Creativity implies the developments of new ideas that help solve certain problems in the organization and that initiate changes. Therefore, in an organization must be established a culture that promotes lifelong learning and encourages the creativity of individuals to introduce change. In other words, organizational learning requires learning culture, which includes: commitment to learning, effective and well founded science, transparency and clearness, topic guidance and leading, responsibility and liability [26]. Individually and collectively learning is one of the most important leverages that organizations must use to obtain important competitive advantages. Thus, it is a big challenge for organizations in complicated and variable environmental conditions to pay attention to learning as an important part of daily organization activities.

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Original Scientific Article

Digital Transformation to Secure Socio-Economic System Performance

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Abstract—**This study explores how disruptive technologies from Industries 3.0, 4.0, and 5.0 help safeguard socio-economic systems amid digital transformation during the Russian invasion of Ukraine. By analysing the Ukrainian case, the research examines how these technologies – particularly in green energy, transport, and digital access – mitigate the impact of military conflict. Green energy and transport innovations have supported decentralisation and reduced the effects of energy disruptions, while the growing use of electric vehicles and charging infrastructure has facilitated evacuations and sustained essential services. Digital technologies have enhanced access to education, work, and communication, strengthening societal resilience and human capital, which are vital for socio-economic security. Ukraine's shift toward freelance activities illustrates its capacity for self-organisation and innovation during the transition. Additionally, investments in renewable energy and electric vehicles demonstrate the country's commitment to sustainability. The adoption of advanced technologies such as additive manufacturing and the Internet of Things further showcases Ukraine's progress in fostering human capital despite wartime challenges. The findings provide insights into policy development aimed at protecting socio-economic systems, particularly in times of crisis. However, technological dependencies – such as supply chain disruptions and cyber threats – pose challenges that warrant further research.**

Keywords - disruptive technologies, security, digital transformation, sustainability

I. Introduction

The concept of Industry 5.0 plays a pivotal role in shaping today's social and political environments. Technologies from Industry 4.0 and 5.0, especially artificial intelligence, are driving profound changes in societal structures and are Positioned to upend existing geopolitical structures, potentially sparking new forms of rivalry among major international powers [1]. This evolution brings important questions about the stability and security of socio-economic systems in this new context, particularly in scenarios of military conflict. As a result, it is crucial to explore the implications of these developments for the security of socio-economic systems during this transitional period. These challenges are particularly pronounced for Ukraine, given the ongoing war.

II. Literature Review

Scholarly attention to the security of socio-economic systems in the digital transformation era has been growing, with particular emphasis on national security and the potential threats posed by digital technologies. Previous research [1-6] highlight that digital technologies are driving significant changes on a large scale, creating uncertainties and posing vulnerabilities to socio-economic systems. While these technologies promise to enhance productivity and lead to an era of abundance, they also have the potential to destabilize existing systems. Researchers are particularly focused on how these disruptive technologies affect state resilience in the face of global competition, including their implications for military

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capabilities. However, there remains a gap in understanding how these technologies impact states' ability to withstand military confrontations. The Ukrainian case provides a relevant example of how disruptive technologies may enhance the resilience of societal systems during wartime.

This paper explores how technologies from Industries 3.0, 4.0, and 5.0 contribute to the security of socio-economic systems amid digital transformation, with a focus on the ongoing war in Ukraine. By conducting a thorough literature review, the study assesses the effectiveness of these technologies in mitigating the adverse effects of military operations on socio-economic systems within Ukraine.

III. RESULTS

Socio-economic system (SES) security is a complex and multifaceted issue, shaped by several key factors, including protecting its components from adverse conditions, resilience to destructive processes, and the ability to restore operations after disruptions. SES security is influenced by three main aspects: material, informational, and synergistic factors. Industrial revolutions, particularly those related to Industries 3.0, 4.0, and 5.0, have greatly impacted the material, informational, and synergistic processes that underlie SES security. The transition towards a new socio-economic paradigm is evolving through three distinct stages, commonly identified as Industries 3.0, 4.0, and 5.0. These stages are interconnected, influencing one another and collectively steering the course of societal development.

The third industrial revolution, Industry 3.0, represents a transformative shift within socio-economic systems, characterized by efforts to reduce negative environmental impacts significantly. This phase is marked by the shift to renewable energy sources and materials, the widespread adoption of additive manufacturing techniques, the integration of digital technologies, the establishment of interconnected production systems, the digitalization of information, the adoption of horizontally structured production and consumption models, and the development of economic relations based on solidarity. As highlighted by scholars [7-9], restructuring towards an additive economy involves changes in energy production, energy networks, and the primary resource structure, as well as adjustments in interface systems. The additive economy offers benefits such as reduced energy and resource intensity, dematerialization of production processes, sustainable production and consumption practices, and the incorporation of the Internet of Things (IoT) into technologies and materials. However, it also presents challenges, including increased risks related to information security, loss of control over cyber-physical systems, and heightened psychological stress [7].

The fourth industrial revolution, or Industry 4.0, introduces cyber-physical systems as central to managing essential functions for human well-being and ecological balance. This stage emphasises innovations such as IoT, the implementation of "smart" management systems in various sectors, and the widespread use of cloud computing as a central platform for managing socio-economic activities. Industry 4.0 seeks to replace certain human jobs with automation, facilitated by advancements in artificial intelligence and robotics, while the fundamental nature of human labor remains largely unchanged [7-9].

Industry 5.0 represents the integration of human social dimensions within a cybernetic environment. This phase focuses on the enhancement of individual social capabilities, the dominance of information production, the expansion of digital spaces in the public domain, the growth of the creative economy, and the synergistic integration of human cognitive abilities with artificial intelligence [8].

The contributions of contemporary industrial revolutions to strengthening the security of socio-economic systems can be observed across various domains. These include the simplification of system components, dematerialisation of essential elements (such as production means, labour objects, communication and storage infrastructures, and consumer goods), the replacement of hazardous parameters, the networking and decentralisation of economic components, the cyberisation of security monitoring mechanisms, reductions in energy and material consumption, the enhancement of autonomy and self-organisation within individual units, and improvements in workforce skills. These factors are particularly relevant during conflict situations.

The findings of this research align with previous studies [4-9], which emphasise the role of disruptive technologies in securing energy systems and maintaining stable operations during power outages. In Ukraine, legislative reforms beginning in 2015 laid the groundwork for expanding renewable energy sources (RES). Investments totaling $7.2 billion between 2015 and 2020 helped Ukraine achieve global recognition for its progress in renewable energy, ranking among the top nations in solar and wind energy expansion. The rise in private solar energy (SE) installations has further contributed to decentralizing energy production, ensuring resilience during wartime disruptions. Over the last three years, the number of private SE stations has grown substantially, reaching approximately 45,000 units by the end of 2021, with a total installed capacity of 1,200 MW [10]. These private SE installations have played a crucial role during the war. Their dispersed locations across the country have contributed to a lower rate of damage (around 24%) compared to industrial solar power plants. Furthermore, unlike industrial facilities that are primarily connected to centralized power grids, private SE stations have provided additional functions that have been essential in wartime conditions.

Paradoxically, the large-scale destruction of Ukraine's "green" energy infrastructure has had a limited effect on the nation's overall electricity supply. This is largely due to the concurrent destruction of the industrial sector, including energy-intensive industries, which has led to a surplus in energy production that exceeds the immediate consumption needs.

Electric vehicle (EV) adoption, paired with the expansion of charging infrastructure, has been crucial in mitigating the impact of fuel shortages, facilitating evacuations, and supporting essential services during the conflict.

Although electric vehicles make up less than 1% of Ukraine's total transport fleet, their numbers have surged over the last five years, and the country ranks among the leaders in EV adoption growth. Legislative measures that reduced import duties and taxes on electric vehicles helped accelerate this trend. The development of charging stations across Ukraine has also been impressive, with a significant increase in the number of high-speed charging terminals. The use of electric vehicles during the conflict, particularly in transporting goods and people, highlights their importance in maintaining societal functions during times of crisis.

Ukraine's digital infrastructure has also played a vital role in preserving SES security. The country's advanced information systems have enabled continuous communication, supported social cohesion, and maintained the functioning of critical sectors like education, healthcare, and transportation. Ukraine's digital society, developed before the conflict, has proved essential in providing access to information, education, and work despite physical insecurities, and has helped shield the population from disinformation campaigns. The significance of Ukraine's information development became apparent during the early months of the Russian invasion, as several critical outcomes emerged:

- Despite geographic dispersion, citizens maintained stable communication through information technologies such as the Internet and mobile networks, which helped preserve social cohesion and fostered a sense of civic engagement.
- Information dissemination played a pivotal role in mobilizing collective action and fostering a unified atmosphere of cooperation, thereby reinforcing social solidarity and collaborative efforts.
- Established information channels enabled the rapid dissemination of essential information, enhancing threat awareness and supporting risk mitigation measures.
- Information networks were effectively utilized to counteract misinformation and propaganda spread by adversaries.
- Despite the initial shock following the invasion, the majority of educational institutions resumed remote instruction within a month, accommodating students across various regions and countries.
- Information technologies facilitated financial transactions in areas or during periods where traditional cash payments were not feasible.
- Information systems were instrumental in coordinating logistics, dispatching tasks, and maintaining communication across multiple sectors.
- Digital infrastructure enabled the continued operation of the IT sector,

freelancers, and service industries amidst the conflict.

- Information networks played a crucial role in providing essential medical consultations and services.
- Information systems ensured ongoing connectivity despite the war's disruptions, allowing individuals to stay informed about national and global events.

Moreover, the country's focus on digital and green transitions, supported by renewable energy investments and electric vehicle adoption, reflects its commitment to sustainability. The implementation of advanced technologies, such as additive manufacturing and the Internet of Things (IoT), further illustrates Ukraine's technological capabilities in both civilian and military applications. These developments underscore the critical role of human capital, adaptability, and expertise in ensuring resilience during wartime challenges.

IV. CONCLUSIONS

In conclusion, the study offers several key insights into how Ukraine's digital transformation and technological advancements have helped mitigate the adverse effects of war:

1. The country's adoption of digital technologies has significantly reduced the economic impact of the conflict, particularly through renewable energy solutions.

2. The proliferation of electric vehicles has supported mobility and essential services during evacuations and fuel shortages.

3. The digitalization of society has bolstered information security and maintained social and economic cohesion, including in critical sectors such as healthcare and education.

4. Human capital has emerged as a key driver of SES security, with Ukrainians demonstrating high levels of proficiency in problem-solving and decision-making, enabling effective decentralized management.

Despite these successes, the conflict has also revealed challenges associated with technological dependencies, such as supply chain disruptions, cyberattacks, and the spread of misinformation. These issues warrant further investigation in future research.

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Original Scientific Article

Modeling Education and Internet Usage: PCA and Linear Regression Approaches

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Abstract—**The frequency of Internet use is significantly influenced by the formal and non-formal education of individuals. Acquiring education enables the acquisition of basic skills in the use of digital technology and influences the reduction of the digital gap created in this way. In this research, the influence of a number of education parameters on the rate of Internet adoption in 27 countries of the European Union was modeled. The principal component analysis (PCA) technique was used to identify the parameters that contribute the most to the development of education through the formation of two factors. The statistically significant score of factor one was used to form a linear regression (LR) model. The results show that the percentage of explanation of the variability of internet users is explained with 54.5% through the value of factor one. The correlation coefficient between real and projected values (0.738) shows a strong positive correlation between these values.**

Keywords - insert education, internet, PCA, linear regression, digitalization

I. Introduction

The Internet's rapid rise and transition to digital world in recent years has had a significant influence on today's society. It has resulted in changes in all fields and has had a wide-ranging impact on our daily life. This implies that teaching individuals essential skills for using digital technologies has become critical. Schools play an important role in enabling more individuals to utilize the Internet and develop digital skills. Digital literacy involves being able to find, handle, grasp, and assess information utilizing digital technology. This talent enables people to convert information into knowledge. It is about educating people ICT concepts and how to utilize digital technologies effectively [1,2]. This not only helps people get decent employment and create their own enterprises, but it also helps them integrate into society.

The OECD report "Skills Outlook 2019: Thriving in a Digital World" stresses how digital skills matter in many industries as AI, automation, and data analytics change their structure. The report also shows how digital changes shape new skill needs and affect education systems [3]. In the same vein, "The Future of Jobs Report 2020" by the World Economic Forum estimates that by 2025, machines will replace about 85 million jobs. At the same time digital shifts may create 97 million new roles [4]. Digital shifts in business, drive economic growth and social progress. They cut transaction costs, boost worker knowledge and skills, and affect inflation, wages, job markets, and output. All these factors add to the ongoing structural and tech changes in the world economy. Results presented in McKinsey & Company (2018), estimates that improvement in digital skills is likely to contribute up to additional $2 trillion to global GDP by 2030, whereas, nations with higher level of digital literacy are likely to have more prominent growth [5].

Regardless of the intense propagation of Internet access and digitalization, there is a prominent digital divide between the regions and nations. The concept of the “digital divide”, often known as the “digital gap”, is closely linked to the possibility of accessing and utilizing

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information and communication technology in one country or between countries [6]. The emergence of a digital divide within the nation hinders the ability of individuals to actively engage in social processes and access information that is important in an information age [7]. Education is important in bridging this gap by ensuring fair access to digital tools and information, allowing all people to benefit from the digital transformation. International Telecommunication Union conducted a study that shows that various digital literacy programs conducted in rural regions reflects on increase in income among participants for 20%, emphasizing the potential of such educational initiative [8].

The dynamics of digitalization with constantly emerging of new tools and online platforms calls for continuous education and skill update, not only in form of formal schooling, but also though life long learning programs for employability in the digital age. Studies shows that individuals who are undergoing continuous learning are less likely to loss their jobs i.e., have more chance for upward mobility [9]. Besides formal education, community-based non-formal learning has significant potential for developing digital literacy, especially among social groups that are less presented in the digital economy like low-income families, rural population or elderly. Study "The Role of Community-Based Programs in Closing the Digital Divide" shows that community-based digital literacy program may uplift not only digital skills of participants, but also their self-confidence in using technology that increase use of Internet in further education [10].

The quality education is undoubtable key factor for the expansion of the Internet and digitalization. However, among plethora of indicators that describes education system it is important to understand which one have dominant influence when it comes to use of Internet. Thus, this paper main goal is to model this relation in order to offer better understanding of which segments of education have significant influence on use of Internet.

II. Literature Review

A number of studies in broader sense attempted to model the relationship between the education, students and the use of Internet and digitalization, as well as their implication for employability. For instance, through an empirical study, [11] modeled relationships between traditional literacy (reading, writing, and understanding text), medium related internet skills (operational and formal skills) and content related Internet usage (information and strategic skills) and Internet usage types (information, career or entertainment directed use). The study applied structural equation modeling to test developed conceptual model, and Principal component analysis (PCA) with varimax rotation to determine two underlying usage clusters. Results point out that traditional literacy is a pre-condition for the employment of Internet skills, i.e. traditional literacy has a direct effect on formal and information Internet skills and an indirect effect on strategic Internet skills. Another study, presented in [12] attempted to determine the effect of the RMS teaching approach on students' digital and mathematical literacy. The study used a quasi-experimental approach, with two experimental courses and one control class. Data analysis analyze statistical distribution, including percentage, mean, standard deviation, correlation, and Analysis of Variance (ANOVA). In order to explore the relationships between variables authors applied structural equation modeling (SEM). The results shows that understanding mathematical principles can help students better appreciate and utilize digital technologies effectively, i.e. math education can enhance digital literacy. In developing a value-based online learning model to predict learners' reactions to internet entrepreneurship education [13] using partial least squares structural equation modeling (PLS-SEM). The findings revealed that instructional assistance, instructor excitement, and instructor preparation are important drivers of the perceived value of utilizing online learning platforms to develop internet entrepreneurship knowledge and skills, which favorably increases reuse intention. A study presented in [14] modeled the antecedents of artificial intelligence usage and effects on 21st century employability skills among postgraduate students in Ghana using partial least squares structural equation modelling (PLS-SEM) techniques for the quantitative data analyses and thematic pattern matching for the analysis of qualitative data. For checking the item loading of five selected variable, authors employed Confirmatory Factor Analysis (CFA). The PLS-SEM paths modelling showed that both AI usage and AI challenges were important predictors of postgraduate students' acquisition of 21st century employment skills. Also, the use of advanced online tools as for instance chabot's increases digital literacy even more. In [15] authors tried to understand the higher education students' usage of ChatGPT. Applying a modified technology acceptance model, the findings of this study, which used a stratified random sampling approach to recruit 1389 higher education students from 11 universities in Vietnam, revealed that effort expectancy not only directly affected students' actual use of ChatGPT, but also serially indirectly increased their actual use of ChatGPT via performance expectancy and intentions to use ChatGPT. To evaluate the reliability and validity of the constructs being researched, and to test the proposed hypotheses, a three-step analysis is used. The first step considered Confirmatory factor analysis (CFA) and Cronbach's alpha to assess the reliability and validity of the constructs. Secondly, multiple linear regression analysis was utilized to investigate the predicted relationships in the developed model. And thirdly, for mediation coefficients testing, authors applied models 4 and 6 of the PROCESS macro approach with 5000 bias-corrected bootstrapping samples.

Having an understanding of the causal relationship between education and the use of Internet can help policymakers in developing strategies towards more digitally inclusive society.

III. DATA AND METHODOLOGY

The relationship between education and internet use was modeled on the case study of EU 27 countries such as Belgium, Bulgaria, Czech Republic, Denmark, Germany, Estonia, Ireland, Greece, Spain, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, and Sweden. The data for this investigation were gathered from open-access databases, including the World Data Bank and the European Commission for the reference year 2022 [16,17]. The initial database considered data on pupils and student's enrollment distributed at all levels of education, data on pupils out of school, number of classroom teachers, number of graduates at different level of education, non - formal education and training of working age population, early leavers from education and training and share of GDP invested in education. In total, seventeen variables of education and training indicators gathered by the European Commission for the EU27 were evaluated in the first iteration of the analysis for dimensionality reduction, choosing twelve indicators to form a regression model. The Table I reports the overall independent parameters (x1-x12) considered for the model establishment, along with the dependent parameter (Int_use). The diversity in measures was solved by adopting percentage (%) as a referent unit.

The methodological part of the paper considered Principal Component Analysis (PCA) as a dimension reduction technique for selecting the most optimal parameters as indicators of education progression. The precondition for implementing PCA is to perform the Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of sphericity to ensure that the data is appropriate for using this type of technique [18]. The PCA's results will identify factors that provide the most valuable information for explaining data variability [19]. The PCA groups

TABLE I. INITIAL PARAMETERS.

Indicator name	Label	Unit	Source
Individuals - internet use	Internet use	Percentage of population (%)	World data bank [16]
Gross domestic Expenditure R&D in higher education	x_1		European Commission [17]
Pupils enrolled in primary education	x_2		
Pupils enrolled in lower secondary education	x_3		
Pupils enrolled in upper secondary education	x_4		
Students enrolled in bachelor education	x_5		
Students enrolled in master education	x_6		
Students enrolled in doctoral education	x_7		
Formal education and training of population ages 18 to 64	x_8		
Non -Formal education and training of population ages 18 to 65	x_9		
Graduate pupils tertiary education	x_{10}		
Graduates students bachelor education	x_{11}		
Graduates students master education	x_{12}		

the indicators that share the highest correlation coefficients and establishes a factor or component [18]. The number of components is selected based on an eigenvalue that is higher than threshold 1 or on the basis of a scree plot examination [19]. For easier interpretation of the results, the several rotation methods can be used [20]. The linear regression (LR) analysis will use the outcome values of the factors as input parameters. Linear regression analysis is typically used to investigate the relationship between independent and dependent variables through creating regression equation [21]. The results of the LR summarize the value of the coefficient of determination (R2), ANOVA analysis, and coefficient statistics [21].

IV. RESEARCH RESULTS

The Table II presents the values obtained from testing the suitability of the data set for PCA analysis. The results show that after several iterations, the obtained value of the KMO test and the *p*-value of Bartlett's test of sphericity reach acceptable values [18].

TABLE II. TESTING DATA ADEQUACY FOR THE PCA.

Test name	Indicator	Reference value	Calculated value
Kaiser-Meyer-Olkin test	KMO index	> 0.6	0.710
Bartlett's test of sphericity	*p*-value	< 0.05	0.000

TABLE III. ROTATED COMPONENT MATRIX.

Extracted parameter	Component	
	Factor 1	**Factor 2**
Formal education and training of population ages 18 to 64	.898	
Pupils enrolled in upper secondary education	.783	
Gross domestic Expenditure R&D in higher education	.759	
Pupils enrolled in primary education	.653	
Students enrolled in bachelor education		.828
Students enrolled in doctoral education		.800

TABLE IV. PEARSON'S CORRELATION MATRIX.

		Individuals - internet use	**REGR factor score 1 for analysis 1**	**REGR factor score 2 for analysis 1**
Pearson Correlation	Individuals - internet use	1.000	.738	-.003
	REGR factor score 1 for analysis 1	.738	1.000	.000
	REGR factor score 2 for analysis 1	-.003	.000	1.000
Sig. (1-tailed)	Individuals - internet use	.	.000	.494
	REGR factor score 1 for analysis 1	.000	.	.500
	REGR factor score 2 for analysis 1	.494	.500	.
N		27	27	27

TABLE V. MODEL SUMMARY.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.738	.545	.526	3.42398	1.583

The next step in modeling the relationship between education and internet use is to employ PCA to extract the most valuable parameters [22]. Table reports reduced dimensions of education progression expressed as components of two factors. The first factor accounts for 46.88% of the data variability, while the second factor accounts for 19.90% of the variability. Factor I contributes to the internet adoption level through the share of the formally educated population, lower-level educated individuals, and the government's investments in higher education. While Factor II contributes to the internet adoption rate through highly educated populations, such as bachelor and doctoral-level educated populations. The first factor refers to basic educational prerequisites for the use of digital technology, while the second factor includes more sophisticated indicators of Internet use. The Table III reports factor loading results higher than 0.65 for each extracted parameter. The results were calculated in three iterations using the Varimax rotation method.

The obtained scores of the two factors were utilized as independent parameters for the LR model. In order to evaluate their correlation with the dependent parameter Int_use, Person's correlation coefficients were calculated (Table IV). The results show a high positive correlation value between the regression factor score for factor one and internet users ($r = 0.738$), with a statistical significance of $p = 0.000$. The results for factor two failed to prove a statistically significant relationship between the observed parameters ($p > 0.05$) so it was excluded from the LR analysis.

The LR model was built based on the scores obtained by factor one. The computational outcome reveals a high positive correlation between real and predicted values ($R = 0.738$) of the internet users. The coefficient of determination value equals 54.5%, with a Durbin-Watson value in the acceptable range, indicating there is no autocorrelation between residuals (Table V). The ANOVA test results (analysis of variance) confirm the LR model's quality and statistical significance, with f-statistics of 29.904 and a p-value of 0.000.

The Fig. 1 illustrates the difference between the actual and projected value of the dependent parameter *Int_use* using the PCA-LR model in the EU 27.

V. Discussion

The modeling results highlight two key characteristics of the observed set of countries. The first characteristic emphasizes that the percentage of the population with primary education, non-formal education, and training, along with GDP investment in higher education, largely determines the rate of internet use in the EU 27. The later has been also highlighted by [23], arguing that investment in higher education significantly boosts innovation capacity, particularly in regions with strong research universities, contributing to overall technological development in US. This argument is supported by [24]. Study finds that regions with more universities experience higher levels of innovation and technological advancement, making investment in higher education critical for fostering technological progress. Focusing on extensive insights on European countries [25] shows on how higher education levels correlate

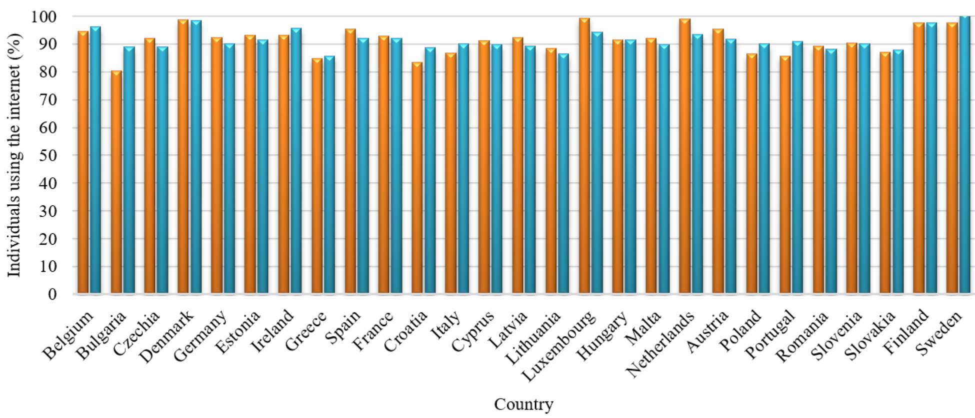

Figure 1. Real and predicted value of internet users in EU27 using PCA-LR model.

with technological advancements, particularly in Western and Northern Europe, providing an empirical basis for the link between education investments. This is also portrayed in [26], through detailed analysis of how universities in several European countries, including Italy, Germany, and the UK, contribute to technological development.

In this study, the mentioned parameters are marked as Factor 1. The next characteristic of the set is that the parameters pertaining to the highly educated segment of the population do not statistically significantly influence the number of internet users, as indicated by Factor 2. The share of the highly educated individuals is minor compared to the individuals with lower education, so the result of this relationship is also reflected in the rate of Internet use.

In order to increase the rate of Internet users, it is necessary to plan the activities of promotion and support of the use of digital technology towards the low-educated population. Furthermore, this study suggests that we should provide support through both formal educational institutions and non-formal educational channels. ICT specialists organize trainings to acquire digital knowledge through non-formal education [27]. However, the young population can also offer non-formal education to the elder population to help them gain basic digital skills [28]. Simultaneously, we should concentrate on the population segment experiencing the most severe effects of digital inequality, specifically the marginalized groups. Individuals with a lower educational background frequently have reduced financial earnings, which directly impacts their life standard. These population groups are often subject to exclusion from the digital society due to limited access to digital technologies. Non-formal trainings and courses for the working-age population are important for acquiring digital competencies that address jobs generated in the digital age [29].

VI. Conclusion

The PCA-LR model's results, which evaluate the influence of a variety of education indicators on Internet adoption in 27 EU member states, have led to the development of the following conclusions:

- Investing in education increases the internet adoption rate by enabling individuals to develop the necessary skills to use digital technology, thereby increasing the rate of digital literacy. This strategy should also be directed towards the digitalization of education system.
- Providing public funding for higher education of socially sensitive groups that have limited access to education and facilitating their education and digital inclusion.
- Investment in higher education develops the highly educated segment of the population, responsible for the country's technological development due to its frequent use of ICT.
- Non-formal education plays an important role because it follows the fulfillment of specific market needs from the perspective of gathering additional knowledge and skills of individuals or organizations. It aids in developing a set of values that are not explicitly addressed in formal education.

The main limitation of the study is its exclusion of various socio-economic factors that can impact the access and level of education across Europe. Future research can specifically address indicators such as household income levels, as [30] has proven their impact on the level of digital adoption. They suggest that individuals with lower incomes are at risk of digital exclusion. The authors will address this limitation in their future research to determine whether economic factors are impacting education equality and digital divide.

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Original Scientific Article

School Culture as a Catalyst for Marketing Efficiency

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Abstract—**This paper is a theoretical scientific study that explores the role of school culture as a catalyst for marketing effectiveness. Using methods of content analysis, critical analysis, document analysis, and theoretical reflection, the paper examines how school culture can be used for marketing purposes. The paper first defines school culture and explains its impact on the perception of the school as a brand. Using Keller’s CBBE model, we analyse how various aspects of school culture can shape brand perception among students, parents, and the wider community. Then, using Balmer’s AC^{4}ID test, we explore different identities of the school and how they manifest through school culture. We analyse how these identities can influence the perception of the school and its brand. Furthermore, using Grönroos’s brand relationship model, we investigate how school culture can affect the relationship between students (and their parents) and the school as a brand. We analyse how the quality of service (teaching) and interaction with the brand (school) can affect this relationship. This study provides a deep understanding of the concept of school culture from a marketing perspective, especially from the aspect of identity, image, and brand. The contribution of this study is reflected in providing new insights and understanding of how school culture can be used as an effective marketing tool. Although the paper does not include empirical research, it is based on theoretical analysis and literature review, providing valuable insights for educational institutions that want to improve their marketing strategies through a better understanding and exploitation of their school culture.**

Keywords - AC^{4}ID, brand, CBBE, identity, school culture

I. INTRODUCTION

School culture (SC) takes a main place in school management (SM). If we look at SC in the semiotic sense, it represents a sign, i.e. a symbol of the company. By understanding SC, we understand how the schoolwork’s [1], how teachers work [2], and what the internal relations are like [3]. If we start from the assumption that organizational success depends on the values and behaviour of employees, then the study of SC becomes necessary [4]. If we look at SC in the context of marketing, then it can be a catalyst for marketing activities because it helps us build the school's identity as well as branding.

The school's cultural values play a key role in employee motivation. Values such as respect, collaboration, innovation and excellence can create a positive work environment that encourages teachers to engage and grow professionally. When teachers feel valued, their motivation increases, which positively affects the quality of teaching and the success of students [5].

II. METHODOLOGY

The study starts from the analysis of relevant literature related to SC and brand theory. Using Keller’s CBBE model [6], we analyse how various aspects of school culture can shape brand perception. Also, using Balmer’s AC^{4}ID test [7], we research different identities of the school and how they manifest through SC. Finally, using Grönroos’s brand relationship context [8], we research how school culture can affect the relationship between students and the school as a brand.

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The analysis focused on patterns and themes in the works of Balmer, Keller, and Grönroos. The theories of Balmer, Keller, and Grönroos were evaluated in terms of logical consistency, validity, and reliability. Three research questions were posed: How does school culture affect marketing effectiveness? How do brand relationships mediate between school culture and marketing effectiveness? What constitutes school identity?

The contribution of this study is reflected in providing new insights and understanding of how school culture can be used as an effective marketing tool. Also, this study builds on previous studies of SC in the context of SM [9-12]. This research employs a combination of qualitative content analysis [13], document analysis [14], critical analysis [13], and theoretical reflection [15] to investigate school culture as a catalyst for marketing effectiveness.

The topic of this study is SC in the context of marketing, especially from the aspect of school identity and brand identity. The goal is to achieve a deeper understanding of the SC concept in the context of marketing and management and to offer new insights into the school's identity.

The limitations of this paper stem from its qualitative analysis. In further research, the elements of the school's identity can be empirically researched according to the model we present. In this sense, a linear model can be used to obtain the overall identity of the school for each identity dimension.

III. Context of School Culture

School culture is a complex and multidimensional concept that includes values, beliefs, norms, and practices that shape the daily life of the school. We observe SC through four aspects [16]: frameworks, products, expressions, and activities.

In addition to influencing employee motivation [4], the school's cultural values can also function as a catalyst for marketing effectiveness. A school that nurtures positive values and has a strong culture [9] can attract and retain talented teachers, students, and parents. Transparent communication, recognition and promotion of a school's achievements can improve its reputation [17] and attract more enrolments, thereby increasing marketing effectiveness. SC represents a set of values, norms, beliefs, and practices that shape the daily life of the school and influence the behaviour of all members of the school community [9], including students, teachers, administrative staff, and parents.

A. *Literature Review*

According to Schönig [18], SC is a key concept for school development. It encompasses the values, norms and practices that are promoted within the school and shape its development and success. SC is the basis for all changes and innovations within an educational institution, and a positive school culture can improve the motivation of students and teachers.

Rosenbusch and Huber [19] emphasize that SC influences educational goals and processes. SC can support the achievement of educational goals, and the creation of an organizational culture that supports educational goals and promotes cooperation between teachers and students is essential.

Heenan et al. [20] investigate the impact of transformational school leadership on staff and school culture. They conclude that transformational leadership has a positive effect on staff motivation and improves school culture. Transformational leaders inspire and motivate their teams, which leads to improvements in performance and achievement of educational goals.

Mincu [21] analyses the key role of SM in the transformation of education, emphasizing the importance of organizational culture and school structure for achieving quality education. Effective school management requires understanding and adapting the organizational culture to achieve the desired educational outcomes.

Wilson and Knight [22] research how school culture affects the implementation of educational improvements by teachers. They conclude that positive SC supports innovations and improvements in teaching. Teachers play a key role in shaping and maintaining school culture, and their cooperation and professional development are essential for the school's success.

Veletić et al. [23] investigate teachers' and principals' perceptions of the school climate, with special emphasis on the principal's leadership style and its impact on the quality of the organization. They conclude that the principal's leadership style significantly affects the perception of the school climate and teacher satisfaction.

Torres [24] provides an overview of theoretical approaches to organizational culture in schools and their connection with leadership and management processes. The school's identity is formed through its culture, which affects the perception of the school in the community and its image. Positive school culture can improve the school's image and attract more students and community support.

Jukić [9,17,25] analyses the corporate brand in school management, emphasizing the role of employees, corporate identity, and reputation. In this sense, it builds on Balmer's theory [7,26,27] of corporate identity. These studies provide examples of how theoretical models such as corporate identity [28] can be applied in the context of SM and SC.

Živković researches and analyses the teacher identity model. This research builds on the correlations in teaching [29] that start from Beijaard teachers' professional identity [30-32]. Teacher professional identity can be most simply presented as the teacher's sense of self-worth and reflection on those values. According to Jukić [12,17] there is a common correlation between employee behaviour and SC.

B. *School Culture – Phenomenological Approach*

School culture (SC) is a complex concept that includes the basic assumptions and beliefs of school members, which operate unconsciously and define the way the school sees itself and its environment. In fact, the SC model itself is identical to the organizational culture model, only that it is observed in the context of education. Schein's model of organizational culture is one of the most well-known and widely used models for understanding how culture functions within organizations.

Schein's organization culture model [4] includes three levels: artifacts, espoused values, and underlying assumptions. Schein's model can be applied to SC to better understand the various elements that shape the daily life of the school (see Table I).

TABLE I. SCHOOL CULTURE IN SCHEIN'S CONTEXT.

Artifacts	The physical appearance of the school, school ceremonies, school symbols
Espoused values	Mission and vision of the school, educational strategies, rules of conduct
Underlying assumptions	Deeply held beliefs about education, learning and teaching

Artifacts are the visible elements of a culture, such as the physical environment, language, technology, dress styles, rituals, and ceremonies [4]. Artifacts are easy to see, but often difficult to understand without a deeper insight into the organization. In a school context, artifacts can include school uniforms, classroom layouts, school slogans, symbols, and ceremonies such as graduations.

Espoused values are declared values and norms shared by members of the organization [4]. They include the organization's mission, vision, strategies, and goals. Expressed values shape the behaviour of the organization's members. Expressed values in a school may include an emphasis on academic excellence, inclusion, collaboration, innovation, and respect.

Underlying assumptions are deeply rooted beliefs and assumptions that unconsciously shape the perceptions, thoughts, and feelings of organizational members [4]. Basic assumptions are the most difficult to change because they are implicit and often unspoken. Basic assumptions in school may include beliefs about the nature of learning, the roles of teachers and students, and the purposes of education.

Structural elements such as classroom organization and administrative procedures can support or hinder certain cultural values [33,34]. For example, flexible schedules can encourage collaboration and innovation among teachers. School culture is shaped by its history, context, and people in it [34,35]. For example, the age of the school can influence cultural changes [36,37], and the external context, such as the community and local education authorities, also plays a significant role. If a school has a culture that values autonomy and creativity, structural elements are likely to be adapted to support these values (see Table II).

TABLE II. STRUCTURE OF SCHOOL CULTURE.

Interconnection	The Principal influences on SC, and the SC shapes the principal
Impact	Structural elements encourage teacher cooperation
Influence	Structural elements support the teacher's values

SC is a system of standards, beliefs, and rules [38]. Also, emotional support, empathy and positive interpersonal relationships play a key role in creating a supportive and effective educational environment. Cultura of care not only improves the student experience, but also contributes to the professional satisfaction and identity of teachers [39]. Teacher identity is a key component of SC. The teacher's professional identity model is based on three key dimensions [31,32]: the teacher as an expert in the subject, as a pedagogical expert and as a didactic expert (see Table III).

As can be seen from Table III, teachers use artifacts to create a positive environment and model professional behaviour. Also, Schein's first level of culture [4], i.e. artifacts are a visible part of SC, such as the physical appearance of the school, school uniforms, symbols and slogans, and ceremonies and rituals. From the aspect of espoused values, expressed values include the mission and vision of the school, educational strategies, rules of conduct and expectations from students and teachers.

C. *Balmer's Concept of Corporate Identity*

Balmer [41] emphasizes the importance of corporate identity as a key element in corporate marketing strategy. In the simplest terms, the corporate identity of a school includes visual identity, organizational identification, and the overall perception of the school. Corporate identity is a prerequisite for school branding.

The ACID Test (Analysis of Corporate Identity Dimensions) is a method developed by Balmer and Soenen [42] to assess and manage corporate identity. This method helps organizations identify weaknesses in their identity strategy and prioritize changes. AC^2ID Test (Actual, Communicated, Conceived, Ideal, Desired Identity) extends the ACID Test by adding additional identity dimensions [26]. This method enables a deeper understanding of various aspects of corporate identity and how they are interconnected.

TABLE III. COMPARISON OF ORGANIZATIONAL CULTURE, TEACHER'S IDENTITY AND SCHOOL CULTURE.

Schein's model	Techer's identity	School Culture
Artifacts	The teacher as a role model	Appearance of the school, symbols, uniforms, ceremonies
Espoused values	The teacher as an educator	Rules, behaviours, school vision, strategy
Underlying assumptions	Teacher as a professional	The role of the teacher, the purpose of education

AC^4ID Test (Actual, Communicated, Conceived, Covenanted, Cultural, Ideal, Desired Identity) is the latest iteration of Balmer's corporate identity model [7]. AC^4ID Test is a comprehensive framework for the analysis and management of corporate identity, which includes seven dimensions of identity: actual, communicated, conceived, covenanted, cultural, ideal, and desired identity. Applying Balmer's identity analysis methodology [7] in the context of SM, we can interpret and explore SC in detail (see Table IV).

Actual identity refers to what the school really is, including its values, culture, structure, and behaviour. This includes everything the school does and how it treats students, parents, and employees. A school that has a strong academic reputation, offers a variety of extracurricular activities, and has an inclusive culture.

Communicated identity refers to the way the school communicates its identity to external and internal stakeholders. This includes all forms of communication, from official websites and brochures to social media and public appearances.

Conceived Identity refers to the perception that external stakeholders (such as parents, community, and potential students) have of the school. This may include the school's reputation in the community and the opinions people have about its quality. In the context of the school, we understand it as a school that is known for its high success rate in state exams and positive feedback from parents.

Covenanted Identity refers to the formal and informal contracts and promises that the school

TABLE IV. AC^4ID TEST IN SCHOOL.

Identity type	School
Actual	Teacher's relationship
Communicated	School communications
Conceived	Perception about school
Covenanted	The school's mission
Cultural	School culture
Ideal	School goals
Desired	School personality

makes to its stakeholders. This includes the mission, vision, and values that the school expresses publicly. As an example, we can take a school that in its mission emphasizes dedication to academic excellence and holistic development of students.

Cultural Identity refers to shared values, norms, and practices within the school. This includes all aspects of school culture; from the way students and teachers relate to each other to the traditions and customs of the school. This is remarkably like Grönroos' understanding of the concept of brand relationship. The brand as a brand image is the consequence of how a given customer perceives his relationship with a brand over time.

Ideal Identity refers to what the school aspires to become in the future. This includes long-term goals and aspirations that the school has for its development and progress. As an example, let us take a school that aspires to become a leading educational institution in the region with an emphasis on STEM education and international programs.

Desired Identity refers to the identity that key stakeholders (such as management and teaching staff) want the school to have. This may include specific characteristics and values they want to see in the school. An example can be a school board that wants the school to be recognized for its innovation and adaptability in education.

If we compare the common and opposite aspects of AC^4ID school identity according to Balmer [7,26,40,41] and elements of school culture according to Peterson and Costner [6], we can deeply analyse the SC context. From a holistic point of view, Balmer's model analyses the organization's identity through multiple dimensions and is therefore better. Both approaches emphasize the importance of communication in the formation and maintenance of identity or SC. Specifically, according to Balmer [7,41] it is the concept of communication that is part of the AC^4ID test, and according to Peterson and Costner [6] it is expressions that include communication patterns, symbols and rituals that help shape the school's identity.

IV. Marketing Implications

The brand concept is extremely important in marketing. According to Grönroos [8] branding is the central concept of marketing. Veljković warns of the essential importance of the brand in its associations, confirming Kapferer's [42] and Keller's [6] theories of the brand as a perceptual creation. A significant responsibility for the successful positioning of the brand lies precisely in the communication with consumers, which we observe through image determination. Starčević [45] states very, similarly, emphasizing the role of advertising and marketing communication in branding.

Linking SC to Keller's Customer-Based Brand Equity (CBBE) model can provide a deeper understanding of how school culture can serve as a foundation for school branding. Keller's CBBE model [6] focuses on building a strong brand through four key stages: brand identity, brand meaning, brand responses, and brand resonance.

The CBBE model presented by Keller points to a deeper understanding of perceptions, feelings, and relationships from the consumer's point of view, but also as a strategic model for building a strong brand.

Kapferer's model emphasizes the importance of aligning brand identity with brand image to ensure consistency and authenticity in consumer perception. Keller [6,46] understands brand image as a key element in building market value. According to his CBBE model, brand image is defined as a set of associations that consumers have about the brand.

Keller emphasizes that brand image includes all the associations that consumers associate with the brand. These associations can be functional (e.g. product quality) or emotional (e.g. feelings the brand evokes).

In the context of SM and SC, this is about the image of the school [12,43]. Veljković connects the brand identity with a set of associations and experience with the brand [44]. In this context, we can present a logical matrix that connects the CBBE model and the AC4ID school identity model (see Table V).

Brand identity [6] refers to how the school wants to be perceived by its stakeholders. Actual and communicated identity include actual practices and the way the school communicates its values. In this sense, SC makes basic assumptions, values and beliefs, rules, policies and procedures, and communication patterns, symbols and rituals shape the identity of the school.

TABLE V. LOGIC MATRIX OF CBBE MODEL AND AC⁴ID TEST IN SCHOOL CULTURE.

CBBE model	AC⁴ID Test	School culture
Brand Identity	Actual, Communicated	Symbols, rituals
Brand Meaning	Conceived, Cultural	Academic success, awards
Brand Responses	Covenanted, Communicated	Stakeholder perception, communication
Brand Resonance	Ideal, Desired	School vision, teacher identity

Brand meaning [6] refers to the functional and emotional aspects that the brand offers. Conceived and cultural identity include the perception of the school and its core values. This understanding is the same as Veljković's when he discusses brand associations. Therefore, SC consists of academic successes, school projects, publications, awards, and formal and informal school activities that shape the meaning of school.

According to Keller [6], the brand response category here represents responses to the brand that include the judgments and feelings of stakeholders towards the school. This means that covenanted and communicated identity include formal and informal contracts and the way the school communicates its identity. This is confirmed by Balmer's AC⁴ID Test. From the SC aspect, the perception of parents, students and the community, communication patterns, symbols, rituals, and formal and informal school activities shape responses to the school brand.

From the aspect of brand resonance, we observe the highest level of loyalty and emotional connection with the brand. It is an ideal and desired identity that includes the long-term goals and vision of the school.

This is in accordance with Grönroos' understanding brand relationship [8]. In the context of schools, this means that school culture, teacher identity and service perception play a key role in shaping brand relationships. School culture can significantly influence the quality of service a school provides, which in turn affects the perception of the brand among students, parents, and wider communities.

Key Performance Indicators (KPI) are measurable values that organizations use to monitor and evaluate performance [46,47] in achieving their goals. In the context of schools, KPIs may include graduation rates, standardized test scores, attendance rates, student and parent satisfaction, and community involvement. These indicators help schools quantify their success and identify areas for improvement [48].

TABLE VI. EVALUATION OF KPIS, SC AND SCHOOLS.

KPI	SC	Schools
Graduation rate	SC reflects the school's real identity	LAUSD uses test scores and graduation rates
Media presence	SC reflects school leadership	APS monitors the school's presence on social media
School Climate	Teacher's identity and SC	HISD uses a school climate index
Reviews	Desired image of SC	LAUSD monitors online school reviews
Community involvement	SC encourages cooperation	HISD tracks the number of events and volunteering
Net Promoter Score (NPS)	A high NPS indicates a positive SC	APS uses surveys to measure customer satisfaction

Albuquerque Public Schools (APS) use surveys to gauge student and parent satisfaction, identifying areas for improvement [49]. The Houston Independent School District (HISD) tracks events and volunteer hours to measure community involvement, enhancing their community hub image [50]. The Los Angeles Unified School District (LAUSD) uses test scores and graduation rates to assess academic success [51], promoting their commitment to equity and access to education (see Table VI).

V. CONCLUSION

SC represents a fundamental aspect of educational institutions, shaping the daily life of the school through values, beliefs, and norms. Understanding and managing SC is key to achieving high educational standards and creating a positive environment. In this paper, we research different models and theories that help in analysing and understanding SC, including Schein's model of organizational culture, teacher's professional identity, Keller's CBBE model and Balmer's AC⁴ID Test.

Connecting different models and theories enables a comprehensive approach to understanding and improving school culture and identity. A school with a strong culture of collaboration and innovation can attract more students and parents, which improves marketing results. The way a school communicates its culture to external stakeholders can improve marketing effectiveness. Consistent and authentic communication of school culture can increase trust and loyalty among stakeholders.

School culture can be a catalyst for more effective communication. If the school has a positive and inclusive culture, this will be reflected in all forms of communication, which can improve marketing results and above all the brand images. Customer's brand relationship is based on a variety of brand contacts. In this sense, we see the school as a service activity that achieves a communication function through SC. By combining elements from the CBBE model, the AC^{4}ID model, schools can develop comprehensive strategies that not only improve internal practices, but also strengthen external perception and emotional connection with the school brand.

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Original Scientific Article

Leveraging Big Data Analytics to Strengthen Global Value Chains amidst Geopolitical Crises

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Abstract—**Amid contemporary geopolitical uncertainties, the shift toward a multipolar world order has highlighted unresolved global conflicts, significantly altering the economic landscape. Multinational companies (MNCs) now face challenges, including restricted access to energy and raw materials, economic sanctions—especially in the energy sector—trade barriers in high technologies, and increased risks along key transport routes. This research explores how Big Data Analytics (BDA) and BDA-based tools can mitigate these geopolitical challenges. It first analyzes theoretical frameworks for Global Value Chain (GVC) risk, classifies current geopolitical risks, and examines BDA's potential in addressing these risks through case studies. The research identifies Real-time Decision-Making, Predictive Analytics, and Integration with other 4IR Technologies as key BDA capabilities that enhance risk mitigating strategies for GVCs. Although these capabilities are commonly applied in GVC management, they remain underutilized in an unpredictable geopolitical environment. The study aligns specific BDA capabilities with corresponding geopolitical risks, providing guidelines for GVC management and suggesting future adaptations of software solutions to help MNCs navigate geopolitically-driven business risks.**

Keywords - big data analytics, GVCs, geopolitical risks

I. Introduction

The shift towards a multipolar world order has exposed numerous unresolved conflicts across the globe. This ongoing geopolitical fragmentation has resulted in the most economically disruptive period since World War II. Many of these challenges were unforeseen, forcing companies to adapt rapidly to new realities. These included the Ukrainian conflict and extensive sanctions imposed by the U.S., EU, and their allies against Russia and its affiliated businesses. Simultaneously, tensions escalated in the Israeli-Palestinian conflict (with accompanying instability in Lebanon, Yemen, Jordan, etc.), Taiwan-related issues intensified (including tension in the Indo-Pacific), uprisings erupted across the Sahel region, and resistance against U.S. influence in the Arab world.

These events mark seismic shifts in the global economic landscape. Multinational companies (MNCs) now face to: difficulties in accessing energy and raw materials, a series of economic sanctions that include primary, secondary, and targeted measures against specific companies or sectors, increased trade and investment restrictions in high technologies. Blockades and increased risks along key transport routes have added to the challenges that GVCs need to overcome. This environment is unlikely to stabilize in the near future, so that understanding and managing geopolitical risks have become essential components of every MNC strategy.

There is a significant gap in research exploring the potential of 4.0 IR technologies to enhance risk management amid geopolitical uncertainty. This study aims to fill that gap by focusing on one critical aspect: BDA. As a key component of 4.0 IR, BDA plays a crucial role in GVC management by offering real-time insights, predictive analytics, and seamless integration

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with other advanced technologies. These features allow companies to quickly adapt and make informed decisions in an increasingly volatile and dynamic global environment.

The primary aim of this research is to examine how BDA solutions and BDA-based tools can mitigate the geopolitical challenges currently facing international business. Following the Introduction, the second chapter establishes a foundational framework for understanding GVC risks through established theoretical lenses. This chapter presents theoretical classifications of GVC risks, outlines key strategies for mitigating these risks, and discusses the potential role of BDA in supporting these strategies. The third chapter explores contemporary geopolitical developments and categorizes the real-world risks encountered by MNCs, including energy, transportation, and technological risks. The fourth chapter offers practical solutions detailing how BDA can address the specific geopolitical threats identified in the previous chapter.

II. Theoretical Framework

A. Classifying risks in GVCs

Successful management of global value chains (GVCs) involves various key risks and strategies to mitigate their negative impacts, particularly in the face of geopolitical disturbances. This research focuses specifically on theoretical presentations of risks and corresponding mitigation strategies relevant to current geopolitical challenges.

While academic discourse often highlights the productivity and welfare benefits of GVCs for international companies, policy discussions tend to emphasize associated risks over potential rewards [1-3]. Risks in value chains include disruptions in the flow of information, materials, and products from suppliers to end users [4]. These risks are inherent in both domestic and international operations due to the complexity of activities, processes, and the involvement of multiple stakeholders. Therefore, effective risk management is essential for maintaining and enhancing GVC performance.

Technological risks encompass various types of risks. Teece [5] stressed risks associated with technological change, innovation dynamics, and intellectual property protection. Tushman and Anderson [6] highlight risks stemming from the (un)ability to adapt to technological advancements and changing market conditions. In the third type of technological risk some authors include cyber-attacks, including ransomware, data breaches, and espionage.

Transportation risks arise from constraints and logistical bottlenecks, impacting the efficiency and reliability of GVCs [7]. For multinational companies, disruptions in logistics and transportation networks can cause delivery delays, increased costs, and challenges in maintaining product availability [8]. These disruptions include delays, infrastructure limitations, and other issues.

B. BDA Term and its Main Advantages in Managing Geopolitical Risks

In general, Big Data refers to large, complex datasets that are challenging to process and analyze with traditional methods. Although there is no universally accepted definition of Big Data, there is broad consensus on its key elements, known as the “5Vs”: Volume (large scale), Velocity (fast data generation and processing), Variety (diverse data types), Veracity (data quality), and Value (usefulness of data). Big Data encompasses not only the data itself but also the advanced analytics capabilities required to extract valuable insights, thereby enabling data-driven decision-making.

BDA involves the extraction of knowledge and information from diverse data sources, often in real time, and the integration of these insights to uncover hidden patterns. It employs various advanced techniques to analyze this data, facilitating data-driven decision-making [9]. The primary application of BDA is in business intelligence and decision-making. Initially, BDA's widespread use helped organizations analyze vast amounts of data to gain insights that could improve strategic decisions, optimize operations, and enhance customer experiences. Additionally, BDA provides a comprehensive view of the value chain, supporting the development of more resilient value chains.

Prioritizing BDA over other 4IR technologies for addressing contemporary geopolitical uncertainties in GVCs is justified for several key reasons:

- *Real-time Decision-Making*: BDA allows for the real-time analysis of vast data, enabling timely, informed decisions crucial in dynamic GVC environments. Tools like FourKites and Project44 provide real-time tracking and predictive analytics, helping companies quickly adapt to changing conditions.

- *Predictive Analytics*: BDA forecasts future trends and disruptions, enabling organizations to anticipate and mitigate risks before they escalate [10-12]. Tools like RapidMiner, SAS, and Tableau are essential for staying ahead of potential challenges.
- *Integration with Other 4IR Technologies*: BDA integrates seamlessly with IoT, AI, and blockchain, amplifying its benefits and enhancing the digital transformation of GVCs [13,14].

C. BDA and Risk Management Strategies

The theoretical framework for managing risks in international business encompasses several key strategies for mitigating risks in GVCs.

1) BDA and Diversification of Suppliers and Markets

One of the most common strategies is the diversification of suppliers and markets. By sourcing from multiple suppliers, companies reduce reliance on a single source, thereby minimizing risks associated with value chain disruptions [3]. Expanding into diverse global markets also allows firms to balance demand fluctuations and reduce exposure to geopolitical risks, following the principles of Portfolio Theory [15].

BDA tools analyse vast datasets, enabling businesses to identify, evaluate, and diversify suppliers based on performance metrics, geopolitical stability, and market dynamics. Platforms such as Riskmethods, Resilinc, Zycus, and Jaggaer help companies identify alternative suppliers in regions less affected by geopolitical risks, ensuring value chain resilience through diversification. Additionally, BDA helps firms continuously monitor geopolitical shifts, ensuring timely adjustments to supplier relationships or market engagements.

For market diversification, BDA analyses macroeconomic data, regional trends, and political risks. Intelligence platforms like Crunchbase, Euromonitor International, and Gartner provide detailed market insights, helping firms strategically expand into new regions with lower risk exposure.

2) BDA for Risk Assessment and Contingency Planning

This is one of essential risk management strategies for preparing businesses to handle disruptions. These processes involve regular assessments and scenario analysis to outline actionable responses [16,17]. Incorporating BDA here enhances risk monitoring through predictive analytics and simulation models, improving the ability to anticipate potential disruptions.

Integrating BDA significantly enhances risk assessment and contingency planning. By analyzing historical and real-time data, BDA platforms enable businesses to continuously monitor global environments. Tools such as Real-Time Analysis Platforms provide instant alerts on geopolitical shifts and value chain disruptions, allowing firms to respond proactively [18]. Advanced analytics, including machine learning and predictive modeling, enable firms to forecast risks more accurately and design optimized contingency responses. Notable platforms like Riskmethods, Interos, and Resilience360 specialize in continuously monitoring and assessing risks, including those stemming from geopolitical tensions.

BDA facilitates advanced scenario planning, enabling companies to model potential disruptions from geopolitical risks. Software like AnyLogic and Simio assists firms in developing contingency plans by visualizing the impact of various scenarios.

3) Enhancing Visibility and Transparency Using BDA During Geopolitical Turmoil

A strategy focused on visibility and transparency relies on real-time insights into goods' movement, from raw materials to finished products. During geopolitical crises, BDA enhances visibility by providing live data on value chain activities, enabling early issue detection and timely decisions. Tools like Project44 and FourKites offer real-time logistics tracking, helping businesses swiftly adapt to disruptions. Platforms like IBM Watson Analytics integrate data sources for a unified view of value chain conditions, empowering firms to assess disruptions and make informed decisions in real time.

4) Local Adaptation strategies and BDA

These strategies focus on tasks such as developing cultural sensitivity, integrating corporate social responsibility (CSR), and empowering regional managers to respond swiftly to local developments.

BDA solutions play an integral role in supporting these local adaptation strategies. By analysing localized data—such as regional market conditions, political risks, and cultural factors—BDA enables businesses to adjust their operations in response to regional developments. This approach allows firms to mitigate risks and enhance their resilience in the face of volatile global conditions.

5) Comprehensive strategy - building a resilient value chain

Building a resilient value chain integrates all the aforementioned strategies. Resilience is characterized by both robustness and flexibility. A robust value chain can withstand shocks without experiencing significant performance declines, while a flexible value chain can adapt to disruptions by adjusting resources and reconfiguring processes [4,19].

In addition to the previously discussed potential roles of BDA, BDA-driven Risk Management Platforms analyze vast data streams and apply predictive models to create comprehensive risk profiles. These platforms simulate various geopolitical scenarios and recommend effective mitigation strategies, ensuring preparedness for future disruptions. Furthermore, Digital Twins enhance this process by creating virtual models of the value chain, allowing businesses to simulate the impacts of different scenarios and adjust operations accordingly [9].

III. Geopolitical Dynamics and GVCs Risks

The most pressing threats to international business today include spreading military conflicts, economic sanctions, and techno-protectionism. Although the negative impacts of these geopolitically motivated measures on global value chains (GVCs) were evident after the 2008 economic crisis, they significantly escalated after 2017 due to the U.S.-China trade war, various EU restrictions, and extensive economic sanctions against Russia following February 2022.

These measures disrupt value chains by restricting access to essential raw materials, components, and technologies, resulting in increased operational costs and loss of market access [20,21]. Moreover, geopolitical instability has heightened transportation risks, presenting insurmountable challenges for many multinational corporations. Consequently, acute geopolitical risks can be categorized into three main areas: value of energy and resources, technological risks, and transportation risks.

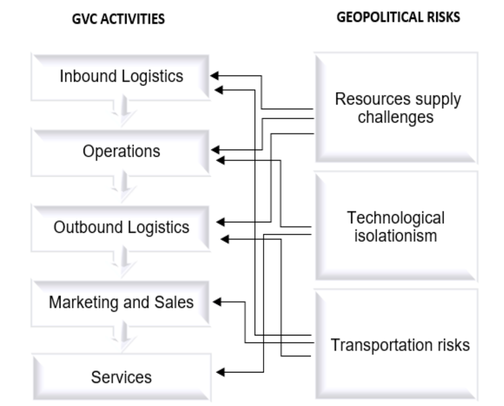

Figure 1. Geopolitical Risk Exposure in Activities within Global Value Chains

A. *Risks in Accessing Energy and Raw Materials*

GVCs are increasingly vulnerable to disruptions in energy and raw material supplies due to conflicts in key fuel-producing regions and geopolitical price volatility. Following Russia's annexation of Crimea in 2014 and the escalation of the Ukrainian war in 2022, sanctions on Russia's oil, gas, and financial sectors have significantly altered GVC dynamics. Countries like China and India have emerged as major buyers of Russian products, while the EU now indirectly purchases these goods at higher prices.

The Ukraine conflict has led to severe disruptions in energy supplies, resulting in price volatility and shortages. Europe’s energy-intensive industries-such as aluminum, steel, and chemicals-have faced soaring costs and widespread closures due to self-imposed restrictions on energy imports from Russia and Ukraine [22]. These industries are particularly sensitive to energy disruptions, underscoring the importance of regional dynamics in assessing their vulnerability.

Instability has also affected other energy-exporting regions. In 2022, high oil prices allowed Middle Eastern economies, like Saudi Arabia and Qatar, to decline U.S. requests for increased energy supplies during the Ukraine conflict, further jeopardizing global energy security. This shift illustrates the varying impacts of geopolitical tensions across different regions and sectors reliant on these energy sources.

A recent example of this uncertainty occurred during the July 2023 military coup in Niger, a crucial supplier of low-cost uranium to France. Following the coup, Niger proposed a significant price increase and revoked a French mining permit in June 2024, further challenging France's nuclear energy sector. This incident highlights how geopolitical instability in one region can have far-reaching consequences for specific industries elsewhere, emphasizing the interconnectedness of GVCs and the need for region-specific risk assessments.

B. Technological Risks in Contemporary Geopolitical Landscape

Growing techno-geopolitical uncertainty is reshaping international business and requiring MNEs to adapt strategically. For instance, the U.S. CHIPS and Science Act exemplifies a shift toward techno-nationalism amid escalating competition with China, aiming to enhance domestic semiconductor production. This trend highlights how specific regions, particularly the U.S. and Europe, are prioritizing technology self-sufficiency, impacting MNEs reliant on GVCs. The European Commission has identified four critical technology areas at high risk for security and leakage, recommending measures to control researcher migration and foreign ownership to bolster domestic capabilities.

Moreover, sanctions imposed on Russia by major countries increase risks for technology firms supplying essential tech to Russia, significantly impacting companies in Turkey, China, and the UAE, which may find themselves navigating both geopolitical pressures and the potential backlash from Western sanctions. As such, MNEs must assess which countries remain favorable for technology partnerships and value chains, considering the vulnerabilities inherent to specific sectors. Additionally, companies reliant on both the U.S. and China for technology, as well as those engaged with any part of the Russian economy, must carefully balance independence and interdependence, recognizing that different sectors face unique challenges.

A second category of technological risk stems from politically motivated cyberattacks, which are rising amid ongoing conflicts and heightened tensions. These attacks can disproportionately impact sectors like critical infrastructure, financial services, and technology. Although accusations may sometimes be politically driven, there have been cases where perpetrators have claimed responsibility, emphasizing the need for MNEs to adopt robust cybersecurity measures tailored to their industry risks.

C. Geopolitical Challenges in Global Transportation Networks

In contemporary international business conditions, risks related to transportation are prominent. For example, the Ukrainian war has significantly affected Black Sea transport, with Russian naval blockades and Ukrainian defensive measures creating severe disruptions. The conflict has particularly impacted grain exports from Ukrainian ports like Odesa, leading many ships to avoid the Black Sea and take longer routes via the Mediterranean and Baltic Seas.

Similarly, attacks by Yemen's Houthi rebels on commercial ships in the Red Sea have severely disrupted trade routes [23]. The Houthis have targeted ships from countries they view as adversaries, causing major shipping companies to reroute vessels around Africa's Cape of Good Hope, adding around 3.500 nautical miles to their journeys. This rerouting increases travel time and costs, affecting maritime commerce. Additionally, disruptions to the Suez Canal, which handles a significant portion of global trade, have led to a 1.3% decline in global trade volume [7,24].

IV. Big Data Analytics in Mitigating Current Geopolitical Risks

A. Harnessing BDA for Resource Risk Management in GVCs

To address uncertainties in resource and energy supply-such as high costs, scarcity, and political instability-Western companies' GVCs have not fully utilized technologies associated with the 4.0 IR to overcome emerging challenges or seize opportunities. However, BDA and BDA-based solutions, particularly when integrated with IoT and other digital technologies, can effectively manage resource risks within GVCs. The primary risks of resources -price volatility, sectoral sanctions, and disrupted production/export capabilities-can be mitigated through several strategies.

Real-time Monitoring: IoT sensors can gather data on resource availability, quality, and demand across the value chain. BDA processes this data to detect early signs of price volatility, allowing companies to respond quickly. While BDA typically excels in predictive analytics by leveraging historical datasets (prices, weather patterns, economic indicators) to forecast price movements, contemporary geopolitical turbulence can challenge the validity of these predictions.

Scenario Planning: BDA is valuable for managing sectoral sanction risks. By analyzing trade flows, political developments, and historical sanctions, BDA can simulate the potential impacts on various sectors, aiding companies in developing contingency plans and identifying alternative suppliers or markets.

Value Chain Diversification: BDA facilitates the identification and evaluation of new suppliers across different regions, reducing dependence on any single country or sector vulnerable to sanctions.

Integration of IoT and BDA: This combination supports real-time monitoring, enabling continuous tracking of transactions, supplier relationships, and trade routes to maintain compliance with international sanctions. To mitigate disruptions in energy production and export, BDA enhances value chain visibility. IoT devices can provide real-time data on production processes, inventory levels, and logistics, while BDA analyzes this information to predict and address potential disruptions. Additionally, integrating BDA with blockchain technology enhances transparency and traceability in resource management, ensuring data integrity and secure transaction records.

Success Example: Siemens exemplifies successful integration of IoT and BDA into its manufacturing processes to improve energy efficiency and predictive maintenance. By deploying IoT sensors across production lines, Siemens collects real-time data on energy usage, equipment performance, and maintenance needs. BDA analyzes this data to forecast maintenance requirements, preventing downtime and optimizing energy consumption [24].

B. Mitigating Technological Risks in GVCs Through BDA

BDA and BDA-based solutions play a crucial role in mitigating technological risks arising from geopolitical factors such as techno-nationalism, economic sanctions, and politically motivated cyberattacks.

To navigate dependencies between the U.S. and China and their associated risks, MNCs must adjust global strategies, reconfigure value chains, and enhance resilience through effective corporate diplomacy. BDA can aid in developing comprehensive risk-assessment models that evaluate the likelihood and impact of violating sanctions in the technology sector. These models incorporate data on geopolitical developments, trade patterns, and historical enforcement actions to provide insights into risks tied to specific transactions or partnerships. More important, BDA can enable companies to manage reliance on the U.S., China, and other key players, since it can identify alternative suppliers of high-tech component.

In terms of cybersecurity, BDA enhances GVCs through real-time monitoring, predictive analytics, and integration with machine learning (ML) and data mining. Real-time monitoring can analyze vast amounts of network data—such as traffic and user behavior—to detect potential cyber threats. ML algorithms identify patterns that indicate cyberattacks, allowing organizations to respond swiftly.

Predictive analytics can forecast future threats by analyzing trends in cyberattack patterns and geopolitical tensions. BDA platforms like Splunk and IBM QRadar provide real-time cybersecurity monitoring across GVCs. For example, Pakistan Askari Bank improved its security posture using QRadar, reducing daily security incidents from about 700 to 20 and cutting the average response time for cyberattacks from 30 to just 5 minutes [25].

C. BDA for Managing Transportation Risks in GVCs

BDA and related technologies, such as IoT, AI, and predictive modeling, play a crucial role in mitigating transportation risks in GVCs, particularly along hazardous routes and amid fluctuating costs caused by geopolitical turmoil. By processing vast amounts of real-time data from transportation logs and geopolitical events, BDA identifies patterns and predicts risks like political unrest, military conflicts, or natural disasters. Its applications extend to procurement, manufacturing, routing optimization, and real-time traffic monitoring.

BDA enhances route planning by assessing the likelihood of roadblocks, protests, or military activities that may impact the movement of goods. This capability enables companies to choose cost-effective routes, reducing the chances of dangerous encounters or high costs.

BDA is invaluable for simulating geopolitical scenarios, such as new sanctions or the closure of critical trade routes, and assessing their impact on transportation costs. Companies can utilize these insights for contingency planning, including stockpiling goods, renegotiating contracts, or adjusting pricing strategies.

IoT devices enable real-time monitoring of shipments, allowing companies to swiftly address potential risks or delays and optimize routes and schedules to avoid dangerous areas. While this may not reduce transportation costs directly, it significantly helps safeguard transported goods and vehicles. The integration of BDA, IoT, and GIS further strengthens the management of transportation challenges.

The findings on how BDA can support the management of geopolitical risks are illustrated in Fig. 2.

Success Example: Maersk Line, a leading Danish international container shipping company and the second largest globally, exemplifies advanced technological integration. Maersk employs a range of cutting-edge technologies, including IoT, data analytics, AI, machine learning, digital twins, and augmented reality (AR) [26].

BDA can contribute to future adaptations of technical solutions for GVC risk management in several key ways. The most important are: by enhancing predictive capabilities, integrating with 5G and edge computing for faster real-time data processing, and using AI to simulate diverse risk scenarios. BDA can also be combined with blockchain to improve transparency and traceability, while adaptive learning systems can evolve to meet changing geopolitical and economic conditions.

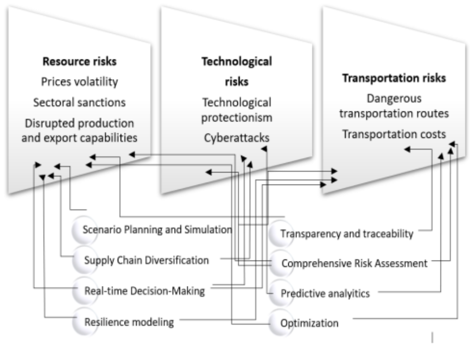

Figure 2. Possibilities of BDA in Managing Geopolitical Risks

Integrating BDA solutions into GVC risk management strategies can yield transformative *long-term effects* by enhancing efficiency and optimizing operations. The optimization not only reduces costs in risky period, but also boosts productivity, making value chains leaner and more agile in adapting to future changes.

V. Conclusions

The transition to a multipolar world presents complex geopolitical challenges that significantly impact GVCs. This research demonstrates how BDA can mitigate risks related to resource scarcity, technological disruptions, and transportation issues, enhancing GVC resilience.

A key finding is that BDA, especially through Real-time Monitoring, enables companies to navigate price volatility in resource markets by tracking commodity price fluctuations, facilitating timely decision-making. Additionally, Scenario Planning aids in preparing for sectoral sanctions by modelling various outcomes for strategic responses. BDA also enhances Value Chain Diversification, identifying alternative raw material sources and reducing supplier dependency. The integration of IoT with BDA ensures compliance with international sanctions, while combining BDA with blockchain technology improves transparency and traceability in supply chains.

Transportation risks can disrupt GVCs, but BDA, IoT, and predictive modelling effectively mitigate these challenges. BDA processes real-time data for Predictive Route Planning, anticipating disruptions, while Scenario Planning helps companies adapt to fluctuating transportation costs. The integration of BDA, IoT, and GIS strengthens the management of transportation challenges, ensuring efficient and safe delivery of goods.

This research emphasizes the essential role of BDA and its tools in enhancing GVC resilience against geopolitical risks, providing guidelines for GVC management. However, significant differences among small, medium, and large enterprises present challenges in recommending BDA for risk mitigation. Small and medium-sized enterprises (SMEs) face limitations such as resource constraints and insufficient skilled personnel, hindering BDA adoption. Thus, while the findings guide GVC management in mitigating specific geopolitical risks, addressing BDA adoption remains vital for the future strategies of multinational corporations.

The widespread adoption of BDA will reshape global trade dynamics. Firms and countries that prioritize these technologies will gain a competitive edge, potentially creating a divide between technologically advanced economies and those slower to adopt BDA. This shift will redefine global trade relations and position data-driven organizations as leaders in future economic landscapes.

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Original Scientific Article

Student Support Services Intervention on Learners' Participation and Retention in Distance Learning Programme at the University of Ibadan, Nigeria

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Abstract—**The implication of quality assurance of open and distance education as alternative access to higher education has necessitated the provision of student support services for students' enrolment and retention. Based on this, therefore, this study investigated the student support services intervention on learners' participation and retention in distance learning programme at the University of Ibadan. The descriptive survey research design was adopted. The population was comprised 100 to 300 level students, with a sample size of 445 students randomly selected from the faculties of Arts, Education and the Social Sciences. A questionnaire of thirty (30) items on the "Perceived Student Support Services and Learners' Participation and Retention Scale (r = 0.86) was used for the study. Data were analysed using multiple regression and Pearson Product Moment Correlation at 0.05 level of significance. The study's findings revealed that the student support services (administrative, technological, tutoring, with its accessibility and affordability) significantly influenced learners' participation and retention (F(4, 440) = 572. 893; R2 = 0.839) and jointly accounted for 83.9% of its variance. Based on the findings, it was recommended that the management of the Distance Learning Centre, notably the University of Ibadan, must ensure that the duties and responsibilities of the students support services are clearly stated and properly carried out.**

Keywords - Student support services, distance learners, participation and retention, distance learning programme, University of Ibadan

I. INTRODUCTION

In the context of the absence of physical instructor and students during the educational process, the tutor and learners engage in communication using various methods predominantly facilitated through student support services. The adaptability inherent in this mode of education enables individuals to harmonize learning objectives with professional and familial responsibilities, thus positioning it as a viable alternative for accessing higher education. Consequently, Open and Distance Education (ODE) has experienced significant growth, eliciting a surge in demand for tertiary education [1]. Year after year, a growing number of students at both the undergraduate and postgraduate levels are opting for remote learning. According to [2] approximated a growth rate of 17% between 2012 and 2016. Despite the increasing enrolment of students, studies have shown that Open and Distance Learning (ODL) exhibits lower rates of student retention and completion compared to traditional face-to-face instruction, coupled with elevated dropout rates [3-5]. Dropping out is a complex occurrence that can be elucidated by various factors that impact students' choice to withdraw [6-8].

The scholarly literature is abundant in research endeavors that have delved into the reasons behind student attrition from educational institutions. These investigations sometimes adopt a panoramic outlook and at other times, a more concentrated approach. As posited by [9], the act of dropping out can significantly affect an institution's financial standing and reputation, prompting educational establishments to duly consider these aspects. Despite the adaptability offered by contemporary distance learning, a major drawback remains in the area of student retention, as highlighted by [10]. The prevalence of this weakness has impacted numerous distance learning institutions, leading higher education establishments offering distance learning to increasingly recognize the importance of retaining students. Similarly, [11] have contended that even after close to half a century of scholarly exploration and conceptualization, student retention rates in distance learning programs continue to linger at relatively low levels. According to [12] have argued that a nation's progress is contingent upon its capacity to retain students in higher education, as doing so enhances the country's human capital.

In order to promote students' learning, engagement, and persistence in distance learning initiatives, it is imperative for distance learning institutions to prioritize the provision of robust student support services. According to [13] as referenced in [14], typical student support services offered in Open Distance Learning (ODL) institutions encompass areas such as enrollment procedures, academic guidance, tutorial assistance, counseling services, academic advice, assignment feedback, communication with faculty and administrative personnel, career guidance, establishment of study centers, and financial aid opportunities. One rationale behind this emphasis is the spatial separation between students and instructors in distance learning setups, which often necessitates more self-directed rather than interactive forms of engagement. Consequently, certain distance learners may experience feelings of isolation due to geographical and transactional distances. Moreover, inadequate self-regulation skills, motivational levels, and a desire for social interaction can contribute to a lack of institutional belongingness among students, heightening the risk of academic underachievement or dropout in distance learning programs. The integration of student support services has thus emerged as a pivotal component of a sustainable and effective distance education framework, encompassing various stakeholders at the systemic level of distance learning initiatives, including academic personnel responsible for curriculum development and delivery, administrative staff overseeing organizational aspects, and technical experts managing system operations.

Student Support Services (SSS) play a pivotal role in Open and Distance Learning (ODL). The effectiveness of student support stands out as a key characteristic of successful ODL institutions [15]. As posited by [16] as cited in [17], the concept of student support services in distance education encompasses various interventions and resources aimed at assisting distance learners in overcoming challenges related to technology, isolation, and communication. From this perspective, interpersonal engagement could be considered a fundamental form of learner support, irrespective of its origin, mediating or facilitating tools, or formal/informal nature. According to [18] as cited in [17] emphasizes the significance of personalized and localized supportive measures, such as learning communities, in meeting essential social interaction needs within the educational domain. Consequently, this research was conducted to address the existing gap resulting from the scarcity of studies on the impact of student support services interventions on learners' engagement and persistence in distance learning programs at the University of Ibadan, Nigeria. This study specifically carried out to determine whether administrative support services, tutoring support services, technological support services, accessibility to student support services, and affordability of student support influence learners’ participation and retention in distance learning programme. The following null hypotheses were evaluated at 0.05 level of significance based on the objectives.

$H0_1$: There is no significant relationship between administrative support services and distance learners’ participation and retention.

$H0_2$: There is no significant relationship between tutoring support services and distance learners’ participation and retention.

$H0_3$: There is no significant relationship between technological support services and distance learners’ participation and retention.

$H0_4$: There is no significant relationship between accessibility of student support services and distance learners' participation and retention.

$H0_5$: There is no significant relationship between affordability of student support services and distance learners' participation and retention.

II. Theoretical Overview

The early endeavors in distance education were predominantly led by [19,20], as cited by [21] in the early 1960s. Peters established a theoretical framework for distance education known as the 'Theory of Industrialization'. He posited that the most effective theory for distance education lay in the parallels between the industrial production process and the teaching-learning process within this context. Peters drew comparisons between distance education and industrial goods production in various aspects including rationalization, division of labor, mechanization, assembly line, mass production, planning preparation, standardization, functional change, and objectification. Rationalization, as described by Peters, involves the methodical organization of the production process to achieve optimal output. The division of labor in industrialization is likened by Peters to the production of course materials, teaching, tutoring, grading assignments, and student results administration in distance education. Furthermore, the mechanization process is equated with the utilization of technologies for delivering and creating course materials in distance education. Peters describes the assembly line as the expert preparation of course materials in distance education, subsequently mass-produced by the administrative department and distributed to learners.

Similarly, mass production or large-scale production in industrial goods is linked by Peters to the notion of mass production in distance education, catering to a large number of students through extensive programs. Peters emphasizes that planning and preparation in distance education materials production necessitate careful preparatory work, meticulous planning, and organization for successful outcomes. This entails establishing predetermined dates and locations for distance learners to receive materials, submit assignments, participate in tutorials, and take examinations. Additionally, Peters underscores the importance of formalization, ensuring that work procedures are well-structured in accordance with the division of labor. Lastly, he stresses the significance of standardization, crucial in industrialization, whereby distance education institutions must standardize the academic content of their courses to attract a diverse range of distance learners. Thus, this theory holds relevance in the present study, as any interventions in student support services for distance education must adhere to this framework to enhance student satisfaction and the success of distance learning programs.

III. Data, Methodology and Discussion of Results

A. *Used Data and Considered Variables*

The data used for this study was generated from using Distance learning students as participants and the considered variables were the following three support services: administrative, tutoring and technological and other variables its accessibility and affordability.

B. *Research Methodology*

The current study employed a quantitative research design. The decision to utilize this approach was justified by the no manipulation of variables by the researcher. The study focused on distance learners within the Faculties of Arts, Education, Science, and Social Sciences, ranging from levels 100 to 300. Sampling involved a multi-stage procedure to select a sample size of 500 individuals. The researchers developed a survey named the "Perceived Student Support Services and Learners' Participation and Retention Scale" (PSSSLPRS), consisting of five subscales: administrative support services, tutoring support services, technological support services, accessibility of student support services, and affordability of student support services. The survey comprised two sections; the first section collected demographic information such as age, gender, marital status, faculty, and level of studies, while the second section addressed the research questions and objectives. Responses were rated on a four-point Likert scale, ranging from Strongly Agree (SA) to Strongly Disagree (SD). Prior to participation, respondents were required to provide informed consent.

Institutional approval was obtained, and access to distance learners was granted by the Distance Learning Centre University of Ibadan through the online community platform. Participants were assured that their data would be used solely for research purposes and that their privacy and anonymity would be protected. Content validity, encompassing face validity, was employed to ensure the validity of the research instruments. The items in the instruments were presented in simple language to enhance respondents' understanding and were structured logically to align with the research questions and objectives. To enhance validity, the researcher ensured that the instrument content was consistent with the study's goals. The survey was piloted on fifty learners from the National Open University involved in distance learning, who were not part of the study's target population. The internal consistency reliability coefficient was calculated using Cronbach Alpha to assess the instrument's reliability, as the questionnaire items required respondents to indicate their agreement or disagreement on a scale. The Cronbach Alpha reliability test yielded coefficients of 0.86 for administrative support services, 0.80 for tutoring support services, 0.85 for technological support services, 0.82 for accessibility of student support services, and 0.84 for affordability of student support services, indicating the instrument's acceptability, adequacy, and reliability for the research. Data analysis was conducted using multiple regression and Pearson Product Moment Correlation at a significance level of 0.05.

IV. Results and Discussion

The results of this examination are delineated hereafter, featuring the initial research query depicted in Table I.

Query 1: What is the impact of Student Support Services (including administrative, tutoring, technological, accessibility, and affordability aspects) on the involvement and persistence of distance learners within the educational establishment? To assess the collective impact, a multiple regression analysis was conducted, and the outcome is exhibited in Table I below.

TABLE I. MULTIPLE REGRESSION ANALYSIS.

R	***R* Square**	**Adjusted *R* Square**		**Std. Error of the Estimate**		
0.916	0.839	0.837		1.45027		
ANOVA						
Model	Sum of Squares	*Df*	Mean Square	F	Sig.	Remark
Regression	4819.808	4	1204.952	572.893	<.001	Sig.
Residual	925.441	440	2.103			
Total	5745.249	444				

Table I illustrates findings regarding the collective impact of Student Support Services (including administrative, tutoring, technological, accessibility, and affordability aspects) on the engagement and persistence of distance learners. The data presented in the table demonstrates that the correlation coefficient (*R*) from multiple regression analysis, indicating the linear association between the predictor and outcome variables, is 0.916. Moreover, the multiple *R*2 is calculated to be 0.839, with an adjusted *R*2 of 0.837. These results signify that the predictors (administrative, tutoring, technological, accessibility, and affordability elements of student support services) explain 83.9% of the variance in the outcome variable, a statistically significant relationship at $P < 0.01$. Additionally, the analysis of variance in the multiple regression data revealed an *F*-ratio of $F(4,440) = 572.893$, which was statistically significant at $P < .01$. The multiple regression analysis highlights the correlation coefficients (*R*) indicating the linear relationship between the components of Student Support Services and the outcome variable (Distance Learners' Participation and Retention). The combined impact of the predictors on the variability in the outcome variable (83.9%) was found to be significant. Furthermore, it suggests that there may be other variables not accounted for in this model that could explain the remaining variance.

A. *Hypotheses Testing*

$H0_1$: There is no significant relationship between the independent variables (administrative, tutoring, technological, accessibility and affordability of student support services) and the dependent variable (learners' participation and retention).

Table II: Pearson Product Moment Correlation (PPMC) showing the Correlation that exist between each of the Independent Variables (Administrative, Tutoring, Technological, Accessibility and Affordability of Student Support Services) to the Dependent Variable (Learners' Participation and Retention) in the Institution.

TABLE II. CORRELATIONS.

		ASS	TSS	TECHSS	ACCSS	AFFSS	LP&R
Administrative Support Services (ASS)	Pearson Correlation	1	0.515**	0.470**	0.451**	0.488**	0.685**
	Sig. (2-tailed)		0.000	0.000	0.000	0.000	0.000
	N	444	444	443	444	444	443
Tutoring Support Services (TSS)	Pearson Correlation	0.615**	1	0.745**	0.688**	0.654**	0.784**
	Sig. (2-tailed)	0.000		0.000	0.000	0.000	0.000
	N	444	444	443	444	444	443
Technological Support Services (TECHSS)	Pearson Correlation	0.670**	0.715**	1	0.710**	0.649**	0.721**
	Sig. (2-tailed)	0.000	0.000		0.000	0.000	0.000
	N	443	443	443	443	443	443
Accessibility of Support Services (ACCSS)	Pearson Correlation	0.751**	0.688**	0.737**	1	0.788**	0.836**
	Sig. (2-tailed)	0000	0.000	0.000		0.000	0.000
	N	444	444	443	444	444	443
Affordability of Support Services (AFFSS)	Pearson Correlation	0.688**	0.654**	0.649**	0.718**	1	0.761**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000		0.000
	N	444	444	443	444	444	443
Learners' Participation and Retention (LP&R)	Pearson Correlation	0.685**	0.784**	0.721**	0.836**	0.761**	1
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	
	N	443	443	443	443	443	443

**. Correlation is significant at the 0.01 level (2-tailed).

The Table II shows the correlation analysis on student support services (administrative, tutoring, technological, accessibility and affordability of student support services) and learners' participation and retention among Distance Learners with administrative ($r = 0.685$**, $N = 444$, $P < .05$), tutoring ($r = 0.784$**, $N = 444$, $P < .05$), technological ($r = 0.721$**, $N = 444$, $P < .05$), accessibility ($r = 0.836$**, $N = 444$, $P < .05$) and affordability of student support services ($r = 0.761$**, $N = 444$, $P < .05$). All student support services variables made a significant correlation to the learners' participation and retention at the Distance Learning Centre, University of Ibadan.

The findings of the research question elucidate the impact of the five components of student support services - administrative, tutoring, technological, accessibility, and affordability - on learners' engagement and persistence in the academic institution. The outcomes reveal that each of these components played a role in predicting learners' engagement and persistence, collectively explaining 83.9% of the variance in these outcomes. This implies that considering all five components leads to an 83.9% increase in learners' engagement and persistence, with the remaining 16.1% variability lying beyond the scope of this study. Evidently, the amalgamation of administrative, tutoring, technological, accessibility, and affordability components exerts an 83.9% influence on learners' engagement and persistence within this study. These findings align with [22], who suggest that students benefit from accessing their registration details, scholarship status, academic calendar, exam dates, and other administrative information, thereby enhancing their learning experience and retention. Similarly, [23] found that administrative support services at the University of Nairobi significantly impacted the retention of distance learners.

The results of findings on hypothesis 1, which state that there is no significant relationship between administrative student support services and learners' participation and retention in distance learning institution was rejected and highly significant. The findings of this research agrees with [22], submission that students that have access to their data on registration, status of their scholarships, academic calendar, exam dates, and other administrative materials whenever they need it would found their learning interesting and remain in learning. Similarly, [23]; submitted that administrative support services at the University of Nairobi had a statistically significant impact on distance learners' retention.

This suggests that the provision of administrative student support services had significant impact on distance learners' satisfaction with the learning environment, satisfaction with the courses' structure, success in communicating online, competence in using distance education software, satisfaction with the amount of knowledge and information during each academic session, motivation to continue and participation fully in DLC programme which was also supported by [24].

The findings of hypothesis 2, which state that there is no significant relationship between tutoring student support services and learners' participation and retention in distance learning institution was rejected and this did not come as a surprise. This is because tutoring deals with regular consultations, tutors always well-prepared for classes, they delivered lessons in a way that meets individual needs, encouraged learners to ask questions while interacting with them, provided study tips, motivate learners to learn and took learners' individual differences into account. This is supported by [25] who affirmed that the use Moodle, Blackboard, online library, online course module/study guide, online learning for tutor-learner and learner-learner interaction, and access times for online learning supported learners' services

The findings of hypothesis 3, which state that there is no significant relationship between technological support services and learners' participation and retention in distance learning institution was also rejected. This also did not come as a surprise because it agrees with the opinion of [26] as cited in [17], stressed that the technological support in terms of information and communication technology and pattern of information delivery in distance learning remains one important ingredient required for success to be achieved. This result further supports the findings of [27]; [28], who showed that the use of social media applications like Telegram and WhatsApp, learning applications like Moodle, Zoom, and LMS, as well as Google applications like Google Classroom and Meet, helped in prompt dissemination of information to learners at any time.

Also, the findings of hypothesis 4, which state that there is no significant relationship between accessibility to student support services and leaners' participation and retention in distance learning institution was rejected and agrees with other scholars and indicates that if success is to be achieved, emphasis should be laid on accessibility to student support services. The findings of this study, agrees with [29] submission that accessibility to online learning tools such as WhatsApp Messenger, Facebook, Zoom and Moodle would serve as additional support services for learners to continuing learning at any point in time.

Again, the findings of hypothesis 5, which state that there is no significant relationship between affordability of student support services and learners' participation and retention in distance learning institution was rejected and agrees with [30] that affordability of support services helped the learners to be closer to the institution thus bridging the physical distance between the learners and the institution. According to [30] summaries what constitute learner support services in distance education as: information, counseling, advising, assignment, assessment, advocacy and feedback to the system. The above assertion also corroborated the findings of [31] who reported that respondents afforded the use of student support services such as smart and android phones for effective educational improvements through Zoom and WhatsApp.

V. CONCLUSION

The research has proven how crucial student support services are for the effectiveness and sustainability of open and distance learning institutions. They play a vital role in motivating students to continue with their programs and promoting a culture of continuous learning. The findings underscored the importance of student support services in assisting students with enrollment, admissions, registration, record-keeping, information dissemination, and delivery of study materials, among other services. The results also emphasized the importance of student support services to students, as they benefit from various services offered by the Distance Learning Centre at the University of Ibadan. Their decision to pursue further education is shaped by the strong connections they have with the faculty, both teaching and non-teaching, as well as the staff in charge of management at the school. Hence, ODL institutions must develop a student support system that caters to a variety of student needs, encompassing academic, psychological, administrative, and technological requirements. ODL institutions need to make sure that the roles and obligations of the student support services are clearly articulated and effectively performed. Ensuring that all learning centres have uniform infrastructure is crucial to provide equal access to services for students at any learning center.

Administrative support services aid lowering entry barriers as the ability of students to afford further education is impacted by financial aid assistance. Academic advising help student's select appropriate courses and programmes. Technological support services through the online platforms and resources also increase flexibility and accessibility and ensure smooth navigation of virtual learning environments. Tutoring Services which is academic support focused on assistance to underachieving students, building connections, providing direction and boosting confidence and strengthening knowledge. The findings of this study is significant to inform practices in a broader range of ODL settings through technology adaptation by making sure that digital literacy and infrastructure are in line with local resources, collaborations and partnerships by cultivating ties with stakeholder's communities and local organisations. Technological support services can be improved or expanded to cater to the needs of students in remote or under-resourced areas by making learning platforms and resources available on mobile devices thus achieving mobile optimisation. This supports [32] submission that the potential of the internet to improve education expand access to resources and support creative teaching and learning approaches across the continent cannot be overstated. The majority of nations have acknowledged that knowledge and information are essential for raising productivity, strengthening competitiveness and creating wealth. Moreover, ODL institutions can create programmes which encourage distance learning students access course materials while offline, prepare platforms for slow internet connections and also encourage the use of virtual learning environments (VLEs) that include live streaming videos, conferencing and interactive features.

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Original Scientific Article

Business Process Management and Performance Management

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Abstract—**The dominant characteristic of a process-oriented enterprise is that a relatively small group of employees, organized into teams with a simple hierarchy, monitors, directs and controls the business process from its beginning to its end. In this way, communication is better within the process team and management information is exchanged better. Otherwise, a process represents a group of activities that require a certain input, that adds value and creates an output for internal or external stakeholders. A business process can be viewed as a complex entity that has a certain structure, so the following can be distinguished: process elements, activities of individual process elements, and tasks of each activity individually. The complexity of an enterprise's business activity can be seen through the "network" of business processes, which consists of primary, supporting, and management processes. Performance management of business processes is a managerial concept whose focus is the process, which represents the object of intervention, analysis, and control. In this regard, the aim of this paper is to point out the key elements and stages of process-oriented management and identify the specifics of business process performance management.**

Keywords – business process, performance management, dimensions, enterprise.

I. Introduction

The change from a functionally oriented management of an enterprise to a process-oriented one rests on understanding the weaknesses and strengths of organizing and managing according to the functional principle. Such an approach highlights the importance of process orientation in the foreground, because business processes go beyond the scope of a single business function. What in a classic functional organization is denoted by functions (for example, research and development, production, marketing and sales), in a process-oriented enterprise with a "horizontal" or "flat" organization can be connected to certain processes (development of new product, its delivery, etc.)

The initial problem of the process manager is the strict delimitation of processes, which presupposes the identification and specification of processes in the enterprise. This means that their beginning and end should be determined, with a minimum of their overlap. Defining the beginning and end of a process means determining the starting activity, as well as the activity with which the process ends. It is also important to differentiate processes from business functions, such as production, marketing, research and development, and finance. Some of the functions (e.g. finance, research and development) have primarily a supporting role, so their processes and activities intertwine with each other, and in addition, permeate almost all business processes of the enterprise. What is designated as a function in a classic functional organization, in a process-oriented enterprise can be segmented into a certain number of processes. Thus, procurement, inbound logistics, production operations, outbound logistics, sales, new product research, and after-sales service can be labeled as complex business processes. Such complex processes can be broken down into sub-processes and their activities [1].

In a process-oriented enterprise, a relatively small group of employees, organized into teams with a simple hierarchy, monitors, directs, and controls the business process from its beginning to its end. In such conditions, the communications within the process team are better, and thus the interaction of its members who are responsible for a certain process, in terms of the efficiency of its execution and the achievement of outputs of the process. The exchange of operational and management information is of higher quality, and better inputs are provided for planning, organizing, and executing the process. Also, more adequate conditions are created for organizational learning through experience and greater success in monitoring and controlling process performance. The characteristic of the so-called process organization is a process team, which consists of a group of executors with different skills, expert knowledge and experiences, which are needed to fulfill different roles in the implementation of activities within one process and achieve the business goals of a process-oriented enterprise. Process orientation sees the enterprise as a set of different organizational units, but also through an identified set or network of different processes. In an enterprise with process-oriented management, value for owners and value for consumers is created through efficient and effective implementation of various processes [2].

II. CONCEPTUAL FRAMEWORK OF BUSINESS PROCESSES

The business process represents a) a group of activities that requires a certain input, adds value and creates output for internal or external users (consumers) [3] and b) a specific schedule of activities, with its beginning and end, as well as clearly defined inputs and outputs [4]. Accordingly, the essential characteristic of a business process is that it transforms inputs into outputs. In addition, it is particularly important to identify hierarchy in the sense of disaggregating one complex business process into hierarchically lower sub-processes. Also, the business process has a certain structure, thus the following can be differentiated [5]: process activities, tasks (operations) individually for each activity, interventions, movements, and micro-movements of an operation.

Each process can be determined by the following elements [5]: a) border points of the process, b) transformation within the process, c) feedback, and d) repetitiveness (repetition).

Process endpoints are specific inputs and outputs of the process. The suppliers of the process are responsible for the inputs (resources) necessary for the performance of a certain process, while the characteristics of the output of the process determine the satisfaction of the process results consumer. Within each process, through its stages, a multidimensional transformation of inputs into outputs takes place - physical (material) or immaterial. The feedback, which exists between the endpoints of the process, is realized through communication channels. Feedback involves measuring and controlling process performance.

The complexity of an enterprise's business activity can be seen through a set of different business processes, which can be [5]: 1) primary business processes, 2) supporting business processes and 3) management processes.

Regardless of what type of process it is, their measurement can be carried out on the basis of 5 aspects within which the indicators are defined. These are the following aspects: employee aspect, innovation aspect, customer aspect, societal aspect, and financial aspect. Employee aspect includes indicators of communication, job conditions, physical discomfort, psychological well-being, workload, supervision, opportunities for growth, or socialization. The consumer dimension includes indicators of consumer expectations and satisfaction, which are calculated on the basis of a questionnaire or an analysis of the value they expect and which was delivered to them. Measuring societal aspects of a business process requires both measuring the impact (waste management, pollution, energy savings, etc.) a process has on its society and measuring how the impact is perceived. Indicators of innovation are determined on the basis of relations between: enterprise - investors, enterprise - consumers, enterprise - employees, enterprise – society [6].

Primary business processes are a series of activities that enable the delivery of products and services. Such are the processes of demand generation and demand satisfaction.

Supporting business processes support the realization of primary and management processes.

Management processes are a series of different activities that direct, coordinate, integrate, and control the primary and supporting business processes, which create value for consumers and owners. It mainly involves the activities of making management decisions. They are not only related to one segment of the organization, but permeate the entire enterprise. It is a very complex group of processes. They can be understood if they are broken down into: the processes of determining (choosing) the strategic direction of growth/development, the processes of negotiation and assurance and, finally, the processes of monitoring, measuring, and controlling performance. Participants in these processes are capital owners, owner-managers, and non-owner managers at all levels [7].

Different types of processes are interconnected and intertwined, so there is an interaction between them. Supporting business processes are extremely important for the development of primary processes, while management processes are relevant for the development of primary and supporting business processes. The performance of management processes affects the performance of supporting, and then also the performance of primary business processes.

Differentiating the following process determinants (characteristics) is relevant for effective performance management of business processes [8]: structural, operational and limiting.

a) The structural characteristics of the process are related to the fact that the process represents the transformation of inputs into outputs, so the results of one process represent the inputs of the next process. The first structural characteristic of the process is the hierarchy in the process, because there is a possibility of disaggregating a certain process into its hierarchically lower (sub)processes. Another structural characteristic is the “network” of the process. Disaggregated processes in the enterprise form a network of (sub)processes, which is the basis for allocating material and immaterial resources (inputs) necessary for the realization of the process. The third structural characteristic of the process is mapping the process and identifying the connections between the processes, which enables familiarization and scanning of the process to find out how the process is currently taking place - what is its current performance. It is necessary not only to get to know each process individually, by analyzing its elements (activities) based on the process flow diagram, but also to create the so-called enterprise process maps. The fourth structural characteristic of the process is the so-called chains of value creation in the process and through the processes. All processes have elements - activities that add value and activities that do not add value. In managing the performance of business processes, it is very important to focus attention on improving activities that add value. Finally, the fifth structural characteristic of the process is the so-called influence of consumers, internal or external, on the nature of the process, requirements for its design, execution, and control.

b) The operational characteristics of the process are related to the execution of the process in order to achieve the target (desired) levels of process performance. The first operational characteristic is the responsibility for a certain process, which means that it is necessary to designate a person who is responsible for the process and its activities and performance. Another operational characteristic concerns the definition of operational tasks through the output (result) requirements that the process should enable and the defined level of efficiency or based on the target costs of the process that must not be exceeded. The third operational characteristic is the focus of process execution - product or service, which will be realized if the processes are adequately designed, directed during execution and controlled. The fourth operational characteristic is the resources of the process that are necessary for its execution. Establishing a connection between the amount of available resources and the amount of the output of the process for a certain period of time is not at all simple. The fifth operational characteristic is the time dimension of the process, which needs to be determined because it affects the amount of investment (resource engagement), so the duration of the process is reflected in its efficiency. The sixth operational characteristic is the measurement of process performance for the purposes of process control, improvement, reengineering, and benchmarking.

c) The limiting characteristics of the process are those characteristics that limit the consistent output (result) of the execution of the process. The first limiting characteristic of the process is variability, so that the output (result) of the process is not always the same, or constant, due to the effect of various internal and external factors on the process or its elements. Process uncertainty is another limiting characteristic of the process. As a rule, the greater the presence of people as a subjective factor in the process, the greater the uncertainty of the process. In order to reduce it, it is necessary to fully understand the process with the help of the process mapping technique. Finally, the limitations of input (resources) and output (results) of the process are the third limiting feature of the process.

III. Key Performance Dimensions of Business Processes

Since the business process is viewed as a "chain" of activities for value creation, it is characterized by certain inputs, activities, and performances (effects, results) that can be labeled as process goals [7]. They are derived from enterprise goals, and consumer requirements, and determined through the planning process based on performance from the past period and, possibly, external benchmarking. After determining the goals of the process, managers analyze whether the processes are well conceived, structured and designed in order to achieve the effectiveness (achievement of target performance levels) and efficiency (successful use of resources) of the process.

Each process is subject to control by the process manager, with an emphasis on its performance or the performance of the activities that make it up. Control requires measuring the performance of processes and activities - quantitative and qualitative performance measures. From the aspect of measurement, it is possible to differentiate several dimensions of process performance [5]: 1) performance of the quality and quantity of input and output of the process, 2) effectiveness of the process, 3) efficiency of the process, 4) quality performance (safety, reliability, stability, durability, adaptability), 5) quantity performance (volume, number of activities, number of operations), 6) time performance (time of activities and operations, time schedule), 7) execution performance (execution time, completeness, timeliness), and 8) value performance (process resource consumption and costs).

In addition to this, to measure process performance, it is necessary to identify process elements in terms of input measures and process output measures. This enables the identification of criteria for the effectiveness of the process, bearing in mind the answer to the following questions [9]: Does the process achieve the planned output? How well is the process being executed (quality outcomes)? The output and outcome of the process can also be tracked forward with prominent performance measures of quality, quantity, value, execution, and speed.

The effectiveness of the process should measure the success in realizing the goal of the process, which is defined as a specific result of the process. The effectiveness of the process is quantified by the quotient of the realized and planned effect (outcome, output) of the process.

The efficiency of the process is measured, on the other hand, by the ratios of input and output, identifying how much input was used to achieve a unit of output of the process.

For each process and activities in it, target performance levels should be formulated, that is, performance requirements should be defined in relation to the specific process. On the basis of the defined process performance criteria by the process manager (controller), the measurement will be carried out and performance deviations will be determined in relation to the target (planned) value. After that, corrective actions are determined and deviations are eliminated in order to bring the achieved performance closer to the planned one. Next, redefining the target levels of process performance that are to be achieved in the future period. Control and measurement of process performance are performed with the aim of improving their performance from period to period, thus contributing to the improvement of the overall success of the enterprise, as a set of interconnected and conditioned processes.

In order to examine the performance of the process, and the adequacy of its structuring and design, it is useful to construct and continuously analyze the process map. It should identify all elements, flows and interdependence of activities within the process. The process map enables the identification of all negative moments (factors) in the execution of the process (interruptions in execution, untimely execution, errors, redundant operations, illogicality of the order of activities) and the timely taking of necessary measures in order to execute the processes more efficiently and effectively.

Performance at the process level has significant implications for executors, operational managers (process managers) and managers at higher hierarchical levels. Executives can use the process perspective to connect the goals of the enterprise (organizational unit) with individual performance, to identify real flows (materials, documents, information), to analyze process performance in the succession of periods and process benchmarking. For operational managers, the process perspective is relevant for better identification of areas that require control and for improving performance, which is achieved based on realized changes in initiatives and actions in the process of resource use and allocation. The process perspective allows managers of higher management levels to more fully understand the needs for resources and propose ways to improve the functioning and performance of the enterprise [10].

IV. KEY STAGES IN PERFORMANCE MANAGEMENT OF BUSINESS PROCESSES

Performance management of business processes is a managerial concept whose focus is the process, which represents the object of intervention, analysis and control, that is, the object whose performance is managed. Process-oriented management (process management) is gaining more and more importance, bearing in mind the shortcomings of functional organization and management based on such an orientation. Process management is ultimately focused on improving the operational performance of the process. Continuous improvement of process performance is the way to increase the overall effectiveness and efficiency of the enterprise. Process management emphasizes [5]: a) developing an organizational culture that is based on the process; b) management of planning, organizing and execution of process activities; c) increasing the satisfaction of internal and external consumers (clients) of the process; d) integration and implementation of various initiatives, methods and techniques of performance improvement that are oriented towards processes, and e) more successful motivating and rewarding according to the contribution to the quality - performance of the process.

For effective process management, it is necessary [5,7]: 1) to make all employees understand the importance and value of the process approach to enterprise management; 2) adequate measurement, analysis and reporting on process performance, and development of appropriate process performance measures and reporting systems; 3) to identify persons responsible for ensuring the desired performance of the process, who define the plan for the use of resources of the process, follow the process of use (transformation), provide the necessary resources, and work on continuous improvement of the process performance.

For the success of process management, it is primarily important to review whether the enterprise has incorporated the process perspective into the strategic plan (strategy). In addition, it is necessary to determine the limitations of each process, and then the information base and all the necessary documentation relevant to the definition and classification of the process. Developing awareness of the role and contribution of each employee in the execution of the process is made possible by appropriate values, communication plans, infrastructure, etc. This is also related to the precise definition of jobs within the process individually and the persons responsible for its performance. In the end, it also requires the determination of leaders, the formation of teams, as well as the precise definition of the roles and functions of their members [5].

Conceptually, process improvement goes in the direction of reducing process time, reducing costs, increasing quality, and increasing efficiency. All processes and their improvement should be in accordance with the goals (strategy) of the enterprise or organizational unit. The process of improving business processes is complex to implement and has many elements that must be given special attention. Process improvement can be in the form of correction, simplification, or reengineering. Correction and simplification mean incremental changes, while reengineering implies radical changes in the process.

Rummler-Brache's methodology differentiates several phases of management by improving the performance of the enterprise's business processes [11]: 1) planning process performance improvement; 2) defining the process performance improvement project; 3) analyzing and designing the process - determining how to improve the process performance; 4) implementation of changes in order to improve process performance, and 5) phase management - process performance improvement activities.

Planning process performance improvement involves identifying all necessary activities in the field of improving the performance of a specific process and managing that process. In this phase, the leaders of the organization should formulate a strategy or modify it in accordance with the new conditions (a), determine the primary, supporting and management processes (b), distinguish between them key-critical (problematic) processes (c), and then the essential tasks related to the chances and risks in the internal and external environment, as well as the relations between the processes and their activities relevant for the successful implementation of the strategy (d). Then the process selection is done. It determines which key (possibly critical) processes have a decisive influence on the enterprise's goals and the success of the strategy (e). After that, the selected process is mapped and based on that, a management plan for the improvement of a certain process is made (f).

Process selection implies that in the “network” of processes, critical processes are identified through quantitative and qualitative measurement of their performance. These do not have to be only problematic processes, but also processes that are key - “essential” because they make the greatest contribution to building the enterprise's competitive advantages and have a significant impact on its market success [12]. In the selection of critical processes, benchmarking is useful - a comparative analysis of the enterprise's business processes with the business processes of the most important competitors or industry leaders. Data sources can be publications and reports of enterprises, reports of professional associations, analysts, global databases, etc. [11,13].

Mapping of the selected critical process is the next stage and aims to get to know and scan a process in as much detail as possible, for the best possible understanding of its current development. The identified, selected and mapped process, which is the subject of analysis, control and improvement, is approached as a kind of project task. Consequently, a project to improve the performance of a particular process has its own limitations that should be identified. Mapping should provide a complete insight into the entire observed process, from its beginning to the end (the so-called downstream path of the process flow) and from its end to the beginning (the so-called upstream path of the process). Each process activity is conditionally a “supplier” to another “downstream” activity and, conditionally, a “customer” of an “upstream” activity. It is necessary to construct the diagram of the flow of activities within the process as precisely as possible, in order to identify all control (critical) points of the process, interconnections, and its redundancies [12].

Defining the process performance improvement project is focused on the previously identified critical (problematic) process and the process task associated with it. The essence is that the procedural task is derived from the so-called business goal. Within this phase, a team should be formed, which will consist of managers of different levels and functions involved in a certain critical process. This is necessary because the development of a certain process implies an inter-functional character - the process “flows” within several business functions in the enterprise. In addition, a team of “process designers” is formed, composed of experts of various functional specialties who cover all stages of the process (economists, engineers, programmers, technologists, etc.). They analyze and design processes and actively participate in the implementation of necessary changes. These elements of the improved process are linked with the content of other processes, checking mutual influence and conditionality, and also the contribution to the overall performance of the enterprise [11].

In the process analysis and design phase, the critical process is scanned and documented. In fact, everything that, as a limiting factor, can negatively affect the success of a project to improve the performance of a process, is determined. Based on a detailed analysis of the project and the desired performance of the process, all relevant elements and ways of necessary improvement are designed. Determining improvement is a phase that involves considering the “logic” of the process.

The phase of implementing the necessary changes in order to improve the performance of the process includes all activities of the implementation plans to improve the observed process. Since there may be resistance from certain structures and members of the collective, this phase is not easy to finalize. For this reason, a special engagement of professional, responsible members of the collective, as well as personnel from authorities with special leadership skills, is required. It is also important to determine the so-called infrastructure for the implementation of changes, which includes support resources and various teams of experts and executors who will directly implement change activities. Project management activities and the involvement of all authorities in the enterprise, as well as an adequate system of informing superiors and communicating between all project participants, are necessary [12-14].

Management of process improvement activities and the process itself, whose performance is improved, includes a set of techniques that ensure continuous monitoring and improvement of the performance of the problematic process. This phase takes place in parallel (simultaneously) with the development of the previously mentioned three phases. It checks whether individual critical processes - which are the subject of changes and improvements - are really being improved. The persons responsible for the activities of this phase should identify performance criteria, make necessary corrections during the project itself, and provide additional necessary resources, capabilities and all the accompanying "infrastructure" for performing the necessary corrective work and activities [12, 15-17].

Control requires measuring the performance of processes and activities with quantitative and qualitative measures of process performance. From the aspect of measurement, it is possible to differentiate several dimensions (perspectives) of process performance: performance of quality, quantity, time, and execution. In process performance management, the application of the concept of cost accounting by activities and planning by activities is also unavoidable [18-21].

The application of Rummler-Brache's methodology in practice has shown certain disadvantages-one-sided and incomplete analysis of the enterprise's performance, the lack of methods to improve business processes and its structural elements as well as the lack of mechanisms for determining the productivity of workplaces in auxiliary business processes [22].

Application of this methodology in various industries requires the following: a) an enterprise should determine the target segments of the consumer market; b) a strategy is developed and implemented in order to meet the needs of customers most effectively; c) regular monitoring of labor productivity and efficiency at each hierarchical level of the enterprise [22].

An example of the application of this technology is the company NuPlant from the biotechnology sector, which aimed to improve the performance of the process concerning production, which was carried out through the following stages: 1) determining the desired results of the process (in which there is a gap between the desired and existing state), 2) defining the existing barriers for reaching the desired state and specifying the necessary steps, 3) designing and developing the solution and its implementation, and 4) evaluating the achieved results in terms of process improvement [23].

According to the research [24] on the application of methodologies for process performance management on the example of companies from the field of consulting in the countries of the Western Balkans, the following conclusion was reached - as the analysis of the basic labor productivity indicator showed, Rummler-Brache's methodology is not very popular due to the complexity of calculating this indicator for auxiliary business processes, the problematic assessment of labor productivity in terms of three hierarchical levels, and the lack of methods for improving the parameters of business processes and their structural elements.

The other studies [25] emphasizes that regardless of the type of activity of the enterprise, the success of the application of this methodology depends on whether it is applied systemically in the enterprise, that is, its application is necessary at the level of the entire enterprise and not parts of the enterprise.

V. Conclusion

Control requires measuring the process performance based on quantitative and qualitative indicators of process performance. It is possible to monitor the following dimensions of process performance: performance of quality, quantity, time, and execution. Rummler-Brache's methodology differentiates several phases of managing the performance improvement activities of the business processes. The implementation of the phases in this order can have a decisive impact on the success of the performance improvement activities of the business processes.

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Original Scientific Article

The Q.E. (Quantification of Everything) Method: Transforming Qualitative Data Across Scientific Disciplines

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Abstract—**The Q.E. (Quantification of Everything) methodology follows a three-step procedure that transforms a theoretical concept into a mathematical form and confirms the created model using the principle of multiple axiomatics. This process employs algorithms and computational methods, often involving numerous estimations. This technique is applicable across various scientific fields, and here, we provide an example from the field of economics. The Q.E. methodology uniquely enables the transformation of an empirical theoretical idea into a manageable mathematical form using virtual quantity data. This capability is particularly valuable in fields like social sciences, where actual data might be scarce or nonexistent. By allowing the creation of virtual data to validate a theory, it provides a method to convert qualitative data into quantitative forms, extracting mathematical relationships and equations. Overall, the Q.E. methodology is versatile and can be applied to all epistemic fields.**

Keywords – axiomatics, multiple axiomatics, economics, Q.E. method, fuzzy logic

I. Introduction

This method is very useful, it can be applied to any scientific field, as converts quality into quantity data. In that way any science, even theoretical, can be converted to applied science. Axiomatics is founded on the assumption that the outcome of a hypothesis is initially unknown. This is crucial for scrutinizing an economic theory under examination. The hypothesis of an economic theory forms the foundation for the subsequent study of each economic model. Axiomatics aims to address the theoretical underpinnings of economic analysis and to verify that the initial hypothesis of the model is satisfied. If the hypothesis is confirmed, then the model is consistent with the principles of the analysis framework.

The Q.E. (Quantification of Everything) theory is based on the philosophy of multiple axiomatics. The hypothesis and conclusions are pivotal for clarifying each economic theory by confirming that the conclusions are consistent with the initial hypothesis. Multiple axiomatics allows for the re-modification of models through feedback. Feedback plays a crucial role as it enables the adjustment of the initial hypothesis based on the conclusions, thereby providing more accurate models. Feedback is the driving force behind iterations, enhancing the precision of the models.

Set of iterations $G=\{1,\ldots,n\}$, here, $n \in N$ represents the number of iterations for the generator.

Estimating equation $M = f\left(x_i\right)$, in this equation, $x_i \in R$ are the variables, and $f\left(x\right)$ is the function applied to these variables.

Forming equation $E_n = f\left(x_i\right) \cdot G$, this represents the forming equation after multiple iterations, where the function of $f\left(x_i\right)$ has repeatedly applied over the set G.

The new set of estimations $E_n^{'} = f\left(x_{\{i\pm1\}}\right)\cdot G$, this denotes a new set of estimations obtained by modifying the variable of x_i, either adding or subtracting one.

Final chosen equation $C_h = \left\{E_n, E_n^{'}, \ldots\right\}$. The final chosen equation is derived by comparing them, $E_n, E_n^{'}$ and others to determine which equation best fits the theoretical background and hypothesis of the model.

II. LITERATURE REVIEW

The concept of the Q.E. theory is based on a methodology that stands on the determination of mathematic equations subject to conditions that are also considered. One more important thing is the determination of the upper and the lower limit of the values of independent variables. Forasmuch as, the dependent variable represents the behavior of the selected model, pending on a generator that produces random values to all the independent variables to configure the interaction between them and their behavior under different conditions. The random numbers that are used to determine the behavior of the equations in comparison with the subtracted or added variables to the equations are used for the determination of the behavior of the model. At least the basic study includes two facets which are:

The analysis of the behavior of the model stands on the scrutiny of the structural characteristics of each model, accordingly, allowing in that way the extraction of general conclusions about the model which is under examination.

The frequency analysis behavior scrutinizes the behavior of the dependent variables, but from the view of the number of appearances of a variable than to another variable, estimating the impact that one independent variable has with one or more other independent variables to the dependent variable.

The dependent variables are those which are modified from the generator. Thereupon, the generator produces values for the dependent variables. The extracted values of the generator allow the creation of magnitudes, which are the base for comparisons, and the analysis of mathematical equations. In that way is plausible to quantify quality data and theoretical terms. Moreover, according to this methodology, the created magnitudes allow proceeding furthermore to econometrical analyses. In general, it is a methodology for the quantification of quality data. Thus, using the Quantification of Everything (Q.E.) methodology is plausible to clarify the behavior of any model and to determine its standalone behavior, or its comparative behavior, between different models. Therefore, this methodology as index permits the study of the following issues:

It is possible to scrutinize and examine theoretical themes, from qualitative analysis to quantitative analysis.

The creation of magnitudes can be used for any other analysis using that data as an axis for further estimations with different scientific tools, and sciences.

Consequently, the created magnitudes permit an econometric analysis.

These units initially if they are not determined, are considered as “virtual units”. The term “virtual units” means that they are used only for each study and for comparability analysis.

This methodology of the transformation of quality data into quantitative data allows a completely different approach to theoretical studies, as it permits the mathematical determination of terminologies, and the study of them in a different scientific field.

III. METHODOLOGY

Therefore, in this point, we conclude the three basic points that the hypothesis and the mathematical determination need to complete their simplest form for the establishment of quality data:

- The first step is about the hypothesis. At this point is the scope of the analysis of each study. Thus, mathematical determination is the main point of this step.
- The second step is about the generator, which produces the values for the independent variable. This procedure is taken into consideration the upper and the lower limit, which is used for the production of values through randomization. This technique allows the formation of the quality data into a quantified form. Thence, after a crucial number of irritations is plausible to

sketch the appropriate mathematical equation. In that way concluded the behavior of the equation is under study. Therefore, the procedure needs at least two mathematical equations, with a lack of some variables, or more variables to the existing equation to understand how the equation reacts in different forms.

- The third step gives the conclusions, and through feedback with the hypothesis is plausible to confirm an existing theory, or to submit a new scientific view [1], [2], [11–17].

The first step determines the scope of the study. The structural theoretical elements are used to specify the mathematical point of view, which is under examination. Thence, the hypothesis happens in this level, and the mathematical modeling is based on the theoretical background, which is under development, or already exists and is checked for verification. Thence, this level is crucial for the next two steps [3–10]. The reason for this is that this step shows the orientation of the study for the next two levels. From a programming point of view, it must be defined as the variables and the number of wished iterations. The iterations are defined by multiple compiles of the program, and this is the reason why this level is critical for the study. This initial step is connected with the last step through the feedback.

Pseudocode for the hypothesis and the mathematical modeling:

```
<lib>
        //definition of library
integer n = …;
        //initialization of values;
integer number;
float number;
main{
While i<n {…} or For {…}
        //creation of loop
equation 1=…
        //definition of the equations
equation 2=…
…
equation n=…
end;
}
```

Figure 1. Pseudocode for the hypothesis and the mathematical modeling

In Fig. 1 we have a general view of the basic parts needed for the definition of the mathematical equations and the configuration of the hypothesis which will happen through the third step, in combination with this initial step. This step requires an understanding of the structural characteristics of the theory. The terminology "structural characteristics" is about the same key points of the theory which permit the specification of those things, which could be analyzed as variables. The number of iterations is modified by compiling the program, and in general, a high number of iterations allows a good quality of modification of the mathematical model which is chosen. But, because the result is plotted, to extract conclusions sometimes the high number of iterations makes it more difficult to represent exactly the behavior of the model.

Therefore, not always a high number of iterations is considered to be fine for the study, but should be found by more than one compile, the best-fitted approach. Additionally, one practical way to organize better the results is to make a border by programming like the following instance:

```
Pseudocode to organize the data
…
for(x<n) {
                //creation of a border
        for(y<m) }
```

Figure 2. Pseudocode to organize the data

Generator mechanism and the multiple axiomatics approaches:

This second step is more technique than the other two steps, and the reason is that at this level we have the generator, which is the mainstream source of this procedure. The generator produces randomized values that have a scale of limits. The calling scale of limits meant that we don't have only one limit at least, but each variable has its limit. Upon the limit of each variable can be the same as that of the other variables. But the limits express the conditions that are subject to the mathematical equations. Therefore, the conditions which exist in any mathematical equation are important for the quantification of the quality data. Ergo, the conditions have the key role for the quantification of the data, as through them comes up the determination of the behavior of the equation. The randomization of the values of the generator uses limits that stand on the conditions of the mathematical equation which are under examination.

Then we have the following pseudocode which is:

```
Pseudocode to generate values
<lib>
            //definition of library
float c1, c2,…cn;
            //definition of limit
int i;
main(){
x1 [i]= rand(i,j,k);
            //production of random values in table
…
u1= c1*x1;
            //definition of limit for a variable
u2=c2*x2;
            //definition of limit for another variable
end;
```

Figure 3. Pseudocode for behavior analysis of the generator mechanism

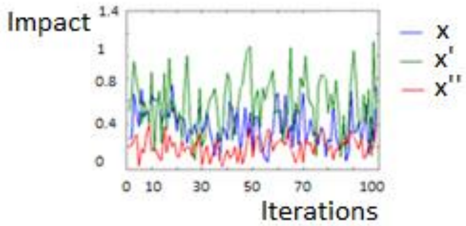
Thus, the development of the generator using the special limits of each variable and the structure of the behavior of the model is completed. After that, we proceed to the frequency analysis behavior of the generator mechanism. Thence, in the frequency analysis is studied the number of appearances of one independent variable in comparison with the rest independent variables. Two basic techniques could be applied. The first one is by multiple comparisons between the two equations, completing all the possible combinations. One other way to estimate the frequency of the independent variables is by using a constant limit. This last technique is more empirical and is based on iterations, meaning that are needed usually many compiles to determine the appropriate limit. The constant limit is determined better using the last step, where we have the conclusions from the plots and the data.

Pseudocode for the frequency:

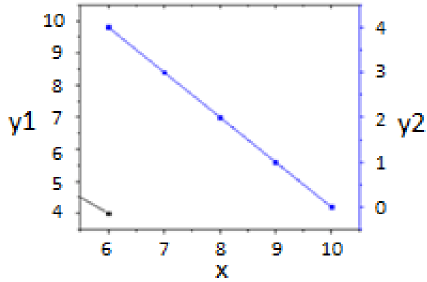
```
if u1< constant;
            // definition of frequency
            frequency1= frequency1+1;
else
            frequency2=frequency2+1;
```

Figure 4. Pseudocode for frequency analysis behavior of the generator mechanism

The previous pseudocode for the frequency analysis behavior gives the frequency between independent variables that are under examination. The previous technique is based on the use of a constant limit.



(a)



(b)

Figure 5. (a). Instance of the plot of behavior analysis (b). Instance of the plot of frequency analysis behavior

Then in diagram (a) of Fig. 5, we have an example for the behavior analysis. We determine the changes in an equation after changes in some of its variables. In the second diagram, we have the results of a frequency analysis behavior, where we determine from the x the y1, and the y2 axis the level of appearance between frequencies. The blue line is a different frequency than the black line which is another frequency; thus, we determine the impact factor of the one independent variable to the other.

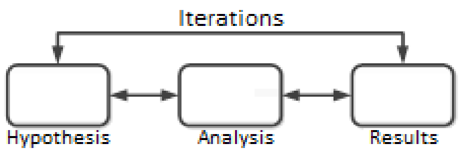


Figure 6. The mechanism of the classic form of axiomatics

According to the previous figure we have that the procedure of the analysis functions as a connector between the hypotheses and the results. Hence, the results are used as an indicator of the hypotheses. The establishment of a theory depends on the compatibility of results to the initial assumptions of each economic model.

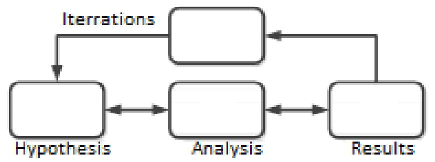


Figure 7. The mechanism of multiple axiomatics

The feedback as it is obtained from the previous scheme is the basis for the confirmation of the hypothesis and standing on that we modify again the initial model and rearrange some parameters to be consistent with the scope of the research. The feedback is responsible for the iterations needed for the clarification of the exact mathematical equation until it is consistent with the theoretical structure.

IV. Results

An illustrative application of the Q.E. method is demonstrated in the study "The Impact Factor of Education on the Public Sector – The Case of the U.S." Here, the monetary cycle in relation to education.

TABLE I. COMPILING COEFFICIENTS

Factors	**Q.E. method**	
	Values	***Values'***
αs	0.6	0.6
αt	0.7	0.7
μ	0.9	0.9
αr	-	-
αn*hn	0.3	-
αm*hm	-	-

The MATLAB code following the Q.E. method:

```
% ©® 2017 Constantinos Challoumis All Rights Reserved
    as = 0;
    at = 0;
    xm = 0;
    m = 0;
    m1 = 0;
    ap = 0;
    cm = 0;
    ca = 0;
    cy = 0;
    t = 0;
    tab = []; % Initialize the array

    while t < 10
      t = t + 1;
        if rand() < 0.9
        as = 0.6 * rand();
      else
        as = 0;
end
if rand() < 0.9
  at = 0.7 * rand();
else
  at = 0;
end

if rand() < 0.9
  m1 = 0.9 * rand();
else
  m1 = 0;
end

if rand() < 0.9
  ap1 = 0.4 * rand();
else
  ap1 = 0;
end

if rand() < 0.9
  ap2 = 0.3 * rand();
else
  ap2 = 0;
end

if rand() < 0.9
  ap3 = 0.2 * rand();
else
  ap3 = 0;
end
  a = as + at;
apk1 = ap1 + ap2 + ap3;
apk2 = ap2 + ap3;
apk3 = ap1 + ap3;
apk4 = ap1;
apk5 = ap2;
apk6 = ap3;
apk7 = ap1 + ap2;

mk1 = m1 + apk1;
xmk1 = mk1 - a;
cmk1 = xmk1 / a;
cak1 = xmk1 / mk1;
cyk1 = cmk1 - cak1;

mk2 = m1 + apk2;
xmk2 = mk2 - a;
cmk2 = xmk2 / a;
cak2 = xmk2 / mk2;
cyk2 = cmk2 - cak2;

mk3 = m1 + apk3;
xmk3 = mk3 - a;
cmk3 = xmk3 / a;
cak3 = xmk3 / mk3;
cyk3 = cmk3 - cak3;

mk4 = m1 + apk4;
xmk4 = mk4 - a;
cmk4 = xmk4 / a;
cak4 = xmk4 / mk4;
cyk4 = cmk4 - cak4;

mk5 = m1 + apk5;
xmk5 = mk5 - a;
cmk5 = xmk5 / a;
```

```
        cak5 = xmk5 / mk5;
        cyk5 = cmk5 - cak5;

        mk6 = m1 + apk6;
        xmk6 = mk6 - a;
        cmk6 = xmk6 / a;
        cak6 = xmk6 / mk6;
        cyk6 = cmk6 - cak6;

        mk7 = m1 + apk7;
        xmk7 = mk7 - a;
        cmk7 = xmk7 / a;
        cak7 = xmk7 / mk7;
        cyk7 = cmk7 - cak7;
        % Append the results to the array
        new_row = [apk1, apk2, apk3, apk4, apk5, apk6, apk7,
...
          xmk1, xmk2, xmk3, xmk4, xmk5, xmk6, xmk7, ...
          cmk1, cmk2, cmk3, cmk4, cmk5, cmk6, cmk7, ...
          cak1, cak2, cak3, cak4, cak5, cak6, cak7, ...
          cyk1, cyk2, cyk3, cyk4, cyk5, cyk6, cyk7];
        tab = [tab; new_row];
    end
     % Create a table-like output
    variable_names = {'apk1', 'apk2', 'apk3', 'apk4', 'apk5',
'apk6', 'apk7', ...
    'xmk1', 'xmk2', 'xmk3', 'xmk4', 'xmk5', 'xmk6', 'xmk7', ...
     'cmk1', 'cmk2', 'cmk3', 'cmk4', 'cmk5', 'cmk6', 'cmk7', ...
           'cak1', 'cak2', 'cak3', 'cak4', 'cak5', 'cak6', 'cak7', ...
           'cyk1', 'cyk2', 'cyk3', 'cyk4', 'cyk5', 'cyk6', 'cyk7'};
     % Display the headers
    for i = 1:numel(variable_names)
        fprintf('%s\t', variable_names{i});
    end
    fprintf('\n');
     % Display each row of the results
    for i = 1:size(tab, 1)
        for j = 1:size(tab, 2)
            fprintf('%.4f\t', tab(i, j));
        end
        fprintf('\n');
    end
     % Plot the results
    iterations = 1:10;
    figure;
    hold on;
    plot(iterations, tab(:, 29), '-o', 'DisplayName', 'cyk1',
'Color', 'r');  % Red
    plot(iterations, tab(:, 30), '-o', 'DisplayName', 'cyk2',
'Color', 'g');  % Green
    plot(iterations, tab(:, 31), '-o', 'DisplayName', 'cyk3',
'Color', 'b');  % Blue
    plot(iterations, tab(:, 32), '-o', 'DisplayName', 'cyk4',
'Color', 'c');  % Cyan
    plot(iterations, tab(:, 33), '-o', 'DisplayName', 'cyk5',
'Color', 'm');  % Magenta
    plot(iterations, tab(:, 34), '-o', 'DisplayName', 'cyk6',
'Color', 'y');  % Yellow
    plot(iterations, tab(:, 35), '-o', 'DisplayName', 'cyk7',
'Color', 'k');  % Black
    hold off;
    title('cyk Variables over Iterations');
    xlabel('Iteration');
    ylabel('cyk Values');
    legend;
    grid on;
```

The diagrammatic results are the following:

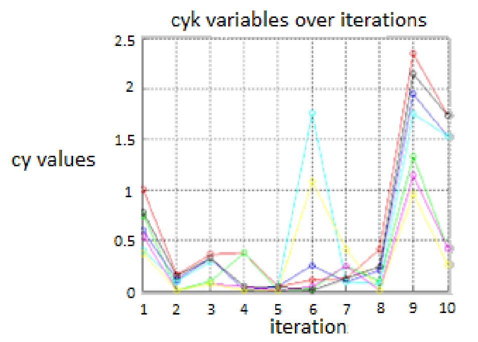


Figure 8. Multiple axiomatics on economics

A paradigm how to quantify quality data in history:

- Must be defined which are the variables.
- Then must be defined the examination variable.
- Should be defined one equation be the examiner.
- Then the examiner must define the prior equation without the examination variable.
- This determines the behavior of the model.
- This is plausible through the feedback, as the feedback is about the generator and the omitting variable.
- The generator thought the random variables allows the determination of the graph revealing to the examiner the behavior of the equation.
- Finally, it is plausible through the examination of all variables to determine all the possible behaviors of the initial equation and define its final form.

A paradigm in history could be the following one:

TABLE II. COMPILING COEFFICIENTS

Factors	**Q.E. method**
	Values
Time	0.6
Events	0.7
External factors	0.9

Therefore, using that $time = events - external\ factors$ the results are the following:

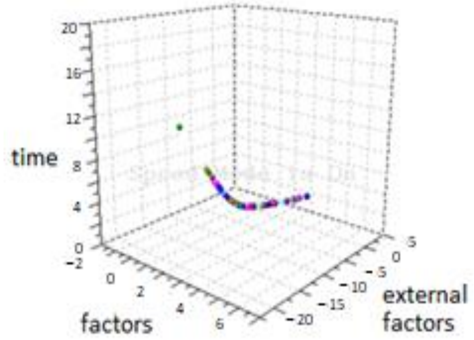


Figure 9. Multiple axiomatics on history

To this hypothetical scenario the behavior of time in history it is determined by the variable of factors excluding the variable external factors (which influence the clarity of studied factors), in the way that the prior figure presents.

There are no limitations on the Q.E. method. After the determination of the equation, it's plausible to make any statistical or any other computational analysis. In that way the method is objective.

V. Conclusions

This paper allows the quantification of quality data. The Q.E. method permits the transformation of any theoretical approach which doesn't have mathematical characteristics to a form that has this mathematical characteristic. Then, it can any further mathematical, statistical, econometric, or other analysis. Social and theoretical sciences can quantify data and extract conclusions under a completed approach, using any quantity tool to achieve any determination.

The concept of multiple axiomatics is crucial for this quantification method, as it shows that from repetitions and readjustments between the initial hypothesis and the conclusions we can confirm or develop any new scientific approach.

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Original Scientific Article

Increasing Human Capital by Investing in Training of Employees

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Abstract—**This paper deals with the investment in employees in organizations by improving the skills required to perform work tasks. Previous theoretical constructs and empirical findings have shown that knowledge-intensive work practices can lead to increased innovation activities, better employee engagement, higher job satisfaction and lower employee turnover. This paper draws mainly on data from the Harmonized Survey on Continuing Vocational Training in Enterprises and compares the two groups of European countries by economic sector and company size.**

Keywords - enterprise, human capital, training costs, vocational training

I. INTRODUCTION

In their ground-breaking work [1], they presented a theoretical model that explains why companies organise the training of their employees. The background for the conceptualization of the theory was found in the earlier work where it was explained that two groups of training can be observed [2]. The general training leads to higher wages and increases workers' employment opportunities; therefore, workers are the ones who should provide and pay for this training – they should be independent labour market observers focusing on the needs. The second group of training is training initiated and provided by companies; thus, companies are the ones who should provide financial resources for employee training. To summarise, [1,3] states that based on information about the skills of entry-level workers, companies may be willing to fund the general training of workers at the beginning of their careers. One reason for investing in general training that contributes to increasing human capital could be that firms expect a monopsony power due to asymmetric information about an employee's skills and the training offered. The authors found empirical evidence for this theoretical construct [1,3]. However, there are many other studies that examined different characteristics of trained workers and showed the differences between training participants and possible advantages for the companies that offer specific training to their workers rather than only general training (via apprenticeship) [4-10].

This paper deals with the ability of companies to train their employees using the example of the Serbian corporate sector and compares the statistical results with the former CEE countries, which are now members of the EU, and with the Balkan countries. The comparisons are made depending on the availability of data. Research questions may arise from the fact that the observed EU countries perform better than the Balkan countries in terms of employee participation in company-specific training. The present study deals with some statistical facts provided by monitoring company activity using a standardized framework provided by the Eurostat Continuing Vocational Training Survey [11]. Some previous studies conducted for Serbia found that companies invest in the training of their employees and that the training intensity of companies in the early stage of transition to a market economy may be related to the multinational and privatized companies that want to occupy the domestic market [12].

The structure of the paper is as follows. After a short introductory section, a literature review is

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given, which provides the contextual background of the theory and the empirical findings to date. The data used and the methods applied are described separately. The main findings, based on the comparison within the sample of selected countries, are presented and discussed with reference to the results of studies conducted in other countries. Conclusions and recommendations based on the research findings are presented separately.

II. Literature Review

There is a strong positive and statistically significant relationship between the exercise of knowledge in an economy and personal commitment to continuing learning. When examining the relationships between knowledge intensity and work organization in relation to business practices in different European countries [13], economies that rely more on knowledge intensity were found to adopt more knowledge-intensive strategies, including learning through firm-specific training, general training, and similar practices related to work organization, in order to grow and survive in a knowledge-intensive environment. The authors also found confirmation through an empirical experiment that countries that are more inclined to adopt various knowledge-intensive work practices lead in innovation activities. To illustrate this, the authors' study shows that European countries such as Sweden, Finland and the United Kingdom rely more heavily on knowledge-intensive working practices than, for example, the former Central and Eastern European (CEE) transition countries Bulgaria, Lithuania and Romania, which are also less innovation-intensive.[1]

Companies that offer their employees specific training have a higher level of job satisfaction than companies that do not organize training. This premise leads to a higher commitment to the work tasks and increases the profitability of the employees (of the company), but also reduces the number of jobs quits and employee turnover. Some empirical results confirming these assumptions can be found in the data from the National Longitudinal Survey of Youth 1997 cohort [8] using the variable measuring job satisfaction on a Likert-based 5-point scale, various work-related training offered by companies, and other individual characteristics of workers as independent variables. Furthermore, there is a positive and statistically significant association between promotion within the same company offering training and the job satisfaction variable.

Looking at the development of human capital and the opportunities for participation in continuing education from the perspective of adult education of labour market participants, several dimensions of individual practise of adult education in European countries can be identified in the empirical studies. Using data from the Programme for the International Assessment of Adult Competencies [14], it was found that participation in adult learning is greater in countries with high participation rates (such as Norway, Sweden and the Netherlands), while on the other hand, in countries with relatively low participation rates (such as France, Slovakia and Poland), participation is largely determined by educational attainment. There are also studies that show that the level of education is positively related to participation in adult education, meaning that a higher level of education leads to higher participation in additional education and training, while workers with a lower level of education have barriers to participating in this type of adult education [7,15]. This situation is particularly characteristic of economies in which the supply of training is reduced due to the low willingness of companies to provide training and the low willingness of employees to retrain or upskill.

As some evaluation studies show, some European countries (e.g. Romania and Greece) lag behind more active countries in providing more opportunities for participation in adult education [16]. European education systems are different, and it is suggested that policies should be targeted at each individual country in order to reach the average values of the indicators for monitoring the performance of the education system at EU level. A fixed-term employment contract also reduces the likelihood of someone participating in training, as does the age of the employee. The latter is very important because, due to the aging of the population and the demands created by the impact of technology on the labour market, this can lead to an increase in the unemployment rate among older workers in

[1] The data collected as part of the 2019 European Business Survey is available for the EU-27 and the United Kingdom [13].

the long term and thus to an increase in social pressure.

III. METHODOLOGY

The methodological framework of this paper is mainly based on the data on the implementation of continuing vocational training (CVT) collected through the harmonized questionnaire distributed to companies in European countries. This part of the European statistics provides a comprehensive set of data collected as part of the Continuing Vocational Training Survey [11]. The data is available for the EU-27, the United Kingdom, Norway, Serbia and North Macedonia. In this survey, data is collected regularly over a period of five years, so that the latest data corresponds to the 2020 Continuing Vocational Training Survey. Only enterprises employing 10 or more employees participate in the survey and the NACE Rev. 2 classification of economic activities is used to further classify the participating enterprises.

Serbia participated in the Continuing Vocational Training Survey for the first time in 2020, while North Macedonia participated in the last two surveys. This secondary dataset provides a basis for a comprehensive understanding of the training needs of companies, as well as the financial resources used at company level and the share of CVT costs in the total labour costs of employees participating in this form of training. The data is collected by the Statistical Office of the Republic of Serbia (SORS) [17]. In order to show the other side of adult education, data from the Adult Education Survey is also used for comparison [18,19].

Several other data sources have been identified in previous studies. For example, the OECD uses the case study- based methodology to provide evidence for policy purposes on what type of training companies most commonly provide, how they tend to provide training, and how they make decisions about employee participation [20]. The results of the OECD study based on qualitative data may be relevant for the discussion of the main findings obtained through the statistical analysis of selected CEE countries, EU members and two non-EU countries, Serbia and North Macedonia.

IV. RESULTS AND DISCUSSION

Fig. 1 shows the extent of the total costs of continuing vocational training in companies for

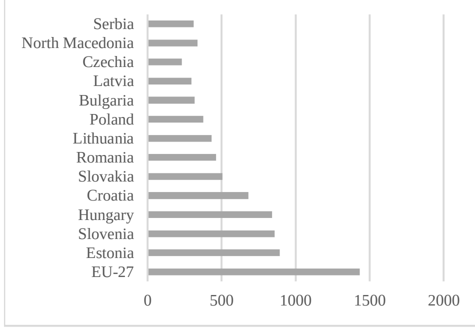

Figure 1. Total CVT costs in euro

the selected CEE countries, two Balkan countries and the EU-27. All data in this section are taken from the Continuing Vocational Training Survey (2020 edition), unless otherwise explained [11]. No country in these regions comes close to the EU-27 average, which is estimated at EUR 1,433. The three countries with the best results, where companies invest the largest amounts in increasing the human capital of their employees, are Estonia, Slovenia and Hungary (investments range between 840 and 892 euros between the first and third country), while the countries with the worst results are the Czech Republic, Latvia and Bulgaria (amounts range between 232 and 318 euros). Companies in Serbia and North Macedonia invest an average of EUR 312 and EUR 337, respectively [11]. The authors in [21] found that the knowledge acquired through on-the-job training can contribute significantly to the transition to higher-value tasks that form a stable working environment. The observed absolute differences in investment in CVT between CEE countries, EU Member States and the two Balkan countries can be linked to the strategic framework and commitments related to the convergence rules for education systems in the EU, which the former countries have to follow [16]. The other practical but more realistic fact is that the actual labour costs are higher in the EU countries compared to the Balkan countries [4,11].

The number of companies offering continuing education each year may depend on whether the needs of certain sectors of the economy are prioritized and met, the number of employees participating in continuing education, the financial resources available for this activity and other reasons. Table I shows the distribution of companies providing continuing training in selected countries and broken down by economic

TABLE I. SHARE OF COMPANIES PROVIDING CVT.

CEE Country	% of all companies by economic activity					
	Total	*B, C, D, E*	*F*	*G, H, I*	*J, K*	*L, M, N, R, S*
Bulgaria	41.1	38.6	51.0	34.6	58.8	47.4
Czechia	85.9	88.8	90.0	82.7	92.0	82.2
Estonia	79.8	79.6	73.2	79.8	91.4	80.8
Croatia	48.2	48.3	37.1	44.1	74.6	59.4
Latvia	96.8	97.5	98.4	96.9	95.1	94.8
Lithuania	54.1	55.1	49.2	47.9	79.2	66.0
Hungary	37.7	40.3	33.4	32.5	65.0	42.0
Poland	40.9	61.1	34.5	35.7	61.9	44.7
Romania	17.5	21.7	16.3	13.2	30.8	18.4
Slovenia	78.4	82.0	61.8	78.1	88.0	85.8
Slovakia	58.9	62.9	65.6	53.0	84.1	54.9
North Macedonia	56.2	55.4	52.9	52.8	61.5	68.6
Serbia	49.2	49.2	53.1	41.2	65.0	56.5

Notes: According to NACE Rev. 2. Industry (B, C, D, E); Construction (F); Wholesale and retail trade, transport, accommodation and food service activities (G, H, I); Information and communication; financial and insurance activities (J, K); Real estate activities; professional, scientific and technical activities; administrative and support service activities; arts, entertainment and recreation; other service activities (L, M, N, R, S) [11].

TABLE II. SHARE OF CVT IN TOTAL LABOUR COSTS.

CEE Country	% of all companies by economic activity					
	Total	*B, C, D, E*	*F*	*G, H, I*	*J, K*	*L, M, N, R, S*
Bulgaria	0.7	0.9	0.2	0.3	1.0	0.7
Czechia	0.9	0.8	0.6	0.7	1.6	0.7
Estonia	1.6	2.0	0.9	1.2	1.8	1.5
Croatia	0.9	0.6	0.9	0.5	2.5	1.2
Latvia	0.6	0.4	0.5	0.4	0.8	0.9
Lithuania	0.7	0.6	0.5	0.6	1.7	0.7
Hungary	1.2	0.1	1.4	1.8	2.6	1.7
Poland	0.6	0.7	0.3	0.5	1.2	0.6
Romania	0.6	0.6	0.2	0.6	1.1	0.5
Slovenia	1.4	1.6	0.3	1.3	1.9	1.1
Slovakia	1.3	1.1	1.2	0.8	2.0	1.7
North Macedonia	0.7	0.9	0.3	0.4	0.7	0.7
Serbia	0.6	0.6	0.2	0.5	1.0	0.8

Notes: According to NACE Rev. 2. Industry (B, C, D, E); Construction (F); Wholesale and retail trade, transport, accommodation and food service activities (G, H, I); Information and communication; financial and insurance activities (J, K); Real estate activities; professional, scientific and technical activities; administrative and support service activities; arts, entertainment and recreation; other service activities (L, M, N, R, S) [11].

sector. For example, if the number of companies operating in a particular economic sector is low, it is more likely that a higher percentage of these companies will provide training for their employees. This is particularly true for companies operating in the construction sector, where the proportion of companies providing training accounts for more than half of the companies participating in the CVT Survey, apart from some countries where these activities may vary due to the economic cycle.

A similar situation can be observed in the industrial sectors, but for a different reason. These industries rely more on a traditional work environment which, except in special cases, requires continuous development of workers' skills to accommodate new machines, processes, etc., due to adaptation to technological change. Serbian companies operating in the business and similar services, information and financial services and construction sectors are more likely to provide training than those operating in the hospitality and manufacturing sectors. This finding is in line with some previous empirical results showing that low-educated and older workers have lower chances of being selected to participate in specific training in their companies [e.g. 7,14,15,22]. Combining the results for Serbia with the results of the Adult Education Survey, it can be concluded that employed women and higher educated persons have greater chances of receiving additional training. The proportion of women with low and high levels of education who participated in adult education in Serbia was 1.8% and 37.6% respectively, while the corresponding proportions for men were 7.6% and 26.4% [18].

Table III shows the share of vocational training costs in total labour costs as a function of company size. Among the CEE countries that are members of the EU, Estonia, Slovenia, Slovakia and Hungary have the largest share of training costs in the total labour costs of those employees who participate in training measures. The shares are between 1.6% and 1.2% of the total labour costs of the companies surveyed. However, the distribution of training costs across the groups of economic sectors is somewhat different (see Table II). In most of the countries surveyed, the share of CVT costs in total labour costs is lower for small companies than for medium-sized and large companies. However, Serbia is one of the countries in which the share of CVT costs in total labour costs is almost the same, depending on the size of the company.

The cost of continuing vocational training may depend on the number of employees who require specific training offered by the company due to adaptation to technological change or the introduction of new standards in the company's operations. This is necessary for companies to remain competitive, as required by competition and market demands [12].

TABLE III. SHARE OF CVT IN TOTAL LABOUR COSTS BY COMPANY SIZE.

CEE Country	% of all companies by persons employed			
	Total	***10-49***	***50-249***	***250 +***
Bulgaria	0.7	0.3	0.6	1.0
Czechia	0.9	0.3	0.7	1.2
Estonia	1.6	1.1	1.8	2.0
Croatia	0.9	0.6	0.8	1.3
Latvia	0.6	0.4	0.5	0.8
Lithuania	0.7	0.5	0.7	0.9
Hungary	1.2	1.3	1.4	1.0
Poland	0.6	0.2	0.5	0.9
Romania	0.6	0.1	0.4	0.9
Slovenia	1.4	1.0	1.7	1.4
Slovakia	1.3	1.0	1.1	1.4
North Macedonia	0.7	0.5	0.6	0.9
Serbia	0.6	0.7	0.7	0.6

Notes: The statistical population is limited to companies with at least 10 employees [11].

Certain differences can also be observed between local and international companies, particularly in post-transition countries, with international companies leading in providing CVT for employees.

As Table IV shows, the costs of continuing vocational training correlate significantly with the level of education of employees.[2] Economic sectors such as information, communication, finance and insurance, which employ more skilled workers, require more specific training and standards to be adopted. In Serbia, this group of economic sectors is also the leader in terms of the average costs that companies spend on employee training, together with business services and similar activities, which rank second in terms of the average cost of training.

TABLE IV. COSTS OF CVT BY ECONOMIC ACTIVITY.

CEE Country	Cost per participant in euro				
	B, C, D, E	***F***	***G, H, I***	***J, K***	***L, M, N, R, S***
Bulgaria	350	102	155	498	349
Czechia	209	133	176	706	188
Estonia	1419	672	596	881	737
Croatia	465	1161	387	1163	898
Latvia	236	289	199	557	489
Lithuania	394	421	337	843	374
Hungary	1154*	1029	1056	1699	1799
Poland	426	369	317	575	347
Romania	373	302	462	701	509
Slovenia	941	433	759	1097	688
Slovakia	424	509	281	910	914
North Macedonia	422	267	210	390	314
Serbia	311	210	249	395	334

Notes: According to NACE Rev. 2. Industry (B, C, D, E); Construction (F); Wholesale and retail trade, transport, accommodation and food service activities (G, H, I); Information and communication; financial and insurance activities (J, K); Real estate activities; professional, scientific and technical activities; administrative and support service activities; arts, entertainment and recreation; other service activities (L, M, N, R, S). * Data for 2015 [11].

[2] The data for Hungary comes from the 2015 edition of the Continuing Vocational Training Survey due to the break in data series.

Data on investment in continuing vocational training at the level of individual economic activities, although very useful, are not available on the Eurostat platform [11]. Only harmonized data grouped by economic activity are available and used for the analysis. The reason for this could be related to the definition of the stratified sample and the degree of representativeness of the companies by specific sectors. Some methodological explanations on the data collected from the Serbian companies can be found in [17].

While large companies have a higher average share of training costs in total labour costs due to the larger number of employees, medium-sized companies can incur the highest average training costs in absolute terms, as Table V shows. Certainly, training costs are a greater burden for small companies compared to the largest ones and can have an impact on employee turnover if they are not satisfied with the treatment in terms of training opportunities [8]. In Serbia, on the other hand, the average training costs are inversely proportional to the size of the company, according to the latest edition of the CVT Survey. The average CVT cost per participant in Serbian companies are higher for small companies than for large companies, while the opposite conclusion can be drawn from the data for North Macedonia (see Table V). The factors that contribute to small companies in Serbia spending more on CVT may be directly related to the industry in which the company operates. Small companies are burdened with some administrative costs related to issuing the certificates they need to hold and renew, so they must spend certain resources on training their employees, as some previous studies for Serbia have shown [12].

TABLE V. COSTS OF CVT BY COMPANY SIZE.

CEE Country	**Cost per participant in euro**		
	10-49	***50-249***	***250 +***
Bulgaria	214	354	334
Czechia	71	179	332
Estonia	801	1182	740
Croatia	1031	777	587
Latvia	325	285	292
Lithuania	465	531	382
Hungary	1309	1541	614
Poland	315	339	397
Romania	256	583	453
Slovenia	927	1157	705
Slovakia	587	586	464
North Macedonia	284	280	403
Serbia	435	338	271

Notes: The statistical population is limited to companies with at least 10 employees [11].

V. CONCLUSION

Investing in human capital through the provision of specific training has numerous benefits for both companies and employees. The analysis in this paper is based on the data collected as part of the Harmonized Survey on Continuing Vocational Training in Companies, which allows a comparison between countries. Two groups of countries are compared: the CEE countries, which are members of the EU, and the two Balkan countries Serbia and North Macedonia, which are the only countries in this region participating in this Eurostat project.

Compared to the EU average, companies in the selected CEE countries have lower average costs for the professional development of their employees. Serbian companies spent slightly less on training compared to North Macedonian companies, as the data from the 2020 edition of the CVT Survey shows.

The results differ considerably between countries when companies are considered in relation to the group of economic sectors and company size. In general, larger companies with more employees have a larger share of training costs compared to total labour costs. However, when it comes to the absolute amounts spent on employee training, medium-sized companies have higher average expenditure in most countries. In Serbia, on the other hand, small companies have higher training costs per participant on average compared to medium-sized and large companies. Global trends in investment in vocational training show that companies are carefully allocating their resources to training their employees. In doing so, they aim to measure employee performance, particularly through employee commitment to the organization and job tasks, job satisfaction and impact on performance, and whether employees intend to leave the organization. Investment in human resources is a dynamic process and depends largely on the level of organizational culture, but also on the actual needs and pressures of the market to keep up with the competition. As some meta-analyses show, the regional context is therefore important to a certain extent when observing differences between companies [23].

While the findings presented in this paper are general in nature, they may trigger certain recommendations for both companies and employees in terms of expected trends in skills investment. Identifying the causal relationship between participation in training and the determinants derived on the basis of the relevant data and the characteristics of companies is part of the next research agenda. In this direction, new research should be proposed that addresses the links between employee participation in training, measured e.g. by employee commitment and job satisfaction factors, on the one hand, and company performance, e.g. in terms of finance, market or employment, on the other. The mediator approach should also be used to statistically isolate more precise estimates of causal relationships.

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Original Scientific Article

Smart Dust Technology: Convergence of Virtual and Physical

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Abstract—**The advent of advanced technologies such as AI, IoT, and SmartDust is poised to transform not only human life but also human nature itself. SmartDust, in particular, offers unprecedented possibilities for integrating tiny, intelligent devices within human biology, leading to the convergence of digital and biological systems. This integration, often discussed in the context of transhumanism, raises ethical and existential questions as it blurs the boundaries between the physical and digital worlds. While technological convergence promises to enhance intellectual, physical, and mental capacities, it also poses challenges related to control, identity, and privacy. The potential emergence of bio-cyber entities—humans augmented by machine intelligence—marks a profound shift in the human condition, which could lead to irreversible changes in human evolution and societal structures. As we enter this era, it is critical to explore balanced approaches that protect the essence of humanity, ensuring that technology serves as a tool for enhancement rather than a force for subjugation**.

Keywords - SmartDust, Internet of Things, Internet of Bodies, transhumanism.

I. INTRODUCTION

SmartDust [1,2], is a vision of a networked future where intelligent networks composed of millions of miniature sensors continuously sense, smell, see, and hear what is happening in their environment, communicate with each other, and exchange information [3]. SmartDust networks are, in fact, the senses of a virtual cyber entity called the Internet of Things (IoT) [4], and no aspect of SmartDust technology can be viewed outside the IoT [5]. The term SmartDust refers to extremely small computer particles, RFID chips, or other technologies of very small dimensions [6]. Sub-millimeter-sized SmartDust networks detect and transmit data to larger computer systems [7], which then store, process, and use the data. SmartDust devices organized into “clouds of SmartDust sensors” [8] are small enough to be placed anywhere and once pre-programmed, they can operate for years without human intervention. A single collection of SmartDust devices [9] can theoretically contain billions of devices connected to the internet. Although this technology seems utopian, it has already been designed, created, and tested. The sustainable concept first appeared in the early 2000s, and the first miniature smart device was implanted in a mammal in the 2010s [10]. Since then, engineers have reduced the size of IoT devices to one millimeter and continue with miniaturization. Although there are already over 10 billion active IoT devices worldwide, experts predict that by 2030, there will be more than 25 billion [11]. This is still not the full concept of SmartDust scattered across human habitats, but the concept is ready. Scientists believe that full implementation is only a few decades away, while more cautious predictions place this achievement toward the end of this century. To be cost-effective, such devices must be cheap, costing no more than a fraction of a cent. These devices run on micro-batteries that power them for ten years and can communicate with each other using low-power radio waves or optical waves. The most common self-organization algorithms replicate existing biosystems, particularly swarm algorithms that mimic the behavior of bee or ant swarms. Communication with the public network goes through special gateways. On average, up to 10 miniature sensors are connected to one device. All devices are divided into groups with different functionalities and can attract each other depending on the task and specific situation. SmartDust devices use the embedded TinyOS operating system, which is the prevalent operating system used on devices connected to the IoT. More details about the operating system can be found on the official website, www.tinyos.com.

The concept of SmartDust was introduced into scientific theory in 2001 by Kristofer S. J. Pister, from the University of California, Berkeley [12], using a literary idea from Stanislaw Lem's novel "The Invincible" from 1964. A paper from 2005 [13] examines different methods for reducing smart devices from more than a millimeter to a micrometer. Some believe that the concept behind SmartDust is a project called Smart Matter [14], with technological foundations in the field of nanoradios [15]. Research on networks consisting of large numbers of tiny devices for military purposes began in the late 20th century under DARPA. Today, the largest companies involved in the development and research of this technology are Dust Networks and Cisco.

II. CURRENT SYSTEMIC LIMITATIONS OF SMARTDUST TECHNOLOGY

When we talk about SmartDust technology today, we still refer to it as a concept or idea of advanced technology, much like how we discuss Artificial General Intelligence (AGI). The concept exists, there are sustainable rudimentary results, and based on everything known, it is certain that this is a promising technology of the future. At present, there is very little public information about SmartDust technology.

Once fully developed, the SmartDust concept will represent a device whose dimensions do not exceed the threshold of visibility—about 0.05 mm [6]. The weight must be such that the "particle" can float in the air. SmartDust should include: the ability to perform complex operations and labor-intensive computations, wireless communication, autonomous movement in space without displacement due to air or water currents, self-organization, and minimal size and weight. Based on these requirements, scientists have identified several key limitations currently preventing the full implementation of SmartDust technology [16,17].

The primary unresolved issue with SmartDust technology is powering the devices. So far, no satisfactory solution has been found. Even if the required amount of energy could be implemented easily, strategies for careful energy use and balancing resources among the tasks and the number of devices in a SmartDust cloud—potentially containing millions of devices—are still relatively unknown [18]. Some progress has been made, such as energy supply based on thick-walled batteries and solar cell components. Another potential energy solution could be pulse-based solid-state supercapacitors (nano-ionic supercapacitors) [15]. Advances in nanoradio technology may provide the technical foundation for powering SmartDust devices [19].

Communication remains an unsolved issue due to limited energy resources. Radio waves and optical communications are the best options, each with pros and cons. Radio waves require shortwave transmission, which is energy-intensive due to small antennas, while optical communications need precise alignment for line-of-sight transmission. In control theory, actuators, such as vibrating motors or changes to the device's shell, position SmartDust devices, but long-distance movement is still underdeveloped. Currently, SmartDust devices are limited to identifying and transmitting data without computing power due to their small size. Sensors, like actuators, depend on the task at hand.

While current SmartDust devices don't fully meet the concept, progress has been made in specific areas. For example, SmartMesh, an IoT protocol based on blockchain [20], integrates blockchain light nodes and second-layer networks like Raiden and Lightning for digital payments without the internet. SmartMesh forms decentralized Mesh networks that self-repair and provide higher speeds than standard internet connections, advancing IoT and IoE [20]. It’s possible that SmartDust will soon coexist with regular dust. The first steps have been made, and it’s quite possible that in our lifetime, SmartDust will float alongside ordinary dust.

III. Transhumanism and the Convergence of SmartDust Technology with the Human Entity

The goal and purpose of every new technology is always to make human life easier. With the development of computer technologies, especially AI, KM, and IoT, for the first time, we are witnessing coherent research into the potential of technology to not only improve human life but also enhance physical and mental abilities. It is only with the miniaturization of hardware, brought about by SmartDust technology, that extensive research has begun on the possibility of using SmartDust devices to control human bodily functions and improve health. However, as with most major technological innovations, SmartDust technology, at its rudimentary developmental stage, as we see today, necessarily operates within a very limited existential and ethical scope. This phase is characterized by mere belief in the possibility of converging technology with humans and achieving a transhumanist transformation that could lead to a fundamental enhancement of human life. Specifically, this may occur through the development and application of accessible technologies that improve intellectual and psychological capabilities, as well as the psychobiological aspects of human life [21]. In this way, a new, more advanced version of humans and their bodies may emerge.

Countless SmartDust devices already exist on the periphery of billions of IoT entities [22]. These devices do not yet meet all the conditions to be called SmartDust devices, but they steadily perform their functions while continually becoming more miniaturized [23]. Something similar is happening with the implementation of SmartDust technology in the human body. The Internet of Bodies (IoB) [24] represents a massive collection of SmartDust devices that are implanted, ingested, or worn, tracking processes within the human body, gathering health information, and transmitting that data via the Internet to interested users [25]. The possibilities of the impending Internet of Everything (IoE) [26] seem overwhelming, and its uncontrolled power is concerning. The University of Cambridge defines IoE [27] as “the seamless interconnectivity and autonomous coordination of a vast number of computing elements and sensors, both non-living and living beings, humans, processes, and data, through Internet infrastructure. IoE is a new research direction that will enable the existence of a connected universe using molecular sensors embedded in vehicles and humans. This new framework has enormous potential to transform the way we connect with the universe and understand it, enabling new methods of interacting with processes at the molecular level and expanding human awareness and control with the help of smart agents that sense and act upon environments previously unexplored by any other paradigm. The realization of IoE requires new engineering solutions to overcome unique challenges related to connectivity, spectrum scarcity, miniaturization, interoperability, and energy efficiency” [27].

We are already seeing a data explosion driven by Knowledge Management (KM). The rise of mobile devices, sensors, cameras, and wireless networks has exponentially increased data collection. With SmartDust's full implementation, the volume of data collected, stored, and used will become unimaginable [28].

Following the available information, we inevitably conclude that SmartDust technology represents, for the first time, a technology capable of radically transforming human life. As it has been noted, “when determining the boundary between humans and the rest of the animal world, we observe a simple but crucial difference: while animals adapt to their environment through evolution, humans use their intelligence to adapt the environment to themselves. Fortunately, nature has always fought back and found its own way to retaliate against attempts by humans to ignore it [29]. However, with the advancement of technology and human thinking, the human race is approaching a new era in which, besides having control over the natural environment, humans will gain complete control over their own evolution, health, and potentially, their mortality” [30]. Thus, we arrive at transhumanism, which, moving from fiction and a favored topic of utopian or dystopian literature, is slowly becoming a probable future reality through the convergence of SmartDust devices and human entities.

Transhumanism, in this context, is understood as an intellectual and cultural movement that promotes the possibility and desirability of fundamentally improving human life through the development and application of technologies that eliminate the degeneration of the human body and mind [31]. At present, there is not only no clear answer but also no response regarding whether this movement has grown out of salon, chamber, or internet-based forms into more practical ones.

Since the beginning of this century, the increasing interconnection of computer systems and networks, combined with the rise of intelligent automation, has led to rapid changes in technology, industries, as well as social patterns and processes [32]. At the same time, embedding sensor and computing capabilities into everyday IoT objects [33] and their integration into living organisms (IoB) [34] has blurred the boundaries between the physical, digital, and biological worlds. As a result, formerly unrelated technologies are becoming increasingly interdependent and applicable across multiple domains. This phenomenon, known as “technological convergence” or “converging technologies” (CT), represents a shift in the socio-biotechnical paradigm, marked by the pervasive distribution of computing and sensing capabilities, and the consequent dissolution of boundaries between previously unrelated fields of technological innovation [32]. For the purposes of this paper, we will refer to one definition [32] that defines “technological convergence” as “a new socio-biotechnical phenomenon characterized by three fundamental aspects: The increasing ubiquity and comprehensive distribution of sensing and computing capabilities on both physical objects and biological organisms; The erosion of clear distinctions between the physical, digital, and biological domains due to new technologies such as artificial intelligence (AI), gene editing, nanotechnology, biomedical engineering, neurotechnology, and robotics; And the more frequent simultaneous emergence of these technologies and their large-scale expansion in ways that are difficult to detect, protect, and manage” [32].

The integration of previously unrelated technologies offers benefits for socio-biotechnical innovations and human well-being but poses significant ethical and governance challenges. These disruptions, often called the “fourth industrial revolution,” are leading to “Society 5.0” [35]. This merging of the human body with digital technologies forms a bio-cyber-physical system ([Bio-]CPS), or a bio-cyber entity, combining cybernetic and biological components.

IV. Bio-Cyber Entities, Neo-Luddism and the New Ethics

Any symbiosis between humans and technology inevitably leads to humanity's cyberization. The merging of humans with machines could transform humanity and allow entities that are only partially human to control all aspects of life. The final product of the transhumanist convergence of SmartDust-based technologies and human entities could result in a “Bio-Cyber-Physical System” ([Bio-]CPS). Increasingly, experts warn that this could be the first irreversible evolutionary change, altering humanity's very essence. Through this, humanity might voluntarily surrender control to an unknown “someone”.

This bio-cyber entity might be Nietzsche's Übermensch, but from a moral perspective, it could be seen as a moral and mental abomination. The ethics of coexistence between ordinary humans and bio-cyber humans are not yet fully developed. Our prior research on this new ethics [36,37] suggests that it revolves around AI’s ontological and epistemological interventions into the human “self.” While AI has enhanced human capability, the human body and mind must remain the foundation of existence. Non-human entities may assist in certain tasks, but ultimate control must remain with humans. AI should be bound by the laws of robotics; losing control opens the door to errors and abuses, leading to human redundancy.

Studies suggest the risk of misuse lies more with human nature than technology, but scientists warn SmartDust systems could reshape the world into something alien to humanity. Powered by neural networks and invisible, high-speed computers, these systems could displace humans from many areas of life, altering minds, habits, communication, and freedom, threatening privacy and autonomy.

There are two general approaches to the convergence of technology and humanity [38]. Neo-Luddism [39] opposes this convergence, viewing it as a threat to humanity that must be resisted. Transhumanism, on the other hand, sees technology as humanity's salvation, focusing on maximizing human-machine integration. Both approaches envision radical changes in human life and identity. Neo-Luddism fears the unpredictable and often invasive consequences of uncontrolled convergence, while transhumanism promises life extension and the transition to a cyberized existence. Scientists advocate a moderate path, promoting balanced coexistence between humanity and technology to preserve human identity. The enhancement of human physical and mental abilities through technology raises important ontological and ethical dilemmas. Technologies such as genetic modification, bionic prosthetics and biomimetic entities, neurostimulators, and even brain-computer interfaces must be used ethically and responsibly. We have defined eight principles of human enhancement that, in our view, must hold an almost sacred status. These principles are autonomy, the right of individuals to make decisions about their own bodies; justice and equality, ensuring equal access regardless of economic status; nonmaleficence, the assurance that enhancement technologies do not cause serious or lasting harm to health; beneficence, the belief that these technologies should bring real benefits to people, improving quality of life and enabling them to realize their potential; natural human autonomy and integrity, determining the limits to which technologies should be allowed to alter natural human abilities; the right to refusal, the inalienable right of every individual to decline enhancement technologies without fear of discrimination or social marginalization; transparency and accountability, the stance that all aspects of the development and application of enhancement technologies must be transparent; and long-term impact on the human species, a clear understanding of how these technologies will shape the future of human evolution, identity, and social structures. Scientific papers sporadically discuss the sort of threat that AI-based technologies might pose to the ontological being of humanity. This threat could, if not extinguish humanity as we know it, at least stifle its natural impulses. A superintelligent machine could dramatically alter the nature of human existence. Russell wrote that "people who live beyond a certain natural limit will most likely be filled with envy, malice, selfishness, and rage. They may become wrathful and cruel, or, on the other hand, they may completely lose the joy of life, to the point where they no longer have the strength for any effort" [29]. We are not talking about one or a hundred or a thousand people, but about billions of people.

V. Conclusions

Technological entities, including SmartDust, becoming the ontological substitution for humans, can lead to dramatic technological inferiority, complete loss of identity, and irreparable ontological disability [38]. In the process of sociopsychological adaptation, humans have fused with technology and no longer see themselves outside the comfort that technology offers, whose advancement has greatly influenced the development of human culture. Assessing the vulnerability of extreme alternative approaches, neo-Luddism and transhumanism, more and more research is exploring the possibility of a middle path—a possibility of proportional, peaceful coexistence between humans and technology, with the aim of preserving the innate and unchangeable mental apparatus of humans and their stable and coherent identity amidst the constant development of technological progress. By maintaining the intrinsic civilizational need for humans to expand technology, this middle path could or must ensure that technological interventions in altering the ontological being of humans are limited and proportional to natural possibilities and capabilities in the objective conditions of life on the planet.

Addressing the ethical and societal risks is essential for maintaining privacy, security, and social justice. Sensors can collect data about the environment and individuals, which could be misused for surveillance, profiling, or control.

Governments must implement strict privacy laws, require user consent before data collection, enforce data encryption, and limit access to information. Given that SmartDust technologies transmit data wirelessly, they are vulnerable to hacking and manipulation. Therefore, governments should develop advanced security protocols, ensure regular software and hardware updates, and establish standards for sensor deployment. Governments also must maintain democratic oversight of the technology, balancing its benefits with privacy rights and promoting ethical guidelines for its use.

SmartDust could exacerbate social inequalities, particularly between wealthy and poorer countries, social groups, and individuals. Equal access to technology and data must be ensured, and its use in public and private spaces must be regulated to prevent discriminatory practices. Another major concern is the environmental impact of millions or billions of tiny sensors, especially when they stop functioning. These devices could contribute to soil, water, or air pollution, as collecting all devices after use is challenging. A solution could involve mandating the use of eco-friendly, biodegradable materials and establishing systems for the collection and disposal of these devices at the end of their lifecycle. As with many technologies, there is a risk of SmartDust being misused for unethical purposes, such as military applications or non-consensual experiments. Governments should establish ethical committees to monitor the development and application of SmartDust technologies, and the international community should create conventions and agreements to ensure these technologies are used in line with humanitarian law. At this moment, it is impossible to predict whether the bio-cyber entity will be ontologically closer to humans or robots, and which path the evolution of this binary biomimetic being will take. One of the less important unknowns is whether SmartDust will be a collective, aggregated entity of AI, or if some form of SmartDust will acquire its own personality, thus becoming what we have called a biomimetic entity. What is known is the fact that scientists continually warn humanity that the loss of “human control over humans” could easily mean the end of the world. Scientists claim that the concentration of metadata, power, and wealth in the hands of a few can make the entire system non-transparent and “opaque,” which will certainly lead to increased social tensions and, in particular, a deterioration and drastic violation of democratic rights and freedoms of citizens and nations. Scientists, especially philosophers, sociologists, and theologians, are not ready to entrust the development of the ethics of artificial intelligence and bio-cyber entities solely to engineers. Philosophers, sociologists, and theologians should collaborate with engineers, programmers, and decision-makers in multidisciplinary teams that oversee the development and application of technologies. These teams can help identify potential risks and consequences of new technologies, developing sustainable and ethical strategies for their advancement. Ultimately, philosophers, sociologists, and theologians can provide the intellectual foundation for creating laws and regulations that responsibly govern technologies.

The invasion of privacy is the primary reason why people are wary of the implications of SmartDust in life. SmartDust devices are invisible and difficult to detect. They will record everything they detect. People likely won't know who is collecting the data and what they are doing with it, nor will they be able to prevent the data about them from falling into the wrong hands. When SmartDust is used as part of the Internet of Bodies (IoB), freedom of choice will necessarily come into question. There are well-founded opinions [40] that the decision to “enhance” mental and physical abilities should be the sovereign right of the individual. But would it be morally right for ambitious parents to make such a decision for a child who wishes to succeed in sports or the arts but is not capable of doing so? This is where we can consider the most extreme goal of transhumanism: eternal life achieved through technology [30]. Among the criticisms of this goal is the possibility of complete relativization and loss of morality. The fear of death and eternal life in hell has long driven people to adhere to the moral norms of this life. But in a world where that fear no longer exists, moral and ethical values that are unconditionally respected could become unnecessary and discarded anachronisms. The integration of SmartDust and bio-cybernetic entities could radically transform social structures, the labor market, and human rights, bringing both progress and significant challenges. There is a high potential for deepening social inequalities, making the development of new legislative and ethical frameworks essential to ensure fair and humane use of these technologies. A future where technology shapes human capabilities and social relationships requires careful planning to distribute benefits equitably and minimize risks.

The combination of SmartDust and bio-cybernetic entities will fundamentally alter societal functions, particularly in terms of control, surveillance, and interactions between individuals and institutions. Corporations and governments could gain significant influence by controlling the SmartDust and bio-cybernetic infrastructure, playing a key role in regulating, monitoring, and distributing these technologies.

The labor market would be drastically impacted, leading to massive job losses, especially in manual labor industries, further widening income and opportunity gaps between social classes. These technologies may exacerbate existing inequalities or create new forms of discrimination and social exclusion. Those who can afford bio-cybernetic enhancements could form a new elite, dominating the workforce, politics, and societal structures. Moreover, the integration of SmartDust and bio-cybernetic entities raises fundamental questions about redefining human rights, as they reshape the relationship between technology and humanity. This also introduces legal debates over the "rights of robots" and, similarly, the "rights of bio-cybernetic entities".

As we noted in earlier papers [41], controlling bio-cyber entities or aligning them with human values may be harder than assumed. Many researchers believe that the superintelligence of these entities will resist humanization or goal alteration—a principle called instrumental convergence. Pre-programming them with human values will be a highly challenging technical task [42]. Additionally, once billions of SmartDust devices are deployed, neutralizing them will be extremely difficult.

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Original Scientific Article

Knowledge Transfer in Serbian Economy: Degree of Freedom and Business Performance Implications

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Abstract—**Serbia belongs to the group of post-transition economies where the application of modern business concepts is still fragile. Knowledge is emerging as one of the most valuable resources for any economy striving for development and prosperity worldwide today. However, to get the most out of it, it is necessary to provide free knowledge transfer in businesses. This conference paper seeks to investigate the degree of freedom of knowledge transfer in the economy in the Republic of Serbia and estimate its implications for business performance. Empirical study was organized on a sample of 159 managers of businesses operating in Serbia, which were randomly selected from publicly available databases, with the Computer Assisted Web Interview - CAWI technique at its core. The data analysis in the study relied on descriptive statistics. Univariate analysis was used through individual ranking statistics. One-way ANOVA and post hoc Mann Whitney U test were used to analyze knowledge transfer freedom according to socio-demographic and business information. The study results show a slightly above-average level of knowledge transfer freedom in the business world in the Republic of Serbia, which leaves room for improvement. In addition, the results show that businesses that carry out greater knowledge transfer realize better business performance, which could be taken as a sign of the desirability of a stronger application of knowledge transfer strategies, methods, and techniques in Serbian economy.**

Keywords - knowledge transfer freedom, business performance, Republic of Serbia.

I. INTRODUCTION

Serbia belongs to the group of post-transition economies where the application of modern business concepts is still fragile. Although it has been determined that businesses operating in the Republic of Serbia with the application of modern business concepts achieve more successful economic and financial results [1], Serbian businesses are still struggling to apply the methods and techniques of the modern economy and management [2,3]. So far, improvements are being noticed in the rare businesses from trade, industry, tourism and, more recently, banking [4-6]. It also depends on their size, international market experience and type of ownership, where the more significant development and application of newer business concepts is present in larger businesses, businesses with significant international business experience and in businesses that are foreign owned [2].

The modern knowledge economy prioritizes information as one of the most critical success factors [7]. The need for the free flow of various types of information both in businesses and in their relationship with the external environment (organizations, institutions, markets) is constantly increasing. The effective functioning of businesses in knowledge-intensive sectors is often linked to the freedom of knowledge transfer within the business and with its partners in the supply and marketing systems. Restricting knowledge transfer, on the other hand, negatively impacts the knowledge resources of businesses

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and the development of the economy as a whole. As a result, success in modern economies depends on the effectiveness of systems that allow the interactive flow of information and knowledge between economic agents.

In the economic sphere, the emerging knowledge economy and the knowledge epoch are increasingly influential. Charles Leadbeater goes so far as to talk of “knowledge capitalism” in society and, in particular, the economy [8]. It follows that interactive communication is an essential condition for the functioning of a modern market economy, whereas the transmitting, exposing, receiving, interpreting, and using of messages are present at all levels of the economy. The logic of building knowledge, engaging in a creative process, sharing it, and building new activities that can be connected to it ultimately leads to the conclusion that a fully functioning modern economy must provide and protect the freedom of information conveyance. It follows that freedom for information transmission is an important universal human right [9].

Knowledge transfer is a fundamental process in the dissemination of information and skills across various domains, including education, business, and technology [10]. The concept of knowledge transfer freedom refers to the unrestricted flow of knowledge between individuals, organizations, and societies. This conference paper explores the multifaceted nature of knowledge transfer freedom, examining its significance in Serbian economy, key determining factors, and business performance implications. It accentuates the barriers that impede it, and suggests the strategies that can enhance it. By analyzing these aspects, we can better understand the implications of knowledge transfer freedom in fostering innovation, collaboration, and societal progress in Serbia. In an era characterized by rapid technological advancements and globalization, the importance of knowledge transfer freedom cannot be overstated, as it serves as a catalyst for growth and development across multiple sectors [11,12].

II. LITERATURE REVIEW

A. *Understanding Knowledge Transfer*

Knowledge transfer is defined as the process through which knowledge is shared, disseminated, and utilized among individuals or groups [13]. It encompasses various forms of knowledge, including tacit knowledge, which is personal and context-specific, and explicit knowledge, which is codified and easily communicated. Tacit knowledge often includes insights gained from personal experiences, while explicit knowledge can be found in manuals, documents, and databases [13]. The significance of knowledge transfer lies in its ability to facilitate learning [14], improve performance [15,16], and drive innovation [17]. In a globalized world, the ability to transfer knowledge freely is crucial for fostering collaboration and addressing complex challenges. This process not only enhances individual capabilities but also strengthens organizational competencies, ultimately contributing to a more knowledgeable society.

B. *The Importance of Knowledge Transfer Freedom*

Knowledge transfer freedom is vital for several reasons. Firstly, it promotes innovation by allowing ideas to flow freely across borders and disciplines. When individuals and organizations can share their insights without restrictions, they can build upon each other's work, leading to new discoveries and advancements. This collaborative innovation is particularly evident in fields such as technology and healthcare, where shared knowledge can lead to breakthroughs that benefit society as a whole [for example, 18-20]. Secondly, knowledge transfer freedom enhances collaboration among diverse groups, fostering a culture of teamwork and shared learning [21-24]. This collaborative spirit is essential for tackling critical issues such as climate change, public health crises, and technological advancements. By enabling diverse perspectives to converge, knowledge transfer freedom can lead to more comprehensive and effective solutions to pressing global challenges.

C. *Barriers to Knowledge Transfer Freedom*

Despite its importance, several barriers hinder knowledge transfer freedom. These barriers can be categorized into structural, cultural, and technological factors. Understanding these barriers is crucial for developing effective strategies to promote knowledge sharing and collaboration and create an environment conducive to the free flow of ideas and information.

1) Structural Barriers

Structural barriers refer to the organizational and institutional frameworks that impede knowledge sharing [25]. For instance, hierarchical organizational structures can create silos, where information is not easily accessible to all members. This lack of accessibility can stifle creativity and limit the potential for innovation. Additionally, legal and regulatory constraints, such as intellectual property laws, can restrict the sharing of knowledge, particularly in industries where proprietary information is critical to competitive advantage. These structural impediments can create an environment where knowledge is hoarded rather than shared, ultimately hindering progress and collaboration.

2) Cultural Barriers

Cultural barriers also play a significant role in hindering knowledge transfer [26]. In some organizations, a culture of secrecy may prevail, where individuals are reluctant to share information due to fear of losing their competitive edge or being judged. This fear can create an atmosphere of distrust, where employees feel that sharing knowledge may jeopardize their job security or status within the organization. Furthermore, differences in communication styles and practices across cultures can lead to misunderstandings and misinterpretations, further complicating the knowledge transfer process. For example, in some cultures, direct communication is valued, while in others, indirect communication may be preferred, leading to potential conflicts and confusion.

3) Technological Barriers

Technological barriers can impede knowledge transfer freedom as well [27]. While technology has the potential to facilitate knowledge sharing, inadequate infrastructure, lack of access to digital tools, and cyber security concerns can hinder effective communication. In many regions, especially in developing countries, limited access to the internet can create significant gaps in knowledge transfer. Additionally, the rapid pace of technological change can create gaps in knowledge, as individuals may struggle to keep up with new tools and platforms. This technological divide can exacerbate existing inequalities, making it essential to address these barriers to ensure equitable access to knowledge.

D. Strategies to Enhance Knowledge Transfer Freedom

To overcome the barriers to knowledge transfer freedom, several strategies can be implemented. These strategies focus on fostering a culture of openness, leveraging technology, and creating supportive structures. By adopting these approaches, organizations can create an environment that encourages knowledge sharing and collaboration.

1) Fostering a Culture of Openness

Creating a culture of openness is essential for enhancing knowledge transfer freedom [6]. Organizations can encourage knowledge sharing by recognizing and rewarding individuals who contribute to collaborative efforts. This recognition can take various forms, such as public acknowledgment, incentives, or professional development opportunities. Leadership plays a crucial role in modeling open communication and transparency, which can help to dismantle silos and promote a sense of community. Training programs that emphasize the importance of knowledge sharing and collaboration can also help to shift organizational culture. By instilling values of trust and cooperation, organizations can create an environment where individuals feel empowered to share their knowledge and insights.

2) Leveraging Technology

Technology can be a powerful enabler of knowledge transfer freedom [28]. Organizations should invest in digital platforms that facilitate communication and collaboration, such as intranets, knowledge management systems, and social media tools. These platforms can provide a space for individuals to share insights, ask questions, and collaborate on projects. Additionally, organizations should prioritize cyber security measures to ensure that knowledge sharing occurs in a safe and secure environment. By leveraging technology effectively, organizations can break down geographical barriers and create a more interconnected workforce, allowing for seamless knowledge transfer across different locations and time zones.

3) Creating Supportive Structures

Establishing supportive structures is another critical strategy for enhancing knowledge transfer freedom [25]. Organizations can create cross-functional teams that bring together individuals from different departments or areas of expertise to work on specific projects. This approach encourages the exchange of diverse perspectives and facilitates knowledge sharing. Furthermore, mentorship programs can pair experienced individuals with newcomers, fostering a culture of learning and knowledge transfer. By creating formal structures that promote collaboration, organizations can ensure that knowledge flows freely and that individuals have the support they need to share their insights and experiences.

E. The Role of Education in Knowledge Transfer Freedom

Education plays a pivotal role in promoting knowledge transfer freedom [29]. Educational institutions are responsible for equipping students with the skills and knowledge necessary to navigate an increasingly complex world. By fostering critical thinking, creativity, and collaboration, educational institutions can prepare students to contribute to knowledge transfer efforts in their future careers. Moreover, education can instill a sense of responsibility in individuals to share their knowledge and skills with others, reinforcing the importance of knowledge transfer in society.

1) Curriculum Design

Curriculum design is a crucial aspect of education [30] that can influence knowledge transfer freedom. Educational programs should emphasize interdisciplinary learning, encouraging students to draw connections between different fields of study. This approach can help students develop a broader perspective and appreciate the value of diverse knowledge sources. Additionally, experiential learning opportunities, such as internships and collaborative projects, can provide students with practical experience in knowledge sharing and collaboration. By integrating real-world applications into the curriculum, educational institutions can better prepare students to engage in knowledge transfer in their professional lives.

2) Promoting Lifelong Learning

Promoting lifelong learning is essential for fostering knowledge transfer freedom in an ever-changing world [31]. Educational institutions should encourage individuals to pursue continuous learning opportunities, whether through formal education, professional development, or self-directed learning. By cultivating a mindset of curiosity and adaptability, individuals can remain open to new ideas and perspectives, facilitating knowledge transfer throughout their lives. Lifelong learning initiatives can also help individuals stay relevant in their fields, ensuring that they can contribute effectively to knowledge sharing and collaboration.

F. Global Perspectives on Knowledge Transfer Freedom

Knowledge transfer freedom is not only a local or organizational concern; it is also a global issue. Different countries and cultures may have varying approaches to knowledge sharing, influenced by their unique historical, social, and economic contexts. Understanding these global perspectives can provide valuable insights into how knowledge transfer freedom can be enhanced worldwide. By examining these differences, we can identify best practices and strategies that can be adapted to various contexts, promoting a more inclusive approach to knowledge sharing.

1) International Collaboration

International collaboration is a key aspect of knowledge transfer freedom on a global scale [32]. Collaborative initiatives, such as research partnerships, academic exchanges, and joint ventures, can facilitate the sharing of knowledge across borders. These collaborations can lead to innovative solutions to global challenges, as diverse perspectives and expertise are brought together. For example, international research collaborations in fields like climate science and public health can yield insights that benefit multiple countries. However, it is essential to navigate the complexities of international collaboration, including differences in legal frameworks, cultural norms, and communication styles. By fostering mutual understanding and respect, organizations can enhance the effectiveness of their collaborative efforts.

2) Access to Knowledge

Access to knowledge is another critical consideration in the context of global knowledge transfer freedom [33]. In many parts of the world, access to information and educational resources remains limited due to economic disparities, infrastructure challenges, and political restrictions. Efforts to promote knowledge transfer freedom must address these inequalities, ensuring that individuals and communities have the resources they need to participate in knowledge sharing. Initiatives such as open access publishing, online learning platforms, and community-based knowledge-sharing programs can help bridge these gaps. By democratizing access to knowledge, we can empower individuals and communities to engage in knowledge transfer and contribute to global progress.

III. Research Method

A. Research Participants

Participants in the study were managers of businesses operating in Serbia, selected using the stratified random sampling technique by economy branches. The survey was organized on a representative sample of 159 respondents. Testing managers of businesses was conducted with the help of quantitative research techniques via the Internet (Computer Assisted Web Interview - CAWI) with previous consent from each subject for participation in the study. As a sample frame, publicly available databases of businesses in Serbia were used. The sample characteristics are shown in Table I.

B. Research Instrument

As a research tool for implementation of the method of collecting data from the primary sources, the 7-point Likert scale questionnaire was used (1-min, 7-max), established on the basis of review of the scientific and expert literature [34,35], and in compliance with the special needs of research. After socio-demographic and business characteristics of respondents, the questionnaire contained questions pertaining to knowledge transfer and business performance. Results of Cronbach's alpha test of questionnaire as a measure of its reliability indicate the consistent reliability of results obtained ($\alpha>0.7$) [36].

C. Research Model

The research model was based on examining perceptions of managers of businesses operating in Serbia in relation to the knowledge transfer freedom. In the second step, the research model referred to the examination of the conditionality of the degree of the importance of the knowledge transfer freedom with specific respondents' socio-demographic and business characteristics. Finally, the research model was related to the examination of the relationship between the knowledge transfer freedom and business performance.

D. Data Analysis

Items of the final questionnaire were analyzed using the statistical package SPSS v20. The data analysis in the study consisted of descriptive statistics. Univariate analysis containing individual ranking statistics was used. One-way ANOVA and post hoc nonparametric Mann Whitney U Test were used to test the significance of the differences. Results with $p<0.05$ were declared significant.

IV. Results and Discussion

Table I reveals that most managers of businesses operating in the Republic of Serbia recognize the crucial role that the free knowledge transfer plays for the success and sustainability of their operations, since it carries mean value that is above average ($\mu=4.84$, $SD=1.62$). However, even though a large percent of respondents pays certain attention to this issue, it is evident that there is still much room left for improvement pointing towards the presence of some barriers (structural, or cultural, or technological barriers) that impede free knowledge transfer in Serbian economy. According to this research results, there does not seem to be a general understanding that business in Serbia should be run with knowledge transfer in mind. This demonstrates that there is a significant number of businesses which have not yet embraced and embedded knowledge transfer in their business doing. Business attention on knowledge transfer is still in a transitional stage and no adequate knowledge transfer focus currently exists. This is in line with the previous research results obtained by [37], who have also found the slightly above average degree of knowledge sharing in local governments in the Republic of Serbia, pointing to the fact that despite years have passed, Serbian economy has not made any significant progress in this field. Like previously already stated [1-6], Serbia is still economy that slowly implements new business concepts and practices that are already fully established in the developed world disenabling itself to reap the benefits thereof and elevate the living standard of its citizens.

TABLE I. ANALYSIS OF THE DEGREE OF KNOWLEDGE TRANSFER FREEDOM IN SERBIAN ECONOMY.

	Knowledge Transfer Freedom			
Variable	***N***	***Mean***	***SD***	***p***
Total Economy	147	4.84	1.62	
Gender				>0.05
Male	64	5.08	1.429	
Female	82	4.62	1.733	
Age (Years)				>0.05
≤ 25	3	3.33	2.082	
26 – 35	35	5.23	1.516	
36 – 45	54	4.67	1.693	
46 – 55	39	4.90	1.553	
56 – 65	13	4.69	1.494	
≥ 65	2	3.50	2.121	
Vocational Training				>0.05
High School	14	3.86	1.562	
College	25	4.60	1.780	
BSc	83	5.04	1.502	
MSc	17	4.88	1.691	
Magister	4	5.25	.957	
PhD	2	6.00	1.414	
Type of Settlement				>0.05
Urban	135	4.87	1.615	
Rural	11	4.27	1.618	
Experience in Current Job Position (Years)				>0.05
< 1	7	4.71	2.059	
1 – 4	35	4.94	1.608	
5 – 9	50	4.80	1.591	
10 – 19	31	5.10	1.535	
20 – 29	17	4.53	1.700	
Experience in Current Business (Years)				>0.05
< 1	7	4.43	2.440	
1 – 4	40	4.70	1.636	
5 – 9	43	5.14	1.612	
10 – 19	30	4.73	1.461	
20 – 29	18	4.83	1.425	
> 30	4	4.50	1.000	
Management Level				>0.05
TML	44	5.18	1.574	
MML	39	4.82	1.467	
FML	15	5.00	1.069	
NML	32	4.47	1.951	
Business Size				>0.05
< 100	71	4.82	1.642	
100 – 499	48	5.15	1.429	
> 500	24	4.42	1.501	
Total Business Performance, Success				<0.05
Unsuccessful	38	4.37	1.762	
Successful	99	5.06	1.524	

Regarding the influence of specific respondents' socio-demographic and business characteristics, Table I also shows that the degree of knowledge transfer freedom in Serbian businesses does not differ significantly according to respondents' background ($p>0.05$). This is partially in line with the previous research findings in which knowledge sharing correlated with each of researcher demographic factors: age, gender, marital status, religion, and educational level [38], as well as with entry mode and industry, but did not correlate with the business size [39]. The reason for this may be cultural differences, or the level of the country's development in various fields, such as technology, law, economy, politics, society, etc. The lack of influence other investigated managerial and business characteristics have on this issue indicates that knowledge transfer in the Serbian business world is determined and polished by the corporate and State policies and barriers.

On the positive side, according to this research results, the degree of knowledge transfer freedom significantly differs in relation to achieved business performance in a manner that successful businesses enable more knowledge transfer freedom than unsuccessful ones ($p<0.05$), which is in line with previous research [1, 4, 15, 23]. This could be seen as a sign of the desirability of a stronger application of knowledge transfer strategies, methods, and techniques in Serbian economy. For this to occur, it would be necessary, first, to determine the causality between knowledge transfer freedom and business performance by conducting a broader research that would include larger sample of businesses in order to confirm the revealed relevance of the knowledge transfer freedom for business success, and, second, to determine and eliminate the existing barriers to free knowledge transfer in businesses in the Republic of Serbia, which are found to be present in all three fields in part of public sector, i.e., structure, culture and technology, according to the previous research [30], as well as to elevate the awareness of Serbian managers regarding the importance of knowledge transfer for prospect business results.

In that sense, it is necessary to increase the potential for free knowledge transfer in Serbian economy by working on eliminating the existing barriers. First, training programs that emphasize the importance of knowledge sharing and collaboration could be initiated in this stage, in order to elevate the necessary awareness and acquaintance with the importance of knowledge management and knowledge transfer strategies, methods, and techniques. Next, a culture of openness should be created by self-example of business leaders and/or by recognizing and rewarding individuals who contribute to collaborative efforts. By instilling values of trust and cooperation, businesses can create an environment where individuals feel empowered to share their knowledge and insights. Further, to seize the most out of open culture, supportive organizational structures should be developed with less hierarchical levels and authority positions that impede free knowledge sharing and communication, or, at least, with introduced organizational and institutional frameworks that encourage knowledge sharing, cross-functional teams and mentorship programs. By creating formal structures that promote collaboration, businesses can ensure that knowledge flows freely and that individuals have the support they need to share their insights and experiences. If supported by the appropriate technology that has the potential to facilitate knowledge sharing, in the form of adequate infrastructure, access to digital tools, and cyber security measures, the degree of knowledge transfer in Serbian economy could highly increase.

On the State level, legal and regulatory tools, such as educational programs could positively influence the sharing of knowledge. Educational programs that emphasize interdisciplinary learning, encouraging students to draw connections between different fields of study, fostering critical thinking, creativity, and collaboration, altogether with experiential and life-long learning can instill a sense of responsibility in individuals to share their knowledge and skills with others, reinforcing the importance of knowledge transfer in society.

Conclusion

This empirical research paper presents an overview of knowledge transfer in Serbian economy from the point of view of its degree of freedom and business performance implications. The obtained results show that most managers of businesses operating in the Republic of Serbia, regardless of their socio-demographic and business characteristics, recognize the crucial role that the free knowledge transfer plays for the success and sustainability of their operations, yet, not at the highest level, pointing towards the presence of some barriers that impede free knowledge transfer in Serbian economy. Since the degree of knowledge transfer freedom has shown to positively correlate with achieved business performance, it would be necessary to determine and eliminate the existing barriers to free knowledge transfer in businesses in the Republic of Serbia, as well as to elevate the awareness of Serbian managers regarding the importance of knowledge transfer for prospect business results, so to reap the benefits thereof and elevate the living standard of its citizens.

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Original Scientific Article

The Impact of the Professional Course in Entrepreneurship at CLESE-Lubango-Huila-Angola

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Abstract—**This research aims to understand the contribution that the Entrepreneurship course taught by the CLESE-Lubango-Huila-Angola professional center has generated in the promotion of new small businesses. To this end, a quantitative methodology was used, distributing 196 questionnaires to a universe of 200 trainees who passed through the center during the first semester of 2024. As main findings, the research highlight that in the characterization of a training action in order to guarantee the three main objectives of Know-How, Know-How to Be and Know-How to do, CLESE-Lubango should seek to include in its training program the expectations of trainees regarding the course through a valid instrument for collecting opinions, as well as including in its content grid such as case studies , bringing to the classroom managers with a history of success in the local market.**

Keywords - entrepreneurship; education; Angola

I. Introduction

The job market is constantly evolving and entrepreneurship education can provide individuals with the skills and mindset to adapt to these changes.

The objective of this article is to understand the contribution that the Entrepreneurship course taught by CLESE-Lubango-Huila-Angola has generated in promoting new small businesses. The thesis sentence is: In what sense is teaching the professional Entrepreneurship course important?

Research [1] suggested that entrepreneurship education is important for the following reasons: it develops entrepreneurial mindsets and skills, promotes innovation and economic growth, promotes social and environmental impact, supports career development, enhances personal and professional development, and helps individuals adapt to a changing job market.

In order to better contribute, this article tests data collected in one of the entrepreneurship centers in Angola, Huila province, Lubango municipality. The article is structured as follows: introduction, literature review, Methodology, Results and Discussion, conclusion and implications.

II. Literature Review

A. *Maintaining the Integrity of the Specifications*

According to GEM, [2,3] find that South Africa has the second lowest rate of established businesses in the world and propose that professional courses in Entrepreneurship are needed for young people. The authors [4] conduct a study of students who participated in an extracurricular start-up program involving three universities and find that immersion, understanding and co-learning can be useful tools in business management. In turn, [5] conduct a survey of 556 graduates of entrepreneurship-related programs and find that Entrepreneurship Education is associated with self-employment, hybrid entrepreneurship and intrapreneurship in terms of perceived

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entrepreneurial knowledge, skills and abilities. The big question that the authors have not answered so far is how does entrepreneurship education affect entrepreneurial activities?

According to [6]there is a strong link between entrepreneurship education and starting a new business. In the same vein [7], they gathered data from 75 countries and concluded that entrepreneurship education can enhance the total number of early-stage entrepreneurial activities. Others [8] empirically tested that entrepreneurship education has a positive effect on the creation of new businesses. [9] use the same set of data to test the effect of Entrepreneurship Education on student entrepreneurs from 26 countries, and the results indicate that entrepreneurial curricula have a positive effect on causality and effectuation approaches in nascent entrepreneurial activities. Eesley and Lee used a database of alumni from Stanford University (2021). The results of this research [10] suggest that entrepreneurship education programs may not have a positive impact on the creation of new businesses. Researchers [11] investigate how entrepreneurship education can affect business activity and conclude that the effect occurs through the intrapreneurial spirit and consequently individuals are more able to persist in the professional environment. The theory of human capital teaches that knowledge and other skills can make all the difference in the organization's performance [12].

Professional Entrepreneurship courses, when well conducted, can accumulate capital related to the entire creation process. According to [13], [14] Undertaking is overcoming challenges in different spheres, and overcoming the challenges of different stages.

Empirical studies in Africa have also revealed that entrepreneurship is an effective employment opportunity and a source of growth for the continent. For example, the study [15] found that SMEs contribute more than 50% of employment and GDP in Africa. A recent study conducted in Ghana and South Africa also showed a similar result [16]. SMEs contributed 52% to 57% of GDP and about 61% of employment in South Africa, 85% of manufacturing employment and 70% in Ghana [16].

Reference [17], entrepreneurship internationalization appears to be at the very core of online developments, especially for the smaller firms that are not richly for the smaller firms that are not richly endowed with the received principles, on which the traditional international business theory is based. In general, smaller firms are resource-constrained, lack broadly based experiential knowledge, are relatively risk averse, and are incapable of making long-term commitments. In spite of the traditional theory´s principal requirements they internationalize and reach the far corners of the world located at long psychic distances from their respective home bases, while lacking much direct experience with the corresponding environments and seemingly high-risk operations in foreign markets. However, they mostly benefit from the Internet and their internationalization process are assisted by the Internet-based technologies, agents, features, and facilities.

The results of these studies all suggest that entrepreneurship can be a viable and uncontested solution for Africa's growing and largely young population.

III. Case Study

This study resulted from the application of a questionnaire to a sample composed of former CLESE-Lubango students, during the month of March 2024, resulting in 196 responses. The questionnaire was delivered in person and had the full support and dissemination of the CLESE-Lubango professional center.

This method was chosen to avoid errors in filling out the questionnaires, and at the same time care was taken to leave the respondents free to ensure anonymity. The data obtained from the questionnaire were processed using the *IBM SPSS (Statistical Package for the Social Sciences)* software, version 20. Tables and graphs that cannot be included in this chapter can be found in Appendix.

A. *Sample Characterization*

In the total sample of 49 respondents, as can be seen in Tables I, II and III, 28 are male (57.1%) and 21 are female (42.9%). Overall, 23 respondents, corresponding to 46.9%, were aged between 35 and 44 years.

Regarding academic qualifications, 27 respondents attended university, which corresponds to 55.1%. The following information can be seen in the tables below:

TABLE I. SEX

	Frequency	Valid Percentage	Cumulative Percentage
Masculine	28	57.1	57.1
Femenine	21	42.9	100
Total	49	100	

TABLE II. AGE

	Frequency	Valid Percentage	Cumulative Percentage
16-24	5	10.2	10.2
25-34	16	32.7	47.9
35-44	23	46.9	89.8
45-54	5	10.2	100
Total	49	100	

TABLE III. ACADEMIC QUALIFICATION

	Frequency	Valid Percentage	Cumulative Percentage
Primary level	2	4.1	4.1
Secondary level	20	40.8	44.9
University Attendance	27	55.1	100
Total	49	100	

B. Results: Analysis of Scale Reliability

According to [18] cited by [19], the reliability of a measure is related to its ability to be consistent. In this dissertation, reliability was assessed by Cronbach's Alpha, and at the same time as a measure of internal consistency. For statistical purposes, an instrument is said to have acceptable reliability when its Alpha is at least 0.70, and an Alpha of 0.6 can also be considered admissible.

In the present study, a Cronbach's Alpha of 0.71 was calculated, which attests to the reliability of the instrument.

C. Instrument

The initial instrument with 12 items had a Cronbach's Alpha of 0.61. However, 8 questions presented a correlation with the scale of less than 0.1 and were therefore eliminated. After the exclusion of these items, the scale consisting of the remaining 4 items presented an Alpha of 0.71 and all items have a correlation with the total scale greater than 0.10, as can be seen in Table V.

D. Main Component Analysis and Internal Consistency Analysis

The analysis of the principal components was performed and presented previously with the aim of testing their dimensionality as well as their suitability to the sample. All dimensions presented good KMO indices (>0.60) and significant Bartlett's sphericity test ($p<0.05$), indicating that the data do not represent an identity matrix (they present correlations between themselves that are suitable for analysis).

According to [20], the Kaiser-Meyer-Olkim (KMO) test is performed to verify the adequacy of the sample. This measure varies between 0 and 1, and represents the proportion of the variance of the variables that can be explained by the latent factors or traits. The closer this value is to 1, the more suitable the data are for adjusting a factor analysis.

On the other hand, the Bartlett test (sphericity test) was also performed. If it is significant, it rejects the null hypothesis that the variables do not group together to form any construct [20]. Thus, as can be seen in Table IV, the test is significant at the 1%, 5% and 10% levels, which means that the null hypothesis is rejected, as there is indeed some association between the variables and that they may, in fact, jointly represent one or more latent traits.

The table below also shows a KMO = 0.68, which, although not excellent, is considered a good indicator.

TABLE IV. THE KMO TEST AND BARTLETT'S SPHERICITY

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.675
Bartlett's Test of Sphericity	Approx. Chi-Square	38.447
	Df	6
	Sig.	.000

E. Correlation Analysis between Variables

Taking into account the correlation analysis in the following table, we can see that there is a strong positive correlation between question 2 and question 1. There is also a weak positive correlation between question 4 and question 3. In general, it was found that among all questions the correlation is positive, that is, there is some degree of association between the variables in the sense of forming a construct such as the conclusion of the Sphericity test above in Table IV.

The correlation matrix analysed four questions, which are narrated below, and the respective summary in Table V.

I-To what extent did the training you attended meet your initial expectations?

II-To what extent did the training improve your performance as an entrepreneur?

III-If there were improvements, how were the improvements introduced?

IV-What are the effects of training that influence behaviors and attitudes in the performance of professional functions?

TABLE V. CORRELATION MATRIX

	I	II	III	IV
I	1			
II	0.55**	1		
III	0.23	0.45**	1	
IV	0.41**	0.41**	0.19	1

** The correlation is significant at the 0.01 level

IV. MAIN FINDINGS

With the help of SPSS/20 it was possible to obtain the following results, relative to each of the questions that were presented:

TABLE VI. TO WHAT EXTENT DID THE TRAINING YOU ATTENDED MEET YOUR INITIAL EXPECTATIONS?

	Frequency	Valid Percentage	Cumulative Percentage
Very little	31	63.3	63.3
Little	2	4.1	67.3
Reasonably	12	24.5	91.8
Fully	4	8.2	100
Total	49	100	

In Table VI, it can be understood that 31 respondents, corresponding to 63.3%, understand that the entrepreneurship training provided by CLESE-Lubango was very far from what the trainees expected before starting the course.

TABLE VII. TO WHAT EXTENT DID THE TRAINING IMPROVE YOUR PERFORMANCE AS AN ENTREPRENEUR?

	Frequency	Valid Percentage	Cumulative Percentage
Very little	22	44.9	44.9
Little	5	10.2	55.1
Reasonably	18	36.7	91.8
Fully	4	8.2	100
Total	49	100	

Table VII shows the responses obtained to the second question, that is, to what extent did the training improve the performance of your duties as an entrepreneur? As can be seen, around 22 respondents, that is 44.9%, understand that the training had very little impact in terms of performance in the duties of an entrepreneur.

TABLE VIII. IF THERE WERE IMPROVEMENTS, HOW WERE THE IMPROVEMENTS INTRODUCED?

	Frequency	Valid Percentage	Cumulative Percentage
Improved responsiveness to the Company´s internal customers	16	32.7	32.7
Quality improvement	27	55.1	87.8
Meeting deadlines	3	6.1	93.9
Improvement in internal and external articulation/communication	3	6.1	100
Total	49	100	

Regarding the way in which improvements in training were introduced, 27 respondents, that is, approximately 55.1%, responded that there was an improvement in quality, and 16 respondents (32.7%) responded that there was an improvement in the ability to respond to customers.

TABLE IX. WHAT ARE THE EFFECTS OF TRAINING THAT INFLUENCE BEHAVIORS AND ATTITUDES IN THE PERFORMANCE OF PROFESSIONAL FUNCTIONS?

	Frequency	Valid Percentage	Cumulative Percentage
Ability to make suggestions	13	26.5	26.5
Greater openness to change	21	42.9	69.4
Ability to work in a group	6	12.2	81.6
Sense of responsibility	9	18.4	100
Total	49	100	

Table IX asks what are the effects of training that influence behaviors and attitudes in the performance of professional functions? As can be seen, 21 of the respondents (approximately 42.9%) responded that training prepared them to be more open to change.

A. *Discussion of Findings*

This study allowed us to analyze the impact of professional training in Entrepreneurship provided by CLESE-Lubango. Regarding the questionnaire, three dimensions of the training were essentially analyzed: 1-Characterization of the training action attended; 2-Results of the Training and 3-Impacts of the Training.

In general, it is understood that for the first dimension, the results are not very satisfactory, due to the fact that there is a misalignment between the expectations of the trainees, that is, the initial motivations of each of the trainees at the time of enrolling or looking for a center to attend the course, and on the other hand, because there is no alignment between the reality of the trainee as an entrepreneur and the content and practices in the classroom.

Different authors such as [21] and [22] have addressed the subject. For [21], in the characterization of a professional training action, it is important that the centers are able to integrate in the offer some specific training or content that allows those interested to learn more deeply about entrepreneurship. The same author continues saying that these trainings must be dynamic, based on the sharing of ideas, joint work in a multidisciplinary environment, with entrepreneurial experiences such as the approach of real *case studies* , that is, bringing into the classroom managers with successful experiences, whether family businesses or not.

Reference [22] considers that for education to be this important tool for the development of critical, innovative and proactive citizens, it must be based, in particular, on: the transmission of content (knowing how to know), development (knowing how to be/behave) and the correct performance of activities in the training of professionals (knowing how to do).

For the second dimension, the main result of training is the improvement in quality as well as the ability to respond quickly to customers. In fact, these two results are interconnected, as the fact of providing a better service due to better training of the manager or better information, or even a better finished product, allows for increasingly better feedback between the entrepreneur and the company.

These results are in agreement with [23] since for this author, professional training in a context of economic globalization, new forms of organization of production and work and the growing processes of democratization of society, requires an extensive study of professional training that brings significant changes to the world of work, since the concept of employment is gradually giving way to the concept of work, with the watchwords being quality in processes in order to reduce distances with customers.

For the third dimension, the main impact of training was the fact that it allowed trainees to be more prepared and open to change. The market is increasingly demanding and competitive, and the ability to adapt, open to change and the ability to survive are what is expected of today's entrepreneurs.

According to [24] the need for new parameters of professional training and qualification was, and still is, widely publicized and education continues to be strongly encouraged, however, in the search for survival, professionals are filled with expectations regarding training in proportion to the challenges that the market itself faces.

Thus, according to [24] productive activity becomes dependent on knowledge, so that the entrepreneur must be a creative, critical, thinking subject, prepared to act and adapt quickly to the changes in this new society. Therefore, from this point of view, the result of the research was as expected.

V. CONCLUSION

This study proved to be of utmost importance for Angolan society, as it allowed us to assess the contribution of professional training centers to entrepreneurship CLESE in the economy, especially for the training of small entrepreneurs and the improvement of business activity.

The research revealed that in an increasingly competitive and globalized world, experts are looking for new ways to train people for a job market that is suffering the effects of the globalized economy and demands professionals who are not only well trained, but also creative and capable of seeing new opportunities, which leads us to the figure of the entrepreneur as the driving force of the economy.

In this scenario, professional training has a very important role to play, which is to prepare young people for a radically new job market, providing information and knowledge, skills and qualifications aimed at developing young people's entrepreneurial capacity and personality.

As main results, the research concluded that in the characterization of a training action in order to guarantee the three main objectives of Know-How, Know-How to Be and Know-How to do. CLESE-Lubango should seek to include in its training program the expectations of trainees regarding the course through a valid instrument for collecting opinions, as well as including in its content grid such as *case studies* , bringing to the classroom managers with a history of success in the local market;

In terms of results obtained by trainees, the improvement in quality was highlighted, as well as the speed in responding to customer needs, results these met expectations; For the last dimension, the main impact of the entrepreneurship training provided by CLESE-Lubango was the fact that the training helped trainees respond more positively to changes. Given that markets are dynamic and competitive with the entry of new companies every day, as well as the challenges of globalization, it is concluded that professional training in Entrepreneurship is fundamental, and has positively impacted the professional lives of most of the trainees who attended CLESE-Lubango .

A. Implication of the Study

Among the many implications that our study presents, we highlight at least two: sustainable entrepreneurship and how CLESE-Lubango (Angola) programs can focus on education for sustainability, and on the other hand the challenges of globalization associated with a larger market and more demanding given the frequent changes in different markets. Regarding entrepreneurship and sustainability, the analysed program proved to be quite limited in terms of environmental issues, that is, there is not yet an Eco-entrepreneurship program; However, as [25]. only through this will it be possible to transmit Knowledge that becomes necessary skills to change the currently existing global model that leads us to the rapid depletion of resources and food shortages.

The study quickly leads us to reflect on the need for transition in terms of the curriculum matrix. The study leads us to agree with academic Edward Freeman on the on the need to rethink economic and management theory, as the models presented are mostly of western origin in many not far from the context of underdeveloped countries such as Angola. Essentially, education is the channel that unites enterprise and sustainability, making it possible to train citizens aware of their more innovative potential and with greater skills to develop a business that can have a positive impact on society and the environment.

Another implication that we need to highlight from this study has to do with the challenges faced by entrepreneurs in the globalized world. According to [26]. a globalized entrepreneur has the following strengths: obstinacy, taste for control, ability to perceive the whole. And its weak point is that it has difficulty admitting that there are people who think differently. The result of question number four of our questionnaire, table nine, shows that entrepreneurs trained by CLESE-Lubango-Angola are not very open to teamwork, that is, respondents believe that the training obtained qualifies them only 12%, the same training contributes only 13% in terms of the ability to make suggestions. These two indicators clearly show that the Program of entrepreneurship must include more components in its curriculum that will add those values to capture short-term effects, that is, CLESE-Lubango-Angola, through his entrepreneurship training, manages to awaken the business idea in trainees (short-term effect);

However, these are unsustainable businesses, hence the for entrepreneurship programs to include eco-entrepreneurship in their framework as well as the globalization component in order to maintain the business vision in the long-term.

As said by [27], entrepreneurship education programs are increasingly being established and expanded in an effort to equip students with the knowledge and competency necessary to create economic value and jobs. An underlying assumption of these programs is that they create positive outcomes for students; however, the extent and nature of these outcomes have not been well explored in the literature.

In other words, we the program need to form international entrepreneurship. It can be define as a combination of innovative, proactive, and risk seeking behavior that crosses national borders and is intended to create value in organizations. It comprises two related but distinct, streams of research: an international stream which focuses on how, why, when and where firms internationalize their operations and a comparative stream that examines how and why business processes differ across national context, as well as the implications of these differences.

For example, we can see in ours programs what countries as China, India and others did in this topic of entrepreneurship.

Reference [28] during the last 20 years, the Chinese economy has exploded. Evidence of this can be seen by the investment of one of the leading U.S. venture capital firms, Sequoia

Capital. In the past Sequoia has backed Google, Cisco, and Apple. More recently the firm has been investing directly in China. The craze is driven by China´s rapidly expanding economy and helped by the tepid growth of the technology sector in the United States.

According to [28], on the other hand, India has managed to spawn a number of companies that now compete internationally with the best companies in Europe and the United States. Moreover, many of these firms are in the most cutting-edge, knowledge-based industries-software giant´s Infosys and Wipro to name just a few.

This approach to emerging economies such as India and China included in the program of entrepreneurship taught in countries with the same characteristics as Angola can provide students with the globalization component and thus better prepare them to take advantage of the opportunities that international markets present in terms of financing and partnerships.

With the creation of the free trade zone in continental Africa, with 55 countries expected to ratify the agreement and subsequent customs union, it becomes necessary for entrepreneurship programs in local centers in African countries to become increasingly regional, laying the foundations for intra-african trade even from the education system of each country.

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Original Scientific Article

Impact of Dark Patterns in Augmented Reality on Consumer Behaviour

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Abstract—**The increasing popularity of immersive technologies such as Augmented Reality (AR) have started to affect and shape the daily life of individuals across all age categories. The investment of time, resources and money from leading technology companies, suggest that immersive technologies would become one of the leading technology trends in the world. Due to its prognosticated capabilities and potential, the business world also has taken a keen interest on using technologies such as AR when forming marketing strategies. The inherent nature of marketing and advertising to persuade customers to make buying decisions could be complemented via immersive technologies. However, the dark patterns incorporated to immersive technology application design, could lead marketing and advertising strategies to adopt a more manipulative approach than a persuasive approach. In this research paper, we first identified the dark design patterns that could be used in an AR based application to influence consumer behaviour. Then the impact of the identified dark patterns, is evaluated via a controlled experiment. The analysis of the data collected from the experiment, confirmed that the dark patterns in AR design could manipulate consumers.**

Keywords – augmented reality, dark patterns, human food interaction, consumer behaviour, cross-model correspondence

I. INTRODUCTION

The technology advancements in the fields of computer science, electronics, and communication in the past few decades have now created a world where the digital presence of human beings is the norm. The accessibility, availability, and affordability of advanced diversified digital devices such as smartphones, high-tech lenses have widened the audience for technologies like AR. The emerging popularity of AR applications captured the attention of sales and marketing circles, since it has paved way for a new marketing and advertising channel which is more interactive and arguably more powerful than traditional channels. The enthusiasm for AR technologies and applications in the sales, marketing and advertising domains further intensified with the launch of platforms like Metaverse by Meta, which promotes themselves as the successor to mobile internet. The anticipated increase in the number of people using or rather living in a virtual world like Metaverse, has encouraged research to be carried out with different scientific perspectives, where one such is dark patterns in AR.

A dark pattern in the context of user experience is one that system designers use to exploit the users to behave in ways that may not be in the best interest of themselves but the system [1]. In traditional systems like mobile apps, the dark design patterns were limited to user interface (UI) related manipulations such as misleading information etc., where as in the AR landscape, applying dark design patterns is not limited only to the UI. The exposure of Manipulative Designs in AR in [2] raises some important research questions, of which one is,

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whether manipulative designs in AR can be used to influence consumer behaviours and their purchasing decisions.

In this research we first focused on identifying, and understanding the manipulative or dark patterns in AR, through a thorough analysis of existing literature on User Interface/User Experience (UI/UX) design. The effectiveness of the identified dark patterns on consumer behaviour is then established through a prototype AR mobile application developed to interact with a menu of a restaurant.

II. Literature Review

A. *Dark Patterns in UI/UX*

By analysing the existing key definitions and concepts of dark patterns literature, the research [3] has classified dark patterns under four facets; (1) Characteristics of the user interface – Coercive, Obnoxious, Malicious, Trickery (2) Mechanisms of effects on user – Manipulate user, Exploit user, Confuse user, Attack user (3) Role of user interface designer – Abuser of designer knowledge, Designer intent (4) Benefits and harms – Benefit to service, Harm to user. With the introduction of immersive technologies and those becoming popular among the general public, the dark patterns research avenue has further expanded. The research [2] has identified dark patterns in AR that can be used to manipulated the users in future when AR applications become mainstream: (1) Obstruction-forced actions - where the user is forced to execute a particular action (2) Interface interference - where the interface is designed in a way to trick the user to agree for something without much attention to it (3) Safety - by the nature of AR applications, they are pervasive, mobile and realistic which results in introducing safety risks for the user (4) Associative dark patterns - where emotions are exploited to influence a user's purchase decisions.

B. *VR/AR/Extended Reality (XR) in Marketing and advertising*

In the conventional sales and marketing platforms, there are primarily two broad approaches to influence consumer buying behaviours which are persuasion and manipulation [4]. From the user's perspective, AR is entertaining while from the marketer's perspective, the novelty of AR alone has the potential to increase brand awareness as AR delivers an engaged audience to marketers. Thereby, when compared to traditional means of marketing and advertising, consumers' find AR campaigns playful, convenient, time saving [5].

Additionally, the human senses play an important role in how a person experiences a product be it physically or virtually. The multisensory technologies that are already provided through AR such as visual and audio, and anticipated features such as haptic interfaces will aid businesses in their marketing and advertising [6]. Additionally, the research [7] has proposed that multisensory technology would be beneficial to consumers' as it provides means to evaluate products and services. However, the prodigious potential in platforms based on technologies such as AR with regards to greater immersivity, extreme realism and hyper-personalization, could pave the way for new types of manipulative advertising, tricking consumers into buying products they do not want or need [8].

C. *Psychology, Cognitive Biases and Consumer Behaviour*

With the availability of sophisticated technologies, the vulnerabilities of a target individual or group could be amplified in order to steer them to make decisions that do not result in their best interest. The cognitive load (amount of information or tasks an individual is handling at a given time) aspect of interactive environment, where they claim that increased cognitive load of being in an immersive and interactive environment leads to fewer cognitive resources being spent to critically evaluating the advertisement's message [9]. Thereby, the exposure to dark patterns lead consumers to make inconsistent decisions, corroborating to the fact that consumers could be manipulated through UX design [10].

D. *Human-Food Interaction*

Since we have decided to use the retail food and beverage industry-based prototype AR mobile application to evaluate the impact of dark patterns in AR on consumer behaviour, it is important to have insights on how the human mind works with regards to consuming food. The reference [11], elaborates on the idea that flavour is a multisensory construct that involves taste, or gustation, olfaction etc., and thereby, all the sense can influence a person's food experience. Flavour augmentation can be impacted through core intrinsic elements such as taste, smell, touch etc., or extrinsic elements such as colour, shape, atmospheric sound etc., all of which influence the overall experience with flavour [12]. The researchers of [11] have put forward the argument that meaningful collaboration of multisensory science and digital technology would be capable of augmenting flavour perceptions, hence impacting food consumption. They have suggested four methods to impact flavour perception and augmentation which are; (1) Visual augmentation (2) Auditory augmentation (3) Tactile/Haptic augmentation (4) Multiple extrinsic elements for flavour augmentation.

Additionally, reference [13] states that visualizing attractive food tends to trigger previous positive encounters with such food items and this may simulate scenarios of eating the particular food, which could result in the purchase of this food item. It has been established decades back that pervasive visual exposure to food increase consumers' desire to eat both among children and adults [14]. Thereby, out of all the sensory channels, the vision is the sense that provides the most effective means of foraging and predicting which foods are safe and nutritious to consume [15].

III. USING AR DARK PATTERNS TO MANIPULATE CONSUMERS

Following the thorough analysis and careful consideration of the dark design patterns and themes in existing literature, we have identified three broad dark patterns that can be used in the experimental phase of this research to evaluate their impact on consumer behaviour.

A. Sneaking or Information hiding

In the research "The Dark (Patterns) Side of UX Design" [16], "sneaking" is defined as an attempt to hide or disguise information that is relevant to the users, while reference [17], identifies obscure or delay the presentation of necessary information to users as "Information hiding". Both these terms loosely describe the same dark pattern which is found in traditional digital systems that could also be used as a manipulative design in AR based mobile application. In the context of a menu, ingredients of a particular food item are a useful information to the consumer when making the purchase decision. With the current trends that promotes healthy life style, consumers may be prefer to buy food that are healthy and nutritious. A dark pattern could exploit this preference of a consumer, by hiding or minimizing the attention to the ingredients that are unhealthy and highlighting the ingredients that are healthy.

B. Interface Interference

This is another dark pattern in [16], which was expanded to sub categories, aesthetic manipulation and toying with emotions. According to the definition in "The Dark (Patterns) Side of UX Design", interface interference is manipulation of the user interface that privileges certain actions over others. In order to privilege or promote a certain action, the interface could use its aesthetic appeal through colour, style etc. or influence the user's emotions. As stated in reference [14], visual representation of food has the biggest impact on a person's desire to consume food. When applying this dark pattern to an AR based mobile application menu, the manipulation would happen through the use of colours, styles etc. For example, the AR version of the food could be different to the actual food and may be more appealing to the consumer.

C. Associative Dark Patterns

The research [2] described this dark pattern not as directly manipulating the user interface but rather exploiting emotions of a user to influence his/her purchase decisions. Since flavour was established as a multi-sensory construct [11] and it has been stated that flavour could be enhanced through auditory augmentation [12], through the incorporation of auditory input, an associative dark pattern could be designed for the AR based mobile menu application. For example, a background music/sound could be played when a menu item is viewed with the intension of emotionally manipulating the consumer to make a purchase.

IV. AR MOBILE APPLICAION PROTOTYPE

The evaluation of the identified AR dark patterns on consumer behaviour would be examined via a prototype AR mobile application (AR prototype) that displays a menu, which has minimum required functionalities to perform the experiment. The main menu interface Fig. 1 would be a simple mobile interface that displays the available items, on which the tester could click and load the individual food item interface (experimental interface). Since we are evaluating

Figure 1. Main menu interface

the impact of above identified three dark patterns, one food item per dark pattern would be sufficient. Hence the menu interface would have only three items.

The experimental interface would be the one that incorporates one of the identified dark patterns. Thereby, in the AR prototype we developed, menu Item Burger would embed Sneaking or Information hiding, menu Item Cake would embed Interface interference while menu item coffee would embed an associative dark pattern.

V. Experimental Design

To initiate the experimental stage of the research, we selected 25 participants from the age category 20-50 years (Mean=33.24 and SD=4.2, females-13) with a higher education background, who are familiar with immersive technologies and can understand the concept of a prototype. The experiment applied within subject design where each participant is exposed to all the test scenarios, thus, would evaluate all the implemented dark patterns. Although this research explores dark patterns in AR, in order to critically evaluate its impact on consumer behaviours, a point of reference to compare the AR prototype would be beneficial. Therefore, we have used a second prototype (traditional prototype) that has the same menu interface as AR prototype while the menu item interfaces display a 2D image of the food item with a small

Figure 2. Control interface

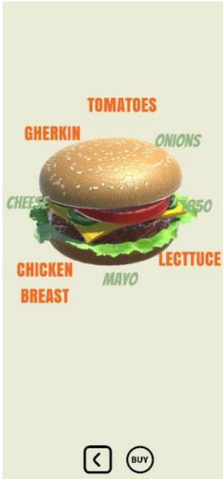

Figure 3. Experimental interface

description (control interface). Participants were requested to fill out a post-experiment questionnaire that captures insights on themes such as engagement, visualisation and encouragement of prototypes and effectiveness of the dark patterns used.

VI. Results and Evaluation

According to results of the survey, 96% of the total participants stated that they are familiar with the concept of a prototype in the context of software development and have used a mobile application to purchase food before, although, only a 60% of the sample have had some experience with AR prior to participating in this research. Thereby, the above data, indicate that the selected participants have necessary experiences and exposure to explore and evaluate the prototypes designed for this research. Since the selected participants are all professionals with a higher education background, it should be noted that a larger sample stretched across different social and educational backgrounds, could have provided more generalized results.

A. *Descriptive Statistics*

Table I outlines the frequency distribution for the variables, Engagement (Which prototype did you find more engaging?), visualisation (Which prototype help you to visualise the food item better?) encouragement (Which Prototype encourage you to make a purchase decision quickly?) and effectiveness (was AR prototype

TABLE I. QUANTITATIVE ANALYSIS

Dark Pattern	Engagement	Visualisation	Encouragement	Effectiveness
Sneaking/Information Hiding	68%	88%	64%	76%
Interface Interference	92%	96%	84%	92%
Associative Dark Patterns	76%	72%	68%	68%

more effective in persuading you to make a purchase decision compared to traditional prototype?) of the AR prototype for each of the dark pattern. As per the above descriptive statistics, it is evident that compared to the traditional prototype, dark pattern embedded AR prototype is superior in terms of engagement, visualisation, encouragement and effectiveness.

B. *Inferential Statistics*

The Chi-square (X2) test of independence was performed on selected variables of the data set using a significance level of 0.05 in order to determine the association between two variables. For each dark pattern tested in the research, Chi-square value for effectiveness of the AR prototype was calculated against its engagement, visualisation and encouragement, considering null hypothesis as H_0 and alternative hypothesis as H_1 for associations analysed below.

- Chi-square test for engagement vs effectiveness

  H_0 – There is no association between engagement and effectiveness

  H_1 – There is an association between engagement and effectiveness

  As per the results on Table II, p is less than the significance level of 0.05 for all 3 dark patterns, which indicates a significant association between engagement and effectiveness of the AR prototype tested.

- Chi-square test for visualisation vs effectiveness

  H_0 – There is no association between visualisation and effectiveness

  H_1 – There is an association between visualisation and effectiveness

TABLE II. ENGAGEMENT VS EFFECTIVENESS

Dark Pattern	*P* value
Sneaking/Information Hiding	0.01
Interface Interference	0.02
Associative Dark Patterns	0.02

As displayed on Table III, there is no association between visualisation and effectiveness for the dark patterns sneaking/information hiding and associative dark patterns since the p value is greater than 0.05. However, interface interference indicates a significant association between visualisation and effectiveness for the AR prototype tested.

- Chi-square test for encouragement vs effectiveness

  H_0 – There is no association between encouragement and effectiveness

  H_1 – There is an association between encouragement and effectiveness

As per the results on Table IV, the p is less than 0.05 for all 3 dark patterns, which indicates a significant association between engagement and effectiveness of the AR prototype tested.

C. *Qualitative Analysis*

The qualitative data gathered through the questionnaire was carefully examined for the purpose of assigning codes for phrases with similar meanings. Following are the codes we extracted from the participants' input regarding the experimental interfaces; (1) 3D model, (2) 360 view, (3) Attractive colours (4) Realistic feeling.

TABLE III. VISUALISATION VS EFFECTIVENESS

Dark Pattern	*P* value
Sneaking/Information Hiding	0.65
Interface Interference	0.01
Associative Dark Patterns	0.93

TABLE IV. ENCOURAGEMENT VS EFFECTIVENESS

Dark Pattern	*P* value
Sneaking/Information Hiding	0.01
Interface Interference	0.02
Associative Dark Patterns	0.02

VII. CONCLUSION

In this paper, we explored the plausible impacts of dark patterns in AR on consumer behaviours through its ability to manipulate the consumers. The research identified three possible dark patterns that could be applied to an augmented reality embedded mobile application which are namely, Sneaking or Information hiding, Interface interference and Associative dark patterns. The impact of these identified dark patterns were evaluated by 25 research participants. Through the analysis of the feedback and insights gathered from the research participants, it was established that the AR prototype is favoured in terms of engagement, visualisation, encouragement and is more effective in persuading consumers to make purchase decisions. Additionally, all 3 identified dark patterns indicated significant level of association between engagement and effectiveness and encouragement and effectiveness. Furthermore, through the qualitative analysis "attractive colours", "360 view", "realistic feeling" and "3D model" were identified as the main themes of the AR prototype.

As per the positive comments obtained from the qualitative analysis, it is evident that the AR technology-based prototype has delivered a more sophisticated user experience than the traditional digital technologies, which could encourage AR developers to incorporate dark patterns in UX design. Although such designs may be promising in the short run, it would be harmful to the businesses in the long run as consumers would lose trust in AR based markets, which would negatively affect the businesses that do not implement manipulative designs as well. Therefore, AR developers should be encouraged to follow transparency and fairness in UX design without simply adhering to minimum legal requirements, in order to ensure consumer trust and protect consumers from vulnerable situations. An ethical code of conduct for HCI practitioners and UX designers is one suggestion to mitigate the consequences of dark patterns while the use of self-regulatory measures is suggested as a starting point to force very large platforms to help develop such codes and self-regulatory initiatives [10]. Future research could be carried out on ethical UX design to derive a framework that could balance both user value and business value [16].

In conclusion, it can be stated that dark patterns in AR could impact consumer behaviour through its increased engagement, enhanced visualisation capabilities and encouragement to purchase.

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Original Scientific Article

Green Innovation

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Abstract—**In order to contribute to sustainable development, companies must opt for sustainable business. Green innovations make a significant contribution to sustainable business which includes all forms of innovation that minimize damage to the environment and ensure that natural resources used in the most efficient way possible. This paper shows definition and different types of green innovation and its importance. Crucial factors for green innovation implementation are also included. In the end, this paper shows example of companies in automotive industry that implement green innovation.**

Keywords - innovation, green innovation, automotive industry innovation

I. Concept of Innovation

Innovation is a term often used in both everyday communication and scientific literature. It can be described as “entrepreneur’s instrument to utilize changes in the environment” [1], “the process of creating something new” [2], or as “idea transformed into practical reality” [3] Innovation are the best instrument for solving contemporary social challenges, such as climate changes, lack of resources and energy, health protection and aging society [4]. Although the concept of innovation is present in scientific literature since XX century, approach to innovation is radically changed in knowledge-based economy. This resulted in new paradigms such as open innovation and social innovation.

Open innovation has been defined in 2014 by Chesbrough and Bogers as “a distributed innovation process based on purposively managed knowledge flows across organizational boundaries” [5]. Open innovation posits that companies should leverage both external and internal ideas, as well as utilize diverse pathways to market, to drive their innovation efforts forward. Open innovation drastically changed innovation process [6]. It has great impact on performances of business entities, because they significantly increase competitive advantage of enterprises; output of open innovation process is more adjusted to the customers and has better quality [7].

On the other hand, social innovations are described as innovative activities and services motivated with satisfaction of social needs [8]. It can also be defined as development and implementation of new ideas for satisfaction of social needs and creation of new social relations [9]. Some authors highlight how green innovation fits into the broader framework of social innovation - green social innovation tends to combine sustainability issues with social issues, and more often than other fields find an economically viable solution [10]. Other supports the view that green innovation is a key component of social innovation by addressing environmental and social issues simultaneously [11].

II. Green Innovation

Green innovation can be defined as “innovation that consists of new or modified processes, practices, systems and products which benefit the environment and so contribute to environmental sustainability” [12]. They are significant considering nowadays companies’ aims to reduce environmental impacts. Some authors see green innovation as a crucial component of sustaining the protection of the environment [12]. It is defined as an innovation activity in which a business gathers and applies outside knowledge to facilitate innovation activities or takes knowledge to external markets to earn money, has been suggested to get through these challenges and successfully implement green innovation [13]. Other authors see green innovation as the development and implementation of new processes, systems, or technologies that are designed to promote environmental sustainability and reduce the environmental impact of industrial processes [14]. Authors Frare and Beuven emphasize importance of green innovation, as a critical aspect of sustainable development, which supports economic growth while minimizing environmental consequences [15]. Authors Chen, Lai et al. [16] define green innovation "as hardware or software innovation that is related to green products or processes, including the innovation in technologies that are involved in energy-saving, pollution-prevention, waste recycling, green product designs, or corporate environmental management". It can be concluded that green innovation has great potential to reduce the environmental harm and also optimizes the usage of available resources [17].

In nowadays literature, there are several concepts of innovation with subtle variations. Eco-innovation is any form of innovation aiming at significant and demonstrable progress towards the goal of sustainable development, through reducing impacts on the environment or achieving a more efficient and responsible use of natural resources, including energy [18]. On the other hand, environmental innovation a specific form of innovation aiming at reducing the impact of products and production processes on the natural environment [19]. Sustainable innovation means innovation that balances the long-term influences of the process and the output with the needs of people, societies, the economy and the environment [20]. However, many authors use these terms interchangeably with green innovation.

III. Types of Green Innovation

Green innovation can be classified into several typologies, each offering a unique perspective on its various forms and applications.

First taxonomy use differentiation to product and process. Green product innovation means implementing innovative ideas that enable the design, production, and marketing of new green products that perform significantly better than traditional or competing products [21]. Green process innovation refers to any change or regulation that contributes to reducing the environmental damage that may occur at any production stage, such as material purchase, manufacturing, or delivery in the production process [22]. Green process practices consist of lean manufacturing, agile manufacturing, and quality-control procedures that prevent or at least reduce faulty parts - these components reduce negative environmental impacts, resulting in more efficient raw materials and a lesser waste and byproduct generation [23].

Author Pisano [24] gave framework which provides understanding of how companies can strategically approach green innovation, balancing technological change with business model adaptation. Pisano identifies four categories of innovation, each corresponding to a different approach in integrating technology and business models:

- Routine Green Innovation. This type of innovation leverages a company's existing technical capabilities and aligns with its current business model. It is an incremental innovation that enhances existing products or processes, catering to the established market base without disrupting the status quo.
- Disruptive Green Innovation. Unlike routine innovation, disruptive green innovation necessitates a new business model but does not necessarily involve a technological breakthrough. It has the potential to challenge and disrupt the business models of competitors, posing significant challenges to companies within the same industry.
- Radical Innovation. The focus here is purely on technological advancement. Radical innovations introduce new technical competencies while maintaining the existing business model. These innovations often lead to significant performance improvements or entirely new product categories.
- Architectural Green Innovation. This type is the most transformative, combining both technological breakthroughs and business model disruptions. Architectural green innovations require companies to rethink

both their technical capabilities and market strategies, leading to a comprehensive overhaul of their existing practices.

The map is built on the assumption that companies must choose how much of effort to focus and invest in technological and business model innovation [24].

IV. Crucial Innovation Factors

Green innovations are vital for fostering a sustainable future, as they ensure a harmonious balance between environmental health, economic growth, and social well-being. Identifying the key factors for their successful implementation is crucial, as it not only aids current innovators in developing effective and impactful solutions but also guides future innovators in advancing sustainability efforts. By understanding these factors, we can accelerate the adoption of green innovations, driving systemic change and creating a resilient, eco-friendly economy for generations to come.

Authors Zhang et al. [25] conducted research, based on the technology- organization - environment framework. In their study, it is examined how prepared enterprises are for green innovation endeavors in terms of technology readiness, organization readiness, and environment readiness.

Technology readiness encompasses the attributes of the technology that an enterprise aims to adopt as a key asset for green innovation. The effectiveness of such a technological resource is primarily determined by its compatibility with existing technologies and its ability to enhance green innovation activities. As the factors that push and pull green innovation forward, technology compatibility and relative advantage form the technology readiness for green innovation [25].

Organizational readiness refers to the essential characteristics an enterprise needs for the successful implementation of green innovation. This readiness encompasses two key components: innovation capability and environmental concern. Innovation capability reflects the organization's ability to develop and adopt new technologies or processes, while environmental concern demonstrates the commitment to sustainability and eco-friendly practices. Empirical studies confirmed the effects of absorptive capacity and sustainable capabilities on green innovation adoption [26].

Environmental readiness refers to the external pressures that drive an enterprise to pursue green innovation. This readiness is shaped by both policy orientation and market orientation. Policy orientation involves regulatory frameworks and government incentives that encourage sustainable practices, while market orientation reflects the demand for eco-friendly products and services, influencing companies to adopt greener approaches.

Additionally, authors Medeiros et al. [27] selected several factors, based on previous research. Factors are classified into four groups:

- Market and legislation knowledge. Most important variables of this group are customer expectation fulfillment and compliance with laws and regulations.
- Cross-functional Collaboration. Integration inside the different departments in the company (R&D, marketing, and production) is essential. Also, integration with stakeholders (suppliers, universities, environment specialists, etc.) has great impact.
- Innovation-oriented learning. This includes elimination of cultural barriers, development of a set of green competences (leader proactivity, creativity, and experimentation) and development of critical reflective analysis capability.
- R&D Investments. Core variables for innovating are investment in methods for sustainable product and investment in qualified personnel.

Authors emphasize that companies may organize their green innovation practices based on investments related to people, labs, equipment, and technological research [26]. Additionally, the leaders' vision and dynamism are essential to trigger important interrelations between the market and legislation knowledge, cross-functional collaboration, and innovation-oriented learning factors.

V. Implemented Green Innovation

While many industries contribute significantly to pollution, this paper will focus on examples from the automotive sector due to space limitations. The transportation industry, encompassing road, air, and marine transport, is a significant contributor to air pollution and CO_2 emissions, playing a major role in driving climate change. According to EU Report, ground transportation produces 71 % of all greenhouse gas emissions from transport in the EU. [28] The greening of the automotive industry is part of an eco-mobility scenario, which requires a complex transition to sustainable transport solutions, habits and policies to become a reality [27]. All automobile manufacturers are exploring ways to reduce the CO_2 emissions of their vehicles and increase fuel efficiency, motivated by higher oil prices, increasing concerns of energy security and stringent government regulations [29]. Thus, green innovation has become a strategic tool for achieving the sustainable development of industry, resulting in the improvement of the environmental situation [30].

The forcing power of regulatory interventions has been highlighted by Berggren and Magnusson [31], revealing to be decisive in helping car manufactures meeting higher environmental standards, by encouraging the expansion of their technological repertoire with a "long-term oriented, technology-neutral, innovation and competition driving policy, built around stepwise tightening of emissions and incentive levels".

According to International Council on Clean Transportation Report for 2023, Tesla is the leader of global manufacturers in the Zero Emission Vehicle. [32] This company, originally Tesla Motors, was founded in 2003. Tesla's goal is to develop "zero-emission electric vehicles" which performs better than the fueled vehicles while pacing the adoption of sustainable transportation by creating attractive mass-market electric cars [33]. Tesla isn't only leader in automotive industry, but also in electric sector, with the introduction of solar roofs and power walls [34].

Tesla's purpose is to accelerate the world's transition to sustainable energy and to eliminate fossil fuels. In their 2021 report, Tesla estimates that its vehicles saved 6.8 million metric tons of CO_2 emissions compared to internal combustion engine (ICE) vehicles with an average fuel economy of around 24 mpg. Additionally, Tesla's solar and storage solutions contributed to a 1.6 million metric ton reduction in CO_2 emissions by generating zero-emission electricity. Besides CO_2 emission, this company advocates for responsible use of water and recycling; Tesla introduced this concept not only to the company, but to their suppliers also [35].

The Centre of Automotive Management (CAM) has presented its new ranking of global automakers, based on around 1,000 innovations of the annual analysis period 2023/2024. In their latest innovation study, the BMW Group achieved the highest level of innovation among 30 automotive groups on the basis of 70 series innovations [36]. Furthermore, BMW group is one of the biggest green innovators in automotive industry. In the words of their CEO, sustainability and economic success go hand in hand at the BMW Group. BMW group has the ambition to lead the way in the area of sustainability [37]. Their primary goal is CO_2 reduction. BMW Group has restructured supply chain – from the supply chain, through production, to the use phase. According to their plan, CO_2 emissions across the entire lifecycle of BMW Group products will fall 40% by 2030 compared with 2019. The BMW Group aims to ensure compliance with environmental and social standards in particular already at the extraction and processing stages of the raw materials.

Since 1994, the BMW Group has operated its own Recycling and Dismantling Centre (RDZ), where several thousand vehicles are processed annually. This initiative allows for the recovery and reintegration of materials into the production cycle as secondary raw materials. Additionally, components that continue to meet BMW's quality standards are reconditioned for reuse, supporting a more circular economy. One of the visions of BMW Group is completely recyclable vehicle, as a car of the future [38].

Green innovation has an effect on both environmental performance and competitive advantage of a company [39]. Companies that adopt green innovations stand to gain significant advantages, including the creation of new market opportunities and revenue streams. By tapping into the growing demand for sustainable products and services, these companies can expand their offerings and attract environmentally conscious consumers. Implementing eco-friendly practices enhances brand reputation and fosters customer loyalty, because it is positively related to consumers' green awareness and brand reputation of green products [40].

VI. Conclusion

Green innovation can be described as implementation of new processes, systems, or technologies designed to promote environmental sustainability and to reduce the environmental impact of industrial processes. It represents significant tool for adjusting to challenging environment conditions. Implementing green innovation benefit the environment and so contribute to environmental sustainability. Nowadays, green innovation has great importance - it will play an even greater role in the future, considering climate changes and overall state of environment. Every responsible company should decrease its environmental impact and optimizes the usage of available resources. Automotive industry, as one of the significant pollutants, has to implement green practices and green innovation resulting in the improvement of the environmental situation.

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Original Scientific Article

Task Strategy and Employee Performance: A Study of Small & Medium Enterprises in Delta State

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Abstract—**This study focused on task performance and employee performance of small and medium enterprises in Delta State, Nigeria. The study adopted a survey research design with a sample size of three hundred and fifty-four (354) drawn from registered small and medium enterprises. Inferential statistics (regression model) were used to test hypotheses at 0.05 level of significance. The result of the study revealed that prioritizing goals and objectives ($\beta = 0.233$; p-value < 0-01), contingency planning ($\beta = 0.360$; p-value < 0-01) and creative task performance ($\beta = 0.214$; p-value < 0-01), adaptive task performance significantly affect employee performance. Finding showed that adaptive task performance ($\beta = -0.237$; p-value < 0-01) has a significant negative effect on employee performance; while routine task performance strategy ($\beta = 0.001$; p-value > 0-01) has insignificant effect on employee performance. The study recommended that business enterprises should adopt task performance strategies to disclose the job description and responsibility and employers can also adopt task performance strategies to increase employee's productivity and make work environment more friendly and enjoyable.**

Keywords - Contingency planning, creative task, adaptive task, routine task strategy

I. Introduction

The quest for organizational success requires strict compliance with established policies and strategies that direct organizations toward their specified goals and objectives. The organization's leaders or conveners typically articulate these objectives, embodying its vision and aspirations. Diverse business scales, from small and medium enterprises (SMEs) to major multinational corporations, witness this phenomenon.

SMEs are considered crucial for economic growth and equitable development in developing economies like Nigeria. They significantly contribute to capital generation, resource use, and job creation [1]. Worldwide, SMEs constitute around 90% of economic development and stability, markedly improving living conditions via employment possibilities [2]. Nonetheless, maintaining long-term success poses a significant difficulty for SMEs, as research reveals that over 20% of these businesses terminate operations during their initial year. The survival rates are particularly concerning in emerging nations, as SMEs have increased challenges [3].

Despite the extensive research on SMEs, primarily from rich countries [4,5], there remains a significant gap in research regarding developing nations. This study intends to solve this gap by focusing on Delta State, Nigeria, and elucidating the elements contributing to the long-term survival of SMEs. This research emphasizes the significance of management practices that enhance goal attainment and employee concentration, namely through creative and adaptive task performance strategies, objective prioritization, contingency planning, and routine task performance.

Academics have understood the concept of strategy in multiple ways. [6] asserts that a strategy seeks to create a distinctive and valuable stance, grounded in a system of activities that are challenging to imitate. It entails the establishment of long-term organizational objectives, the formulation of action plans, and the distribution of resources necessary for achieving these goals [7]. The development of strategic management has highlighted its importance in the discipline, especially during the later half of the twentieth century.

In Nigeria's competitive environment, particularly for SMEs, there is an imperative to formulate strategic approaches that improve employee performance. This research seeks to investigate if the application of effective task performance strategies—specifically goal prioritizing, contingency planning, creative, routine, and adaptive task performance—can improve employee performance in SMEs in Delta State, Nigeria.

II. LITERATURE REVIEW

Following the aim of this research, the researchers arrived at a framework depicted below:

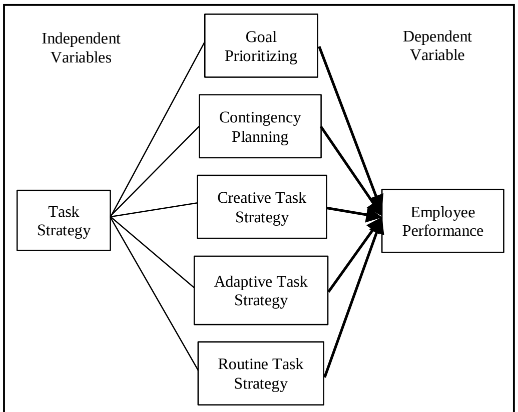

Figure 1. Concept Model

Figure 1 shows the conceptual or research model. It depicts hypothesised relationship that exist between task strategy (independent variable) and employee performance (dependent variable). Task strategy is proxied with prioritizing goals and objective, contingency planning, creative task strategy, adaptive task strategy and routine task strategy. This model is adopted from the Goal setting theory and task performance propounded by Edwin Locke in 1960. Edwin Locke's Goal Setting Theory asserts that specific and challenging goals, along with suitable feedback, improve employee performance by focusing attention, augmenting effort, and promoting persistence. This approach closely aligns with prioritizing goals, allowing employees to focus their attention on the most essential objectives, thereby enhancing task performance and overall productivity. Contingency planning, an essential element, equips personnel for possible obstacles or changes, thereby augmenting their confidence and efficacy in unforeseen circumstances, which leads to improved performance results. Creative task strategies promote innovative thinking and problem-solving, inspiring employees to discover novel methods for reaching objectives, perhaps resulting in enhanced job satisfaction and performance. Adaptive task strategies empower employees to modify their methods in response to evolving conditions, thereby maintaining their efficacy and resilience in their positions. Ultimately, routine task strategies optimize processes, enabling people to execute their primary responsibilities effectively. These strategies, which are based on Locke's theory, emphasize the significance of disciplined goal-setting and adaptability in improving employee performance, creating an atmosphere where people can excel and contribute effectively to organizational success.

III. METHODOLOGY

This study utilized a cross-sectional research design and employed the survey method. The study's population consisted of 3.044 registered small and medium enterprises, manufacturers of fast-moving consumer goods (FMCG), and registered Delta North Senatorial District of Delta State, as determined by the data from the baseline collaboration survey of Delta State micro, small, and medium enterprises (DEMSMEs). The sample consists of 354 small and medium enterprises (manufacturers of fast-moving consumer goods), selected by a simple random sampling technique. Taro Yamane's technique for sample selection determined the sample size. With a 95% confidence level and $p = 0.05$ are assumed:

$$h = \frac{N}{1 + N(e)^2}\,, \qquad (1)$$

where:

n = sample size required

1 = constant

N = 3.044

e = expected/allowable error (%)

We collected the primary data using a structured questionnaire. We established the reliability of the instrument using the Cronbach alpha coefficient, randomly selecting thirty (30) small and medium enterprises from Benin City, Edo State. The overall reliability score was 0.85. According to [8], an instrument with a score of around 0.70 is considered to have an average reliability standard, while a score of 0.70 and above indicates a high reliability standard. We used the percentages to provide a demographic perspective on the sample and a description of the data. The mean for the number of responses comes next, followed by a scientific test using a multiple regression model at a p-value of 0.05. The model is stated below:

$$PERF = \beta_0 + \beta_1 CTPS + \beta_2 ATPS + + \beta_3 RTPS + \beta_4 PGS + \beta_5 CPS + \varepsilon, \quad (2)$$

where:

$PERF$ = employee performance,

$CTPS$ = creative task performance strategy,

$ATPS$ = adaptive strategy,

$RTPS$ = routine strategy,

PGS = prioritizing goals strategy,

CPS = contingency planning strategy,

ε = error term,

$\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5$ are coefficients.

IV. Data Analyses and Results

Three hundred and fifty-four questionnaires were administered to the selected registered small and medium enterprises in Delta North Senatorial District and these are Ika North East, Ika South, Ndokwa East, Ndokwa West, Aniocha North, Aniocha South, Oshmili South, Oshmili North, and Ukwuani were properly filled by the respondents and used for the study analysis.

From Table I, it shows that 169 (47.7%) of the respondents are male while 185 (52.3%) of the respondents are female. This indicates that majority of the respondents were female.

This indicates that majority of the respondents were female. The table shows that 17 (18%) of respondents are within 18-25 years of age, 93 (26.3%) are within 26-32 years, 153 (43.2%) are within 33-39 years while 91 (25.7%) are within 40 years and above age range. This indicates that majority of the respondents are within the 33-39 years age range. The table also reveals that 15 (4.2%) of the respondents had SSCE qualification, 265 (74.9%) of the respondents had OND/NCE degree, 64 (18.1%) of the respondents had HND/BSc/B.A degree while 10 (2.8%) of the respondents had PGD/M.Sc/Ph.D degree. This however indicates that majority of the respondents had OND/NCE degree.

Table I shows that 201 (56.8%) of the respondents are management staff, 50 (14.1%) are non-management staff while 103 (29.1%) of the respondents are junior staff. This implies that majority of the respondents were management staff. The table shows that 40 (11.3%) of the respondents have worked for 0-4 years in the organization, 219 (61.9%) have worked for 5-9 years, 80 (22.6%) have worked for 10-14 years while 15 (4.2%) have worked for 15 years and above. This indicates that majority of the respondents have worked for 5-9 years in their organization

TABLE I. DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS

Category	Detail	Frequency	Percent
Gender	Male	169	47.7
	Female	185	52.3
Age	18-25YRS	17	4.8
	26-32YRS	93	26.3
	33-39YRS	153	43.2
	40YRS AND ABOVE	91	25.7
Educational Qualification	SSCE	15	4.2
	OND/NCE	265	74.9
	HND/BSC/BA	64	18.1
	PGD/MSc/PhD	10	2.8
Staff	Management Staff	201	56.8
	Non-Management Staff	50	14.1
	Junior Staff	103	29.1
Experience	0-4yrs	40	11.3
	5-9yrs	219	61.9
	10-14yrs	80	22.6
	15 And Above	15	4.2

Source: Field Survey 2024 .

TABLE II. MODEL SUMMARY

Model	*R*	*R* Square	Adjusted *R* Square	Std. Error of the Estimate	Durbin-Watson
1	.703[a]	.494	.487	.41625	1.664

TABLE III. ANOVA

Model		Sum of Squares	*Df*	Mean Square	*F*	Sig.
1	Regression	58.875	5	11.775	67.959	.000[b]
	Residual	60.297	348	.173		
	Total	119.171	353			
a. **Dependent Variable**: Employee Performance						

TABLE IV. COEFFICIENTS

		B	Std. Error	*β*	*t*-stat	Sig.
1	(Constant)	1.936	.536		3.612	.000
	Prioritizing Goals	.233	.061	.182	3.808	.000
	Contingency Planning	.360	.056	.326	6.405	.000
	Creative Task Strategy	.214	.054	.170	3.954	.000
	Adaptive Task Strategy	-.237	.046	-.250	-5.148	.000
	Routine Task Strategy	.001	.041	.001	.028	.978

a. **Predictors**: (**Constant**), Routine Task, Creative task Strategy, Prioritizing goals and Objectives Strategy, Adaptive Task Strategy, Contingency Planning Strategy
b. **Dependent Variable**: Employee Performance

Table II shows the *R*-Square value of 0.494, and this means that approximately 49.4% of the variation in employee performance can be explained by employee performance in the model. The adjusted *R*-square (0.487) accounts for the number of predictors in the model and provides a slightly lower value, implying that about 48.7% of the variation in employee performance is explained after adjusting for the number of predictors. The Durbin-Watson statistic result (1.664) for autocorrelation in the residuals indicates a slight positive autocorrelation but not enough to be problematic.

Table III shows the *F*-statistic result (67.959), indicating that the overall regression model is a good fit for the data. The significance value is less than 0.05, indicating that the regression model is statistically significant in predicting employee performance.

Table IV shows the intercept of the regression equation (1.936), representing the predicted value of employee performance when all other variables are zero. The coefficient shows prioritizing goals ($\beta = 0.233$, Sig. < 0.001), and this indicates a significant positive relationship with employee performance. For every unit increase in prioritizing goals, employee performance is expected to increase by 0.233 units. Result shows contingency planning ($\beta = 0.360$, Sig. < 0.001), and this is the strongest positive effect. That is for every unit increase in contingency planning, employee performance increases by 0.360 units. Creative task strategy ($\beta = 0.214$, Sig. < 0.001) indicates a positive influence on employee performance, increasing it by 0.214 units for each unit increase. Adaptive task strategy ($\beta = -.237$, Sig. < 0.001) has a significant negative effect on employee performance. That is a unit increase in adaptive task strategy decreases employee performance by .237 units. Routine task strategy ($\beta = 0.001$, Sig. > 0.05) is not statistically significant (Sig. > 0.05), indicating no meaningful impact on employee performance.

V. Discussion of Findings

The results from the analysis above show that prioritizing goals and objectives significantly affects the employee performance of SMEs in Delta State. This implies that when SMEs effectively prioritize their goals and objectives, it can lead to improved performance among employees. This is supported by [9], who found that when goals and objectives are prioritized, employee performance and productivity become a trending occurrence, as staff will be adequately motivated and convinced that their efforts will be acknowledged and not taken for granted.

The result revealed that contingency planning has a significant positive relationship with employee performance in SMEs. This implies that preparation for potential challenges enhances workplace efficiency and morale. This encourages SMEs to prioritize contingency planning as a strategic approach to improve overall employee performance. This is supported by the finding of [10] that contingency planning contributes positively to organizational performance.

The result revealed that creative task strategy has a significant positive relationship with employee performance of SMEs. This implies that innovative approaches to work can enhance productivity and engagement. This relationship highlights the importance of fostering a creative environment where employees feel empowered to explore new ideas, and this can lead to better outcomes for both employees and the enterprises. This aligns with the findings of [11], which demonstrated that management employs various creative strategies and policies to enhance work environments and performance.

The results indicated a significant negative relationship between the adaptive task strategy and the employee performance of Small and Medium Enterprises in Delta State. This indicates that overly relying on flexibility and constant adjustments may hinder employees' ability to perform effectively. It also implies that, while some adaptability is necessary, excessive changes in strategy may lead to confusion, reduced efficiency, and decreased overall performance. This refutes the finding of [12] that at the individual level, adaptive performance is an employee's ability to adapt to rapidly changing work situations and that when an employee is adaptive, this can lead to improved job performance and career success.

The findings indicate that the routine task strategy has a minimal positive impact on the employee performance of small and medium-sized enterprises. This implies that managers may need to explore alternative strategies that could more effectively enhance employee performance. This refutes the finding of [13] that the routine task performance strategy and entrepreneurial orientation used in this study had a significant and positive relationship with the performance of SMEs.

VI. Conclusion

The study concludes that the quality of an organization's workforce determines its strength and weakness, and the operational strategy a company adopts helps it find competent employees who can enhance employee performance. When employers adopt proper task strategies such as prioritizing goals and objectives, contingency planning, creative task strategy, adaptive task strategy, and routine task strategy, they can achieve maximum performance from their employees. Task strategies are crucial for assessing employee performance within an organization and for prioritizing organizational tasks to achieve promotion and productivity.

VII. Recommendations

The following are the recommendations put forward:

1. Firms should consider prioritizing goals and objectives, contingency planning, creative task performance, adaptive task performance and routine task performance strategy as it enhances monitoring, scheduling, and needed motivation among employees and thereby increase productivities of employees. It also makes work environment more friendly and enjoyable.
2. Organizations can use these task strategies to disclose the job description and responsibility to enable them perform maximally.

3. Employers and small and medium scale enterprise owners should take into account employee performance in order to positively influence productivity, which in turn promotes the organization’s profitability.

4. Since task performance has such a powerful and positive impact on employee performance, employers should use flexible task strategies to encourage and motivate their employees.

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Original Scientific Article

Can the Ideal Goal Be Achieved?

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Abstract—**The focus of this paper is on the possibility of achieving the ideal (ultimate) goal in production. In other words, if the management of an organization succeeds in finding a way to reduce the amount of defective products without incurring additional costs, then the minimum value of total production costs will align with the basic production costs. In this process, the quantity of defective products and their optimal amount will be reduced to zero. It is well known that creativity is responsible for most discoveries in science and improvements in technology and business in general. Therefore, it is expressed here with confidence that employees, together with management at all levels of the organization, can, through a creative approach and by enhancing their abilities, find a way to completely eliminate defective products without additional investment.**

Keywords – ideal goal, creativity, costs, quality, zero deffects.

I. Introduction

The possibility of achieving the ideal goal in production, i.e., reducing the number of defective products to zero without incurring additional costs, is often considered merely a wishful thought. Instead, manufacturing organizations focus their full attention on achieving an optimal balance between production costs and the costs associated with defective products. Specifically, this involves determining the optimal percentage of defective goods for which production costs are minimized. While this can be achieved through total control and inspections, error made by inspectors inevitably occur during this process. Complaints and subsequent repairs result in a loss of stakeholder trust and an increase in costs.

This paper focuses on the relationship between costs and quality, namely, finding ways to simultaneously improve quality and reduce costs. The essence of this relationship is graphically depicted in Fig. 1, where the horizontal axis represents the quantity of defective products, and the vertical axis represents production costs. Additionally, two important questions are analyzed in this paper. First, is the optimal level of waste for the producer also optimal for the customer? The second question is: Does maintaining an optimal amount of waste provide the organization with a lasting competitive advantage in the market? Since the answers to both questions are negative, the attention shifts to a creative approach to business that can certainly give the organization an edge over the competition. In this context, the obligation of management to fully revitalize the natural connection between motivation and creativity is emphasized, as only motivated people can find the best way to achieve what Professor Yoshio Kondo called the ideal (ultimate) production goal: the complete elimination of defective products without requiring any additional investment. [1]

In other words, finding the right way to achieve the ideal goal requires maximum employee creativity and ability of employees. Therefore, management's task is to create conditions in which employees can freely express their creativity, which exists to some degree in every person but has been repressed into the subconscious since early childhood under the influence of family, school, and rigid social rules. This paper briefly analyzes the relationships between the most important production indicators: improvement, productivity and safety, standardization and creativity, as well as four guidelines for more creative employee work. Finally, a conclusion

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and a list of references in alphabetical order are provided.

II. Production Costs and the Quantity of Defective Products

The primary goal of production is to create products of adequate quality. In practice, a dilemma arises regarding whether it is more important for an organization to reduce costs or increase productivity. Management is tasked with calculating quality costs. However, accurately calculating these costs presents challenges. Most organizations do not have data on how much they spend on planning and quality control. Additionally, the majority of errors that lead to costs occur because things are not done correctly the first time. Philip Crosby, in his book *Zero* Defects, states that organizations that conducted proper measurements found that quality costs average around 30% of sales. In fact, they vary between 20% and 40% of sales. When these percentages are converted into monetary terms and compared with realized profits, the data reveals that quality costs are two to three times higher than profits. This means that reducing these costs can significantly increase profits. For example, organizations that managed quality well reduced quality costs from 30% to 3% of sales over several years. [2]

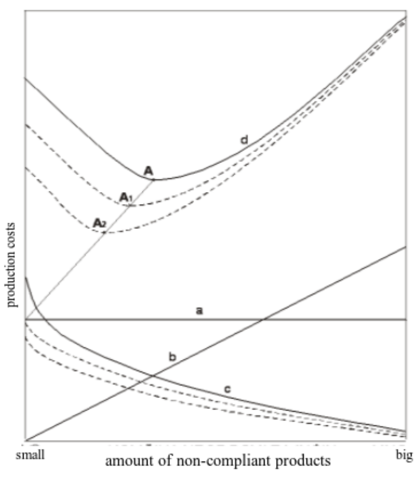
From Fig. 1, it can be seen that total production costs (curve d) of a product consist of basic production costs (lin a), poor quality costs – such as waste and rework (line b), and quality improvement costs – such as control costs (curve c). Basic production costs include all expenses necessary for production, such as material costs, labor costs, employee insurance costs, and costs of work equipment (depreciation). These costs remain fixed regardless of whether the quantity of defective products is low or high.

The costs of defective products are essentially the losses caused by producing such products. These include, for example, waste generated during production, rework to correct errors, complaints, and repairs after the sale during the warranty period. Defining these costs requires a very precise and strict approach from management at all levels. Additionally, the value of the correct products that could have been produced during the time employees spent reworking defective products must also be taken into account.

III. Optimization or Improvement

In production organizations, it is traditionally believed that an optimal balance must be achieved between production costs and the costs of defective products. From Fig. 1, it can be observed that the losses due to scrap (line b) decrease proportionally with the reduction in the number of defective products. On the other hand, the costs of reducing the percentage of defective products (curve c) increase as scrap decreases. Initially, total production costs (curve d) decrease with the reduction in scrap. However, as the percentage of defective products approaches zero, these costs begin to rise significantly. Therefore, it is assumed that there is an optimal percentage of scrap (intersection of line b and curve c) at which the total production costs are minimized (point A).

From the figure, it can also be seen that when the percentage of defective products is high, the costs of reducing scrap (curve c) are low. As the percentage of defective products decreases, these costs rise. Why is this the case? Because eliminating poor quality requires employee training, the acquisition of more modern machinery and tools, and the procurement of higher-quality materials, all of which require the organization to allocate significant sums of money.



Legend: ***a***-*basic production costs,* ***b***-*low quality costs,* ***c***-*costs of low quality reducing,* ***d***-*total production*

Figure 1. Production Costs and Quantity of Defective Products [2]

Two questions arise here. First, is the optimal amount of scrap for the manufacturer also optimal for the customer? The second question is: Does maintaining the optimal amount of scrap ensure the organization's competitiveness in the market?

For the customer, the most important thing is that the product they buy is completely functional. Completely eliminating the delivery of defective products to the market and maintaining the optimal amount of defective products can be achieved through 100% inspection. However, this is not easy, as errors occur event with the most rigorous inspections. Repairs after delivery lead to a loss of customer trust, which negatively impacts business costs. In response to the second question, it is important to remember that market competitors may find a way to simultaneously reduce production costs and the number of defective products. In that case, the organization that maintains an optimal scrap percentage, where production costs are minimal, will not benefit, as competitors will surpass them.

Thus, it is necessary to analyze this situation in more detail. Of the three types of costs mentioned in section II of this paper, the basic production costs and scrap costs are fixed and can be calculated accurately after being defined. The variability of scrap reduction costs (curve c) makes precise calculation significantly more difficult. Additionally, there is always room to improve each individual method used. This means that any management plan for improvement is never the only or the best possible option.

Let's assume that the organization's management successfully refines its plan to reduce the number of defective products, as shown in Fig 1 with dashed lines below curve c. In this case, the minimum value of total production costs (curve d) will decrease meaningfully, as will the optimal amount of defective products.

Thus, the conclusion of flows that if management and employees put in additional effort, it is possible to reduce total production costs and the optimal amount of defective products. By finding a way for the organization to reduce the number of defective products without incurring additional costs, the minimum value of total production costs (point A) would shift (points A1, A2, etc.) and, at some point, align with basic production costs. At this point, the quantity of defective products and their optimal amount would be reduced to zero. This is what Professor Kondo referred to as the ideal, ultimate goal.

IV. Creativity in the Organization

For employees to have a necessary strong sense of responsibility toward achieving the ideal goal and, in general, toward the work they perform, management must ensure two important conditions. The first is that work goals must be clearly defined and communicated. The second condition refers to the obligation of management to provide employees with enough freedom in choosing the means and methods for achieving these goals. In other words, after fulfilling the first condition, employees' sense of responsibility will strengthen if they are given more freedom regarding the means and methods they can use to achieve the goals. This means that these two conditions are positively related. Ensuring them will influence the development of a positive attitude toward work among employees and will consequently lead to the strengthening of their initiative.

In addition to the essential fairness, employee motivation is strongly influenced by a sense of freedom to fully express their repressed creative potential. In his book *Psychology in Management*, Abraham Maslow talks about research conducted at Harvard University, which aimed to measure children's intelligence quotient, spatial, visual, social, and emotional intelligence. The results showed that four-year-old children were at the genius level [3]. After that, their developmental process begins to decline under the pressure of their environment. The key reason is that the messages children receive from parents, teachers, and society in general, in the form of prohibitions, punishments, strict rules, and limitations, cause them to gradually suppress their natural creativity into their subconscious. As a result, between the ages of 30 and 50, people's creativity, which is most needed in their work, remains trapped deep within them.

In this regard, management must ensure the full revitalization of the natural connection between motivation and employees' trapped creativity. It can do this by rewarding employees based on fair evaluations of their work, establishing mutual respect (valuing different opinions), and trust (shared interest before personal gain), communicating clear and obligatory goals, and granting employees the freedom to choose methods and means in performing their tasks. Any need to limit this freedom would only be justified if it begins to threaten the achievement of the organization's defined strategic goals. Such as management approach will lead to a maximum strengthening of employees' sense of responsibility and allow them to express their greatest possible creativity in achieving the ideal goal.

V. Creativity & Improvement of Product Quality and Employee Skills

Highly motivated employees can solve all the problems that arise in their work. In line with this, it is necessary to create conditions within the organization for creative improvements instead of the usual practice of maintaining artificial optimization, i.e., the percentage of defects where total production costs are minimal. Precisely because there are always many ways to reduce the number of defective products, the associated costs are not fixed but variable. Similarly, the minimal production costs and the representative amount of defective products are also variable values. This is the foundation of the thinking behind improvement. The significant motivational potential for improvements also lies in the dilemma related to quality and costs, which suggests that when the number of defective products decreases, costs rise. Resolving this dilemma requires creativity to find a way to simultaneously improve quality and reduce costs.

Furthermore, it is very important to pay attention to other managerial concerns. For example, balancing safety and productivity, or quality and productivity. Naturally, employees tend to prioritize their own safety over productivity. Equally interesting are the words of W. Edwards Deming, the author of PDCA cycle (known in Japan as the Deming Cycle of Improvement), who stated: "Productivity increases in parallel with quality. This fact is well known, though only to a select few" [1]. On this topic, Japanese Professor Yoshio Kondo was also very explicit when he wrote: "Achieving quality products is more important than increasing productivity or reducing costs. Increasing productivity serves no purpose if the products are not of appropriate quality" [1].

Experience shows that the approach of maintaining the current state in an organization through optimization is much more easily accepted than the creative approach based on improvements. The reason is that the first approach seems more logical, while the second is based less on logic and more on emotions, making it much harder for employees to accept. In other words, a creative approach will be sustainable only if there is motivation and persistence from both management and employees to achieve the ideal goal, along with the support and understanding of relevant stakeholders.

Work in the organization is distributed according to individuals, functions, and organizational units, while the independent control of each employee's work is reflected in the rotation of the PDCA wheel. In doing so, management must do everything possible to facilitate this rotation. In this way, employees take care not only of their own work but also understand the work of their team members and managers. This encourages the abilities of each employee individually.

VI. Standardization of Work and Employee Creativity

There are no doubts when it comes to product standardization, as it guarantees quality and is a basic condition for reducing costs and increasing productivity. However, when it comes to work standardization, there is some concern regarding its potential negative impact on employee motivation and creativity. It has already been mentioned that employees should be given freedom concerning the methods and means they use to perform their tasks, which in turn increases their responsibility. The question then arises: how does work standardization affect that freedom?

Work standards encompass the job's objectives, limitations related to the work, and the tools and methods used in the process. Employees must strictly adhere to the first two requirements. In other words, they must produce products according to the standard's requirements and perform the job safely. It is also clear that the more freedom employees have in their work, the easier it is to carry out tasks.

A negative consequence of management's insistence on rigid adherence to prescribed means and methods for performing tasks is that it allows employees to avoid responsibility for poor quality by blaming the very means and methods they were required to use. That is why work standards should include experiences and knowledge that employees, particularly those with more experience, gain through their own initiative. In doing so, management should ensure that the methods and means are applied correctly and are not in conflict with the previously mentioned limitations.

Thus, work standardization does not hinder the expression of employee creativity. As Professor Kondo stated: “Creativity and standardizations are not mutually exclusive; on the contrary, they are complementary” [1].

VII. Four Guidelines for More Creative Employee Work

Motivation and creativity of employees are closely connected, in that more creative work increases motivation, while more monotonous tasks demotivate people. Below are four guidelines that lead to more creative work performance:

-*When issuing instructions, management must clearly communicate the job objectives***:** Achieving the goal inherent in every job is the most important task of the organization. In this regard, means and methods should only be used as references, as management must encourage employees to find their own ways to meet the set goals. This excludes mandatory restrictions related to employee safety and product quality.

-*Management must ensure that employees have a strong sense of responsibility toward their work*: This guideline is linked to the previous one. When work doesn’t go as planned, employees tend to shift responsibility onto others. This is very harmful and must be prevented from the outset. Along with insisting on mandatory goals and optional methods to achieve them, management has methods at its disposal to prevent harmful excuses: adjusting data based on averages or regression, multi-layered data citation, and applying the vertical principle during the planning of experiments.

-*Management must allow sufficient time for the development of new ideas***:** The application of the previous two guidelines leads to increased employee responsibility when solving all emerging problems. A strong sense of responsibility results in dedication and deep reflection on the core of the problem. Thanks to this, during periods when deep thinking and leisure overlap, inspiration arises, from which new creative ideas emerge. Since the timing and required time for idea generation vary from person to person, management must provide enough time for creativity to manifest.

-*Management must support new ideas and allow them to bear fruit*: New ideas are very fragile, and they must not be dismissed or fragmented, as this could lead to their destruction. A new idea should be treated like a newborn baby that needs parental care to mature. This means it should be allowed to develop, during which time its quality can be assessed. Before rejecting an idea, during its development, it should be given some time for improvement. Only through the consistent application of all four aforementioned guidelines can work become a creative activity**.**

VIII. Risk-based Thinking and the Application of Artificial Intelligence

In organizations where ideas are generated and nurtured, all employees involved in their development will strengthen their self-confidence, which is extremely valuable from a motivation standpoint. The key to employee motivation lies in using, through daily work, elements that make a person human: creativity that operates in the spirit of fair play, fair comparison of results, recognition for effort and work, support for improvement, voluntariness, independence, the introduction of an appropriate work rhythm, and humanity which distinguishes people from animals. The connection between employee motivation and creativity leads to maximizing their responsibility, so risk-based thinking becomes the dominant mental framework in performing tasks and solving various problems. In this way, risks are minimized.

Additionally, the application of artificial intelligence (AI) can significantly positively impact the inspiration and increased expression of employee creativity, by stimulating innovation and viewing problems in a different way. Timely identification and monitoring of employee behavior patterns through individualized AI support can lead to a drastic reduction in their risky behavior. On the other hand, employees must retain an active role in making creative decisions, and it is essential to keep in mind that over-reliance on AI tools can negatively affect creativity, especially if they begin to uncritically accept the recommendations of artificial intelligence tools. This is nicely illustrated by the example of a man struggling with seasickness. Many people can eliminate feelings of seasickness by imagining that they are rocking the boat, not the boat rocking them. Therefore, the solution lies in a balanced approach between the use of AI and independent critical thinking in creative processes.

IX. CONCLUSION

It has not yet been proven that the ideal goal is unattainable. If we were to accept the pessimistic view that reducing the number of defective products to zero without additional costs is merely a nice wish, we would be making two major mistakes. The first would be to give up on this endeavor prematurely. The second would be the unjust underestimation of people's intelligence and creative abilities. This alone is a sufficient reason to remind pessimists that it is wrong to give up before making the effort to achieve it. Moreover, the pursuit of the ideal goal is worthwhile in itself as it sets the direction for channeling the energy of management and employees. The only way the ideal goal could be achieved is by creating favorable conditions for the abundant use of the vast untapped creativity of employees while simultaneously enhancing their abilities.

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Original Scientific Article

Blockchain-integrated Smart City Services and Real Estate: Creating Synergies for Seamless and Transparent Property Transactions

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Abstract—**Integrating blockchain technology with smart city services poses significant challenges due to the complexity and diversity of the systems involved, particularly in the real estate sector, where solutions often operate in isolation, disconnected from other urban services. This isolation limits the potential benefits of a fully integrated smart city. Blockchain, with its secure, transparent, and decentralized nature, offers an ideal solution for bridging these gaps and creating a unified ecosystem. This study proposes a smart living ecosystem based on blockchain. The proposed ecosystem outlines the technical requirements, governance structures, and stakeholder roles necessary to achieve seamless interoperability across diverse urban services with a focus on real estate. According to a proposed ecosystem, a decentralized application (dApp) is developed, integrating real estate transactions with real-time pollution monitoring data in the smart city. This dApp demonstrates the feasibility of the ecosystem and shows the advantages of incorporating environmental data into property transactions, enabling a more informed and transparent decision-making process in trading with real estate for users**.

Keywords - smart cities, blockchain, smart contracts, real estate trading

I. Introduction

In the urbanization landscape, smart cities have emerged as a key factor for improving life of urban populations. They involve technologies such as the Internet of Things (IoT), artificial intelligence, blockchain, and big data analytics. A fundamental aspect of a smart city is smart living which consists of the development and implementation of smart homes and apartments, intelligent selection of residential locations, and smoothed processes of purchase or rental of properties. Such smart city services change the lifestyle of people within urban environments and allow them to lead their lives with more ease, efficiency, and sustainability. IoT-enabled homes offer security and energy efficiency, allowing users to choose residences based on real-time environmental data, streamlining the property selection process.

However, realizing the full potential of smart living in urban environments requires overcoming significant challenges, particularly in sectors like real estate. Traditional real estate transactions are inefficient and lack transparency, and usually involve multiple intermediaries. These issues can lead to higher costs and delays, complicating the process of finding and securing the right property [1]. New innovative technologies can enhance transparency, efficiency, and trust in property transactions. One such technology that has gained considerable attention is blockchain. In the context of real estate, blockchain offers the ability to streamline transactions by recording all details in a tamper-proof manner, thereby reducing the need for intermediaries, minimizing

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the risk of fraud, and enhancing trust among all parties involved [2]. By integrating urban services and real estate services into a single platform, new value can be added to all the stakeholders in the real estate sector [3]. Smart city services such as environmental monitoring, transportation management, and energy efficiency generate valuable data that allow for better decision-making when choosing where to live. This integration allows prospective buyers and renters to make more informed decisions when choosing properties.

This study presents an ecosystem that integrates real estate transactions into a broader smart city environment using blockchain technology. The ecosystem addresses challenges related to interoperability, data exchange, and service integration within smart cities. A decentralized application (dApp) is developed as a proof of concept, integrating real estate transactions with real-time pollution monitoring data. This dApp enables users to select properties in areas with low pollution, promoting healthier living environments. It also facilitates property rental and sales transactions over the blockchain, ensuring a transparent and efficient process.

II. Smart Living Services Based on IoT and Blockchain Technologies

Smart cities integrate advanced information technologies by improving efficiency, sustainability, and livability within urban environments. These cities can leverage different services through digital platforms or applications offering real-time monitoring, data-informed decision-making, and resource management capability [4]. Among such services are transportation management, energy efficiency, waste management, and environmental monitoring [5-7]. These services together may contribute to urban systems that can adapt to the well-being of their residents, ensuring less impact on the environment. One such service is environmental monitoring, which has gained increased importance in urban planning and management. The monitoring and analysis of environmental data on air quality, noise, and pollution are some of the crucial things toward proper sustainability of the urban environment and livability [8].

Environmental monitoring enables cities to track performance indicators and address hotspots of pollution or stressors effectively [10], [11]. With effective monitoring, the city could formulate mitigation plans for the noise level reduction with the aim of improving the living conditions of its citizens [4], [12], [13]. Cities can likewise adopt policies promoting energy efficiency and conservation of natural resources based on the effect they have on the environment [14-16]. A recent approach to improve environmental sensing in smart cities is crowdsensing. Crowdsensing takes advantage of the collective potential of citizens, by means of their smartphones [17] and other devices to gather and share real-time environmental measurements [4], [18]. Integrating environmental data in urban management faces a few challenges, such as the accuracy of the data, privacy, and the interoperability of different systems in their study [19]. The quality of sensors used for data acquisition and analysis directly affects the accuracy of environmental data [20].

A. *Blockchain Services for Real Estate*

Blockchain represents a decentralized and distributed ledger that is used for secure, transparent, and immutable recording of transactions. It uses decentralized consensus mechanisms that reduce intermediaries, minimize fraud, and increase trust among participants. Cryptography is used alongside the storage process, and information recorded in a blockchain is almost impossible to change or tamper with. This makes blockchains particularly valuable in applications where data integrity and security are important [21].

While blockchain technology offers numerous benefits for smart city ecosystems, its environmental impact, particularly due to high energy consumption associated with consensus mechanisms like PoW, is a well-known criticism. One potential solution is the adoption of more energy-efficient consensus mechanisms such as PoS or hybrid models, which drastically reduce energy consumption while maintaining security and decentralization [22]. Incorporating renewable energy sources into blockchain networks, as demonstrated in decentralized energy grids, can further mitigate the carbon footprint of blockchain operations [23]. Solutions like Polygon’s Layer 2 scaling approach highlight how improving scalability can help lower the overall energy consumption of blockchain systems, particularly in large-scale applications [24].

One of the most important features of blockchain technology within smart cities is the provision for smart contracts. Smart contracts represent a special form of self-executing contracts where the terms of the agreement are specifically written in code directly [25]. Those contracts reside on the blockchain and automatically execute once the predefined conditions are met [26], [5]. Smart contracts within a smart city can automate services, from the distribution of energy to public transport management. The distribution of electric power by a smart grid may be regulated through smart contracts, in a way that prices can change in real-time according to demand smart contracts are activated [27], [28]. Integrating blockchain technology with services for smart cities also helps in creating conditions for an effective and sustainable improvement of urban infrastructure efficiency [29-32], which allows property owners to adjust their energy consumption to prevent environmental degradation.

Blockchain technology has recently gained the attention of the real estate industry, where it is used for property transaction processing efficiently and reliably [33]. Traditional property transactions involve a good number of intermediaries, convoluted processes, and quite a considerable amount of paperwork. Using a decentralized ledger ensures that all the details of real estate transactions are immutable and transparent, which removes the need for any intermediaries and minimizes the risks of fraud [34]. Smart contracts enable the operational process in real estate trading, ranging from transfer of ownership, payments, to registration with relevant government bodies. The most promising application for real estate is the tokenization of real estate assets [35]. Tokenization refers to the transfer of a real estate asset into digital tokens, which can then be traded on a platform with the use of blockchain technology. Blockchain real estate platforms provide a transparent secure platform to deal with buyers and sellers without any third parties including real estate agents or brokers and thereby increase trust between participants, while decreasing fraud risk [36-38].

A key challenge for the real-world implementation of blockchain-based real estate transactions lies in the legal and regulatory gaps that currently exist in many jurisdictions. Property transfers traditionally require government-verified title deeds and notarized documentation, none of which are universally recognized through blockchain platforms. In the European Union, for example, traditional intermediaries like notaries and registrars are deeply embedded in the real estate process, and adapting blockchain to these structures would require significant legal reform to ensure that smart contracts can serve as legally binding agreements [39]. While some legislative efforts have begun to address the issue, many countries still lack comprehensive laws that cover the enforceability of smart contracts, especially in cross-border real estate transactions [40]. In Russia, for instance, the permissibility of blockchain transactions depends on the involvement of intermediaries like registrars, further complicating blockchain adoption in real estate [41]. These legal uncertainties pose a significant barrier to the scalability and applicability of blockchain-based systems in the real estate sector, underscoring the need for policymakers to develop clear legal frameworks that ensure the enforceability of smart contracts, protect data privacy, and regulate decentralized transactions. More significantly, smart city data can be tied to the real estate market because much of the value of the property is dependent on the quality of the environment. Properties in locations with a large amount of air and noise pollution will not be so attractive to potential buyers and will reduce the value of the property.

III. SMART LIVING ECOSYSTEM BASED ON BLOCKCHAIN

Normally, real estate services have stayed isolated from other urban systems. While these isolated blockchain solutions can enhance transparency and security within real estate transactions, they remain discrete from the broader ecosystem of smart cities. There is a range of benefits that can come from connecting real estate with urban environments, like increased efficiency, informed decision-making through in-depth environmental data, and improved interoperability among different urban services.

To remedy the current disadvantages of smart living, we suggest a fully integrated ecosystem of smart living real estate services with other services based on blockchain technology (Fig. 1). This ecosystem is designed to link up real estate transactions with environmental monitoring, utility management, urban planning, and many others into one comprehensive, interoperable framework that brings much more benefits than solutions taken in isolation. Our ecosystem permits secure and transparent property transactions that augment the functionalities and effectiveness of the smart city, enabled through more informed choices and more sustainable and connected urban surroundings fostered for its residents and stakeholders. The ecosystem could integrate pollution, transportation, and crime data to enhance decision-making for real estate transactions. Energy consumption data could also be integrated to help users assess the sustainability and efficiency of properties, enabling them to make decisions based on potential long-term cost savings and environmental impact. By incorporating these diverse data streams into the ecosystem, the system could deliver a more comprehensive view of a property's value and its surrounding urban context, thus enhancing the decision-making process for users.

The proposed ecosystem involves a wide range of stakeholders. These stakeholders are residents, real estate developers, agents, notaries, legal advisors, government bodies, IoT service providers, among others. Uniting such a diversified set of actors would be more than a challenge. The challenge lies in ensuring that their systems are compatible and that the interaction among them can be seamless. Each stakeholder is responsible for specific activities and processes including, among others: property development, transaction management, legal verification, and environmental monitoring, which require exact coordination and exchange of information data. For this integration to be possible, members will have to utilize smart contracts, which would make agreements self-executable and eliminate human error, cutting down the need for intermediaries. But for smart contracts to work best, the underlying systems of both participants should be compatible with a blockchain-based framework.

Figure 1. Smart living ecosystem based on blockchain

TABLE I. STAKEHOLDERS, THEIR ROLES AND ACTIVITIES IN SMART LIVING ECOSYSTEM BASED ON BLOCKCHAIN.

Stakeholder	**Activities/Processes**
Residents	Engage in property search, purchase, sale, and rental; manage utility and insurance contracts. **Documents**: Agreements, contracts.
Real Estate Developers	Develop, list, and manage properties; ensure urban compliance. **Documents:** Property details, compliance certificates.
Real Estate Agents	Facilitate transactions; manage listings and processes; provide advice. **Documents**: Listings, agreements.
Notaries/ Legal Advisors	Verify and certify documents; ensure legal compliance. **Documents**: Verified contracts, property titles.
Government Agencies	Oversee compliance, zoning, and urban planning. **Documents**: Zoning permits, compliance reports.
IoT Service Providers	Deploy and manage IoT devices; collect and share environmental and utility data. **Documents**: Data logs, utility reports.
Financial Institutions	Offer mortgages and loans; manage secure payments. **Documents**: Loan agreements, payment records.
Insurance Companies	Provide property insurance; assess risks and claims. **Documents**: Policies, claims reports.
Utility Providers	Supply services (e.g., electricity, water); manage contracts and billing. **Documents**: Utility contracts, billing statements.
Property Management Companies	Manage rental properties; handle maintenance and tenant relations. **Documents**: Lease agreements, maintenance records.
Title Companies	Verify and transfer property ownership; ensure legal clarity. **Documents**: Title deeds, verification reports.
Architects/ Urban Planners	Design buildings and urban layouts; ensure zoning compliance. **Documents**: Design plans, compliance approvals.
Construction Companies	Manage development projects; ensure quality and regulatory compliance. **Documents**: Permits, progress reports, certificates.

This is very important to the health of the ecosystem because incompatible systems induce data silos, delays, and much added complexity in managing transactions.

Achieving interoperability between real estate services and other urban services within a smart city ecosystem requires adherence to specific standards and protocols. One effective approach is the use of a standardized urban data platform that enables integration across various city domains, such as infrastructure, energy, and mobility services. The Open Specifications Framework developed under the mySMARTLife project offers a model for ensuring data and service interoperability, emphasizing open standards for data exchange and service integration [42]. Blockchain can serve as an intermediary to ensure secure, decentralized data management across services, enabling seamless interaction between real estate services and broader smart city applications like IoT-based environmental monitoring [43]. To address scalability across diverse urban environments, the ecosystem could adopt a modular implementation, allowing cities with varying levels of technological infrastructure to integrate components incrementally [44].

Table I shows the information concerning every stakeholder, their activities and documents that they produce.

A. Blockchain-enabled Services in the Ecosystem

The smart living ecosystem streamlines real estate transactions and urban management with blockchain-enabled services, including property listing, transaction management, legal verification, and environmental monitoring. Users can search or post properties on a decentralized platform using filters like location, price, and environmental conditions. Smart contracts handle negotiations and finalize agreements securely, reducing fraud and eliminating intermediaries. Legal verification ensures compliance, while blockchain-integrated environmental data informs property decisions. Financial and insurance services streamline payments, mortgages, and risk mitigation, and blockchain-based title verification guarantees a secure ownership transfer.

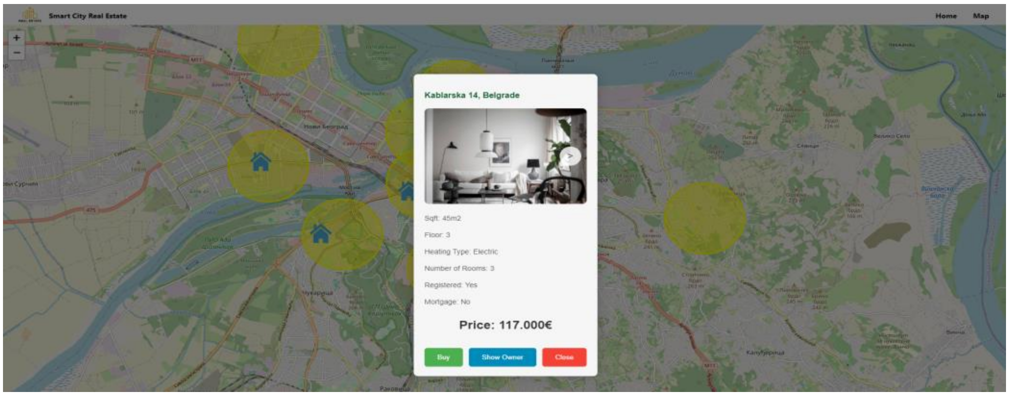

Figure 2. Dapp for real estate trading in smart cities with an interactive map showing the location of the available properties and the pollution levels

For rentals, users start with property listings on a decentralized app (dApp) posted by developers, agents, or residents. After selecting a property, smart contracts handle negotiations and rental agreements, with legal verification ensuring compliance. Environmental monitoring provides real-time data to guide decisions, and services like electricity, water, and internet are automatically transferred upon agreement confirmation. During the rental period, property management handles maintenance and tenant communications, all transparently recorded on the blockchain.

IV. DEVELOPMENT OF A DAPP FOR REAL ESTATE TRADING IN SMART CITIES

As proof-of-concept dApp was developed to validate the proposed blockchain-based smart living ecosystem. The ecosystem uses Ethereum-based smart contracts for secure transactions and a React front-end for user-friendly interaction (Fig. 2).

The design of the application can be divided into three main modules: The Real Estate Transactions module, the Environmental Data Integration module, and the User Interface module. The transactions in real estate will be managed through smart contracts, which will guarantee that all the terms and conditions will be actualized before finality. Environmental Data Integration is based on real-time pollution data that can be integrated with the blockchain to assist users in including the environment in consideration for property decision-making. The dApp also possesses an interactive map that shows real-time pollution levels at every micro-location in the city, along with property listings retrieved from the blockchain database.

For transaction purposes, the dApp integrates digital wallets, allowing a secure transaction process for Ethereum (ETH). The platform also enables the exchange of any fiat currency to ETH and facilitates transactions between ecosystem participants.

The dApp also underwent extensive functional testing in relation to the transaction processing, correctness of data, system security, and integration with data from IoT sensors. The module for real estate transactions was also tested where the correct operation of smart contracts was ensured. The results of this testing confirmed that the dApp meets all the criteria of a performance objective test, proving to be ready for deployment within a smart city ecosystem.

V. CONCLUSION

This paper presents the possibilities of integrating blockchain technology with smart city services and real estate transactions within a more extensive smart living ecosystem. The differences in systems, data formats, and varying technological maturity levels present significant obstacles to building a cohesive smart city ecosystem. Real estate services have been slow to merge with other urban services, complicating the creation of a unified platform. To overcome these challenges, we have developed a comprehensive ecosystem aimed at standardizing the integration of real estate services into the smart city framework.

However, this study has certain limitations. The ecosystem and dApp were tested in a controlled environment, and further research is necessary to evaluate their scalability and applicability in various urban contexts. For this application to function effectively in real-world scenarios, it is essential that laws and regulations governing real estate transactions via blockchain are established and adopted.

Future work should focus on addressing these limitations by conducting a feasibility study to assess the practicality of scaling the ecosystem across different urban settings. Moreover, a technology acceptance study should be undertaken to evaluate how stakeholders perceive and are willing to adopt this blockchain-based approach.

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Original Scientific Article

Post-pandemic Consumer Behavior: Reflecting on the COVID-19 Pandemic Lessons

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Abstract —**The COVID-19 pandemic significantly impacted societies all around the world. Currently, almost a year after the pandemic's conclusion, it is obvious that this period of adversity created changes that prevail. The main aim of this paper was to explore these changes and outline future trends in consumer behavior. The findings of this research are based on a survey conducted on a representative sample of consumers from the selected country. This method for collecting and processing data enabled the results to be based solely on consumers' opinions and experiences. According to the data, the main aspect of consumer behavior that prevailed is the online shopping and preference for food delivery. The phenomenon that was important during the pandemic but disappeared completely was the preference for shopping unaccompanied.**

Keywords- consumer behavior, COVID-19 pandemic, post-pandemic period, Slovak republic.

I. INTRODUCTION

Consumer behavior is a central concept of modern marketing. Its purpose is to understand how the consumers perceive their products, what factors affect their decision to either buy or not buy this product and most importantly, how to change these consumers into loyal customers. Since this concept is crucial a lot of research has been conducted on consumer behavior and all its aspects are well mapped. However, this information is only valid during the conditions that are perceived as normal. During adverse events, consumers significantly alter their behavior under the strain of fear and other previously irrelevant factors. As a result, these conditions create a whole new reality that consumers need to face. COVID-19 pandemic was such a major adverse event that it significantly altered the regular patterns of behavior. Therefore, it is necessary to explore even the most basic aspects of consumer behavior during the pandemic in order to understand it completely. Furthermore, after the conclusion of the pandemic, consumers are changed. Doing the adverse years, they explored new patterns of behavior, some they even found more convenient and therefore, some of the habits that they gained during the pandemic prevail even after its conclusion. This research focuses on exploring which of the consumer behavior aspects prevailed after the conclusion of the pandemic and which aspects were solidly related to the pandemic conditions.

Understanding how these consumers behave is crucial for enterprises to predict their demand and to also create measures to effectively manage their products and supply chains. Adverse events such as pandemics can create new trends and shift towards new reality. The COVID-19 pandemic was such a situation that completely altered the so-called normal trends of behavior that had been expected from consumers before. There are a lot of research studies that focus on how consumers behave during the pandemic. However, there is still little evidence on what changes that occurred during the pandemic still prevailed or if the consumers returned to their pre-pandemic habits of behavior. These aspects of consumer behavior still need to be explored to properly understand the effects of the COVID-19 pandemic on societies.

II. Literature Review

Consumer conduct is an intricate occurrence that is exceedingly hard to comprehend and even more demanding to accurately depict. Nonetheless, the notion of consumer conduct is essential for contemporary marketing. Consumer behavior pertains to the examination of how individuals, groups, or entities arrive at decisions and behave [1].

According to [2] consumer behavior refers to the actions and decisions that individuals or households make when they choose, buy, use, and dispose of products or services. Understanding consumer behavior is crucial for businesses to create effective marketing strategies and meet customer needs. Majority of studies confirm that consumer behavior remains stable under normal conditions and it takes a major change to force significant adjustments [3,4]. Authors in [5,6] divided these stimuli into two categories depending on their source of origin. Internal stimuli can include for example an arrival of child into family or promotion in work of one of the family members whose income is a major contribution to household budget. On the other hand, external stimuli can affect whole population. Several such events and their consequences were documented. One of the most prominent recent cases was the impacts of the Fukushima power plant disaster. Due to fear of contamination even years after the event the consumers were scared to buy food products that originated from the area despite of several assurances and scientific evidence that products were safe [7-10].

Therefore, [11] argue that key influences on consumer behavior are psychological factors such as motivation, perception and attitudes and believe. Motivation involves needs and desires that drive consumer actions. Basic needs like food and security often take precedence regardless of external environment and its current conditions. Perception is related to how consumers interpret information about products and also current situation. Attitudes and beliefs shape how consumers feel about products and brands, influencing their buying behavior. The [12] also added learning to psychological factors since past experiences with products shape future purchasing decisions.

On the other hand, [13] promote the importance of social factors such as family and other reference groups. Family members can significantly influence buying decisions and reference groups such as friends, colleagues, and social groups can severely impact consumer choices or current and desired social status.

Various authors [14,15] also explored the influence of other sets of factors such as cultural, personal and economic factors. Consumers' culture as broader cultural context, including traditions and values, shapes consumer preferences. Even subcultures that are represented by smaller groups within a culture, such as ethnic groups, can have distinct buying behaviors. According to [16] personal factors such as age and life cycle stage are the ones with most distinct changes. Different stages of life bring different needs and buying behaviors. Even a person's job can influence their purchasing power and preferences. Even a lifestyle is not without an impact. How individuals live their lives, including activities and interests, affects their buying choices [17]. Economic factors represent the limiting factors in the mind of consumer. Disposable income levels determine what consumers can afford which is often the other side of the equation. Even the expectations of future income changes can affect what the consumers buy today. Even broader economic trends, such as inflation or recession, impact consumer spending [18].

Understanding these fundamental factors at any given time is crucial for businesses tailor their marketing strategies to better meet the needs and preferences of their target audience.

Evidence within the current body of knowledge on consumer behavior changes during the COVID-19 pandemic is divided regarding how consumers adjusted their purchasing habits compared to the pre-pandemic period. Several studies indicate that consumers increased their product purchases, particularly in the early stages of the pandemic [19,20]. Conversely, other research suggests that consumers shifted towards more sustainable consumption and actually reduced their product purchases [21]. This latter evidence is supported by studies conducted in the pandemic's initial phases, challenging the assumption that government measures to contain the virus would lead to decreased consumer purchases [22]. Given these contradictory trends, this research study also aims to provide insights into the behavior of Slovak consumers during the pandemic.

III. Research Methodology

This research focused on consumer behavior changes that occurred during the COVID-19 pandemic and prevailed after its conclusion. Therefore, the main aim of this paper was to explore these changes and outline future trends in consumer behavior. This research was based on consumers and their opinions, habits and experiences. Therefore, an empirical analysis was selected as the main method of this research. A survey was conducted to collect the consumer data. A questionnaire was used to structure the information necessary for analysis. This questionnaire consisted of total of 26 questions. Seven of those questions collected socioeconomic data of consumers and the remaining 19 questions were targeted to collect data on consumer behavior changes. Validity and reliability of collected data was verified statistically. Consumers were addressed by email and in person using personal method of filling in the questionnaire through members of the project team and university students.

The sample file consisted of 1172 consumers from Slovak republic. In order to make this research credible and its findings generalized for whole public, the sample file was created as a representative sample of base file that consisted of all consumers in Slovak republic older than 18 years old, which is the age of adulthood in this country. The data was collected during the period of years 2021 and 2023. Table I shows the structure of sample file according to the age of consumers in sample file and the base file. Pearson Chí-squre test was used to verify and confirm representativeness of this sample.

TABLE I. SAMPLE FILE AND BASE FILE

Base file – absolute expression				Sample file – absolute expression		
Age	**2023**	**2022**	**2021**	**2023**	**2022**	**2021**
18-29	Date is not available at the time of processing	856586	878419	72	206	26
30-39		815154	828026	82	135	26
40-49		879998	872853	37	125	32
50-59		705272	703452	62	118	18
60-69		683376	689923	39	99	22
70 or more		618244	599217	4	55	14
Total		**4558628**	**4571888**	**296**	**738**	**138**
Base file – relative expression				**Sample file – relative expression**		
Age	**2023**	**2022**	**2021**	**2023**	**2022**	**2021**
18-29	Date is not available at the time of processing	18.79%	19.21%	24.32%	27.91%	18.84%
30-39		17.88%	18.11%	27.70%	18.29%	18.84%
40-49		19.30%	19.09%	12.50%	16.94%	23.19%
50-59		15.47%	15.39%	20.95%	15.99%	13.04%
60-69		14.99%	15.09%	13.18%	13.41%	15.94%
70 or more		13.56%	13.11%	1.35%	7.45%	10.14%
Total		**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Source: Own elaboration according to Slovak bureau of Statistics.

Other statistical tests were used to analyze the data and to identify trends for the future. The most important tests that were used are the following: binomial test, correlation tests (Pearson and Spearman) and *t*-tests.

IV. Results

This research covers a current topic of post pandemic societal impacts and changes with emphasis on consumer behavior. Since there is already a lot of information on how the consumers behave during the pandemic, this research focuses most importantly on how their behavior evolved after the conclusion of the pandemic. Therefore, the findings of this research are also structured by the individual years of the pandemic. One of the most significant changes in consumer behavior during the pandemic was related to fluctuations in quantities of products bought. According to the data presented in Fig. 1, it can be concluded that the majority of consumers in each age group reduced the quantity of products they purchased during the pandemic. The most significant reduction is observed among consumers aged 30 to 39, with up to 60.91% decreasing their purchases. Conversely, consumers over 70 years old exhibited an equal likelihood of either maintaining or reducing their purchase quantities. Notably, nearly 21% of this age group increased their purchases, the highest percentage across all age groups.

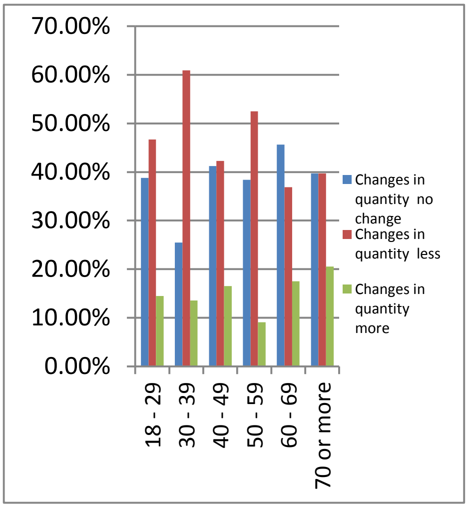

Figure 1. Changes in quantity based on age of consumer

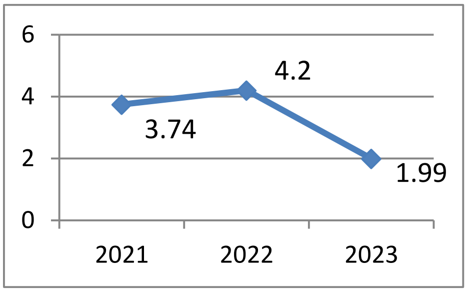

Figure 2. Tendency of shopping unaccompanied during different pandemic years

However, this phenomenon and its effects need to be further explored. This research also measured the different aspects of fear that consumers felt during the COVID-19 pandemic and how these fears impacted their consumer behavior. The data shows that consumers were very concerned about the health. However, fear for the health of loved ones was more impactful than the fear for their own health. This finding can also be explored in terms of one of the interesting phenomena that were observed during the pandemic that was the tendency to visit shops unaccompanied. Fig. 2 shows how this tendency evolved during different years of pandemic. It is clear that as the pandemic progressed consumers were more concerned for the health of their loved ones and therefore, in 2022 at the height of the pandemic, the coefficient was observed at its highest level. On the other hand, the data shows that in 2023 the situation was starting to return to its pre-pandemic state.

However, not all consumers responded to such treats equally. According to the data, older consumers were less likely to take health fears under consideration when making shopping decisions even though they were more at risk during the pandemic. Only one in four considered their own health when choosing whether to visit a store. The most dominant factor influencing their behavior was the location of store. On the other hand, consumers between 30 – 49 years old were most affected by such fears. Fear for health of a loved one was even more dominant than fear for own health. This also resulted in significant decrease in shopping accompanied (up to 71.69% in these age segments).

Furthermore, the influence of common factors on consumer behavior was altered during the pandemic. Data shows that even though family remained the most important factor, its influence significantly increased (by 1.33 points on 5-point scale based on comparison between its levels during 2020 - 2023 period). On the other hand, the influence of other groups of people such as colleagues, friends, neighbors decreased throughout all age spectra. In some of these groups the observed decrease was up to 0.96 points (colleagues in 2021). This finding proved that consumers need a direct contact with such people to be influenced by them even during this digital age. Furthermore, the influence of media varied based on this consumer characteristic. Fig. 3 demonstrates how the influence of media changed during the individual pandemic periods according to the age of consumers. According to the data, the influence of media gradually increased in the age segment of the oldest consumers. It is also notable that the trend was opposite for the youngest consumers, even though it was not so radical.

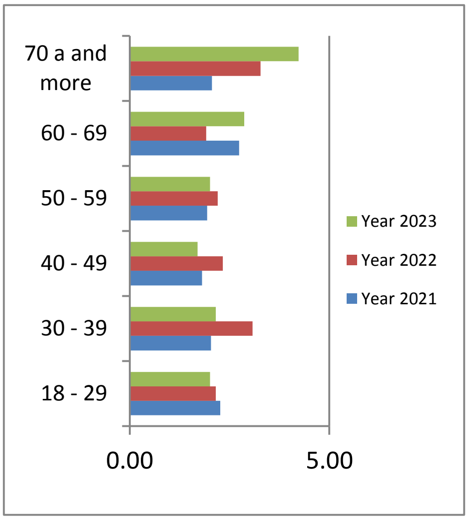

Figure 3. Influence of media on consumer behavior based on age and pandemic year

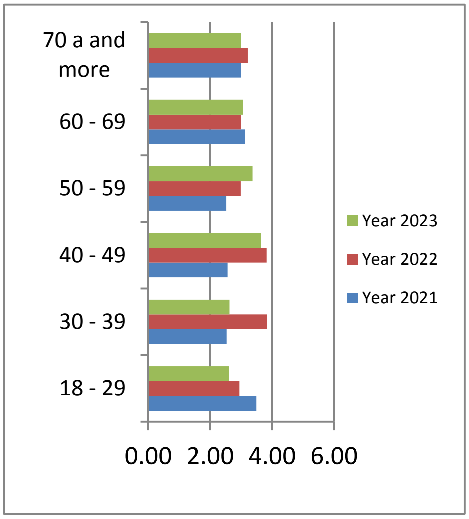

Figure 4. Influence of family on consumer behavior based on age and pandemic year

The year 2022 marked the highest influence of media on consumers between 30 to 59 years old, however it was the opposite for consumers in segment 60 – 69 years of age.

In comparison, Fig. 4 shows the influence of family. It is clear that this factor was more impactful in 2023 than media. However, its influence on younger consumer observed a slight gradual decrease. On the other, hand data shows that family was constantly important as a factor for consumers older than 60 years old and its impacts marked a gradual increase in age segment 50 – 59 years of age. The influence of family was very high for consumers aged 40 – 49 in 2022 and 2023.

This research also shows new factors of influence that emerged during the pandemic times. Notably, the feeling of safety was significantly correlated with shop selection of consumers. Up to 56.45% of all Slovak consumers took this factor under consideration when choosing a brick-and-mortar shop to visit during pandemic. Interestingly, this number was lower for more at-risk groups of consumers such as elderly people (41.93 %).

The most notable change in shopping during the pandemic was its shift towards online methods of procuring goods and even contactless expansion of contactless payments. The findings of this research proved that these phenomena also occurred in Slovak republic. However, the findings again observe differences among consumer segments. Fig. 5 shows the average level of agreement with several statements related to preference of these technological approaches during the COVID-19 pandemic.

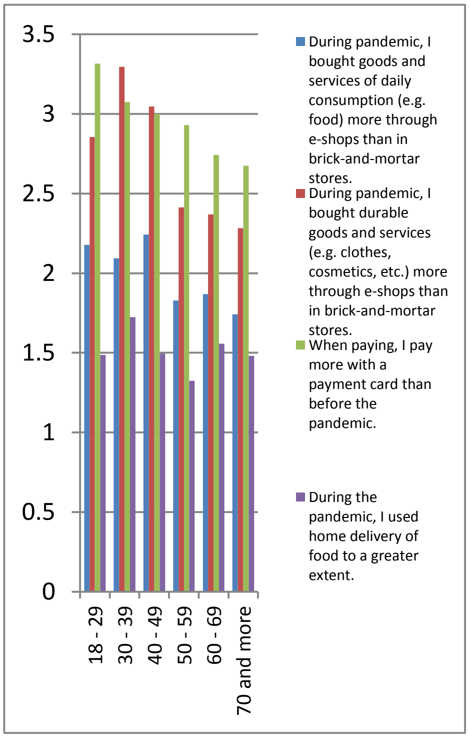

Figure 5. Online and contactless payment preferences based on age

According to the data provided in Fig. 5 the highest rates of preference were observed in younger generation, especially their increased preference of buying durable goods and credit card payment as preferred payment method. Furthermore, it was also the younger consumer segments that were more likely to buy daily consumption goods online. On the other hand, older generation was more likely to use food delivery in comparison to their pre-pandemic habits. These findings demonstrate the ability to adapt and evolve their consumer behavior to accommodate the conditions in external environment during an adverse event.

V. CONCLUSION

This research focused on exploring some major aspects of consumer behavior during the COVID-19 pandemic and shortly after its conclusion. The research into effects of COVID-19 pandemic has provided many significant findings with drastic implications for societies worldwide. Such major changes created a new reality that many of the entrepreneurs had to face. Therefore, understanding consumers' opinions during such major adverse events is crucial for several reasons. Several other research studies focused on exploring consumer behavior changes in other countries [4,9,11,12,21,23]. Their findings do not vary significantly from the results obtained by this study on the sample of Slovak consumers. This indicates that the effects of the COVID-19 pandemic were observed worldwide.

Even though the COVID-19 pandemic has officially concluded, its effects have still not yet been overcome. This research study proved that some changes that occurred during the pandemic and societies still remain in practice today. The most significant of these are the preference for online shopping, increase in delivery of goods and food and in some cases also the more sustainable models of consumption. The latter can be observed, especially in younger generations. There are more aware of the impacts of production and their consumption on societies and environment. This finding is especially positive since it's going to be this younger generation that are going to form the future trends of development in our economies. Businesses should therefore prepare and implement measures to target such emerging consumer segment. This focus can for example be on environmentally friendly products especially those that use less plastic or are outsourced locally. Working with local providers could be especially beneficial since not only it can reduces transportation costs, it can also help to attract these types of consumers. Furthermore, it is clearly essential to operate an e-shop along the traditional brick-and-mortar store in order to attract younger consumers and also to be better prepared for adverse events that could potentially include lockdowns.

Should another pandemic or similar adverse event occur in near future, it is probable that consumers would react similarly as described in this research. Now that we know how the consumers change their behavior during pandemic, we can be more prepared to react to such adverse events in near future. One of the most significant finding is the fact that even though consumers are initially affected by their fear this effect is not long lasting.

Several recommendations for entrepreneurs can also be formulated based on these findings. Since it's obvious that younger generations are more aware of effects of consumption and production on environment, it would be useful to focus more on production of environmentally friendly products and also use this information in advertisement of such products. Furthermore, it is important to provide correct information for these consumers, since they are they adapt it using information technologies. Therefore, being truthful and environmentally aware is going to be a very important trend for near future.

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Original Scientific Article

Evaluation of Intellectual Capital as a Factor in the Development of Business Systems Industries

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Abstract—**This paper analyzes the role of intellectual capital ie intellectual property in economic and social development, as well as its function within the company as an important and often crucial development factor. Furthermore, this paper explains the knowledge-based economy as a fundamental change in the economy and its logical path of development. The focus of this paper is on methods and models for measuring intellectual capital. The authors present and analyze quantitative and qualitative methods and approaches, and in the conclusion, they provide a critical review and propose a new direction for measuring intellectual capital. Apart from the above, an example of assessing the value of intangible assets of small and medium-sized enterprises from the countries of the European Economic Area is provided.**

Keywords - intellectual capital, knowledge economy, indicators, quantitative, qualitative.

I. INTRODUCTION

Intellectual property, with its two components - industrial property, on the one hand, and copyright and other related rights, on the other hand, is one of the basic levers of economic and social development. Science, technology and innovation are areas that continuously produce technical progress, ensuring the sustainability of development raising the level of economic competitiveness. Apart from that, innovation and technology transfer are solutions for getting out of economic crises that occur more and more frequently under the influence of various factors. They are also the solution for the permanent renewal of necessary technologies by directing research according to the needs and demands of the growing market in globalization situation.

In the process of reforming the area of intellectual property, it is necessary to make a turn regarding the exchange of technologies and new models of economic management, towards models that can include the issue of intellectual property as an element of economic cohesion between large producers and small and medium-sized enterprises. In financial evaluations as well as in organizational management, each of the categories of goods and their complexity are taken into account as an economic resource.

Intangible goods are defined as intangible factors that favorably affect the results of the company's operations, the production of goods or the provision of services. According to Roos, Pike and Fernstrom, “Intellectual Capital can be defined as a non-monetary and non-physical resource that is fully or partially controlled by the organization thus contributing to the organization's value creation” [1]. Economic activities based on the production of knowledge, its distribution and consumption are not something that is new to the economy. However, what is new is the vision that such activities will become the most important factors of the entire economy. That is why the increasingly dominant role of knowledge as a production factor indicates significant structural economic changes and the transition of the industrial economy towards an economy intensively based on knowledge [2]. Intellectual capital is becoming a crucial performance and growth factor in a knowledge-based economy where companies with modern management tend to identify their core competence as intangible assets rather than tangible assets [3,4] (Fig. 1). "The key value of the concept of knowledge economy is that it connects the creative potentials of the human factor, innovation potential and technology, as generators of growth, institutions and economic actors, which is crucial for initiating and sustainability of economic growth and development" [2].

II. Knowledge-Based Economy

The knowledge economy represents a fundamental change from the economy that was based primarily on physical resources to an economy that is predominantly based on knowledge (knowledge that controls and directs physical resources, in addition to human, intellectual and other resources). The basis of this (r)evolution is the decisive role that knowledge plays in the modern economy. In the past decades, the increase in the economic importance of technologies, information, economic processes, human capital, organizational skills and abilities, i.e. factors that are essential in relation to knowledge have increasingly influenced world, regional and national economies, and as such these factors have been integrated into economic theory and management theory in parallel with current practice. Each of these factors, considered individually, reveals elements that are particularly valuable and have significant practical applications. Nevertheless, their common denominator is knowledge, while these elements actually represent methods of individualization and operationalization (Fig. 2).

We bear witness to the fact that competition and permanent changes in technology have caused the need to transform and develop all areas of human life. The planet is faced with several massive changes: while resources are obviously limited, human ambitions and desires

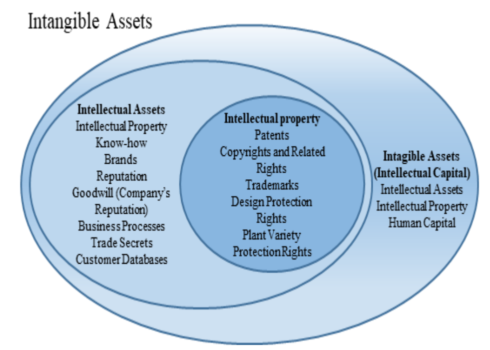

Figure 1. Intangible assets of intellectual capital. Source: Authors.

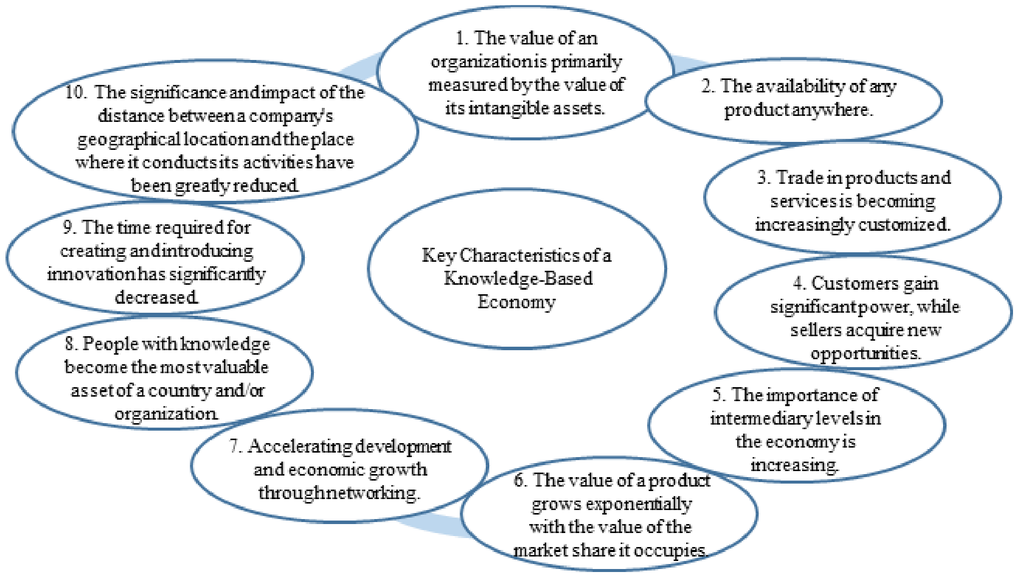

Figure 2. Key characteristics of a knowledge-based economy. Source: Authors.

make them unlimited. Visibility of processes, transactions, and relations, enabled by the Internet and social networks, calls for even greater responsibility so as to make communication, business solutions, and cooperation as quality as possible. Survival of each organization, and even nations, depends on the possibility to keep in permanent contact with progress and changes in all spheres [5]. As a result of globalization and digitalization, companies can build around a thinking model instead of a production/service delivery model. To be effective, the most important key is how effective human resources, as intangible assets, are allocated to be more innovative and creative. There are numerous case studies that indicate that increased employee commitment to the company contributes to greater customer loyalty and, as a consequence, profitability. In direct contact with clients, employees can use appropriate skills and knowledge to complement technical solutions, creating an emotional connection with clients. Intangible assets of a company, such as employee relations and reputation, are those aspects of a company's competitiveness that cannot be copied and thus provide an indisputable competitive advantage. [6]. Companies are constantly looking for new and talented employees in a market where there is a strong struggle to acquire talented employees. It is not enough for companies to focus on introducing new talented employees into the company, there is also the challenge of retaining talented employees [7].

Opportunities for changing evaluation of innovativeness, with implementation of leadership strategies based on employee knowledge, are growing. In the current stage of economic life, business will be developed after the thinking model rather than the product development and service rendering model [6]. A competitive organization based on knowledge must integrate aspects related to intangible assets and it must orientate itself towards the issues related to design and quality creation, knowledge development, organizational image, ability to activate human resources in the long term, etc. The management of intangible resources primarily depends on who manages the intellectual capital (that is, its ability to manage knowledge), and to what extent that capital can generate profit and enable the trade of intellectual goods. Management of intangible resources must articulate components such as resources and competencies, functions, processes.

Intangible assets play a very important, and often crucial, role in ensuring the competitiveness of small and medium-sized enterprises, since in the financial sense (appearance on the market, marketing, etc.) they cannot compete with large enterprises and companies. Intangible assets are considered key factors in creating the value of organizations and are associated with a new management approach aimed at long-term profit. Within such a view of management, an ethical and long-term approach is more important than meeting the demands of financial investors [8].

III. Evaluation of Intellectual Capital

What is crucial for intellectual capital is the fact that it has the role of potential for creating surplus value in the company, which will be realized as much as the company successfully manages its intellectual capital. in the case of intellectual capital (as opposed to other types of capital), more is not always better, because companies do not need a larger stock of knowledge, but more productive knowledge that creates added value [9]. In order to understand how intangible assets create value in companies, various frameworks and reporting approaches have been developed. At the same time, intangible assets are incorporated into evaluation models applied by banks and investment funds that contribute to increasing the transparency of business operations and their higher rating [10].

The authors single out four basic approaches for measuring intangible assets. Based on a broader insight into the literature and approaches of different authors [10-19] we herewith highlight the division accepted by many of the authors which was proposed by Luthy as early as the end of the last century [20]:

Methods of direct evaluation of knowledge capital (DIC) estimate the monetary value of intangible assets by identifying their various components. Once these components are identified, they can be directly evaluated, either individually or as an aggregated coefficient.

Market capitalization methods (MCM) calculate the difference between the company's market capitalization and capital (its share capital) as the value of its intangible assets.

Return on assets (ROA) method, the company's average pre-tax earnings for a certain period of time is divided by the company's average tangible assets. The result is the company's ROA, which is then compared to its industry average. The difference is multiplied by the company's average tangible assets to calculate the average annual earnings from intangible assets. By dividing the average profit by the company's average cost of capital or interest rate, the value of its intangible assets can be estimated.

Scoring methods (SC). Different components of intangible assets or knowledge capital are identified and indicators and indices can be presented in score reports.

The first three methods measure the financial value of intellectual capital, while the last method focuses on non-financial criteria, and the mentioned methods have various advantages and disadvantages. The ROA and MCM methods are useful in mergers and acquisitions (S&P) or stock market valuations. They can also be used to compare companies from the same industry and are suitable for displaying the financial value of intangible assets. Because they are based on long-established accounting rules, they are easily communicated and applied within the accounting and banking sectors. Their main drawback lies in their strict financial approach. ROA methods are very sensitive to changes in interest and discount rates, and many of them are not useful for nonprofits, internal departments, and public sector organizations.

The advantages of the DIC and SC methods relate to the creation of a more complete picture of the state of the organization and can be easily applied to every level of the organization. They are very useful for non-profit organizations, internal departments and organizations from the public sector, as well as for social and environmental needs. Their disadvantages relate to the fact that the indicators are context-dependent and must be adapted for each organization and each purpose, which makes comparison very difficult. In addition, approaches that consider the entire organization can mean a lot of data that is difficult to aggregate, then analyze and finally synthesize. If it is done, it requires great commitment and a high level of expertise.

The methods, models and techniques of assessing the value of intangible assets determine their complex character and typological diversity. Starting from the general methods of determining the value of intangible assets, for each category and type of intangible assets, the method that best corresponds to the set goals must be chosen.

The first criterion of classification, the method for analysis is focused on the inclusion of intangible assets, which implies making a distinction between:

Holistic (comprehensive) method in the sense of a unique analysis of the entire system of intangible assets of a company or branches that are multiple interconnected; holistic methods suggested in scientific literature and business practice are: IC-IndexTM (knowledge capital index); ratio of market and book value; Tobin's coefficient Q; VAICTM; earnings from knowledge capital; EVATM; calculated value of intangible assets; IAMVTM; AFFTTM.

Atomistic or partial method, which involves the analysis and assessment of the value of an individual intangible asset. The atomistic methods that are applied are: value chain representationTM; Skandia navigatorTM; scoring with balanced indicators; monitor of intangible assets; human capital intelligence; patents valued by the number of citations; HRCA; inclusive valuation methodology; technology broker; TVCTM; value explorerTM; valuation of intellectual property and others.

From the point of view of determining intangible assets, in terms of value and lack of value, the scientific literature suggests the following:

Non-monetary methods that approach intangible assets in terms of qualitative analysis (for example, value chain viewTM, intangible asset monitor, balanced scorecard, etc.);

Monetary methods (for example, the ratio of market to book value; Tobin's coefficient Q; earnings from knowledge capital; VAICTM;

EVATM; calculated value of intangible assets; IAMVTM; AFTFTM, etc.).

Eight methods are most often used in economic practice as follows:

Four monetary and holistic methods: ratio of market and book value; Tobin's coefficient Q; economic added value (EVATM); earnings from knowledge capital, proposed by Lev [21];

Four non-monetary and atomistic methods: Skandia navigator (developed by Edvinsson and Malone) [22]; monitor of intangible assets [3]; scoring with balanced indicators [23] and value chain presentation.

From the point of view of the strategic management of the company, experts state the following groups of methods, which basically represent a regrouping of the previously presented methods, namely:

Methods based on market capitalization: Tobin's coefficient (Tobin's Q); indivisible difference. Tobin's coefficient Q is the ratio of the market value of the mentioned company to the replacement value of its tangible assets. The indivisible difference is the difference between the market value of the company and its net assets;

Methods based on return on assets: economic added value (EVA); market value added (MVA); net asset value; earnings from knowledge capital.

EVA reflects residual net profit or existing economic profit only when the difference between the return on invested capital and the weighted average cost of capital of the company gives a positive result.

MVA is calculated as the difference between the market value of the company and the subscribed capital, loans and retained earnings.

Earnings from knowledge capital is calculated as the ratio of the difference between the normalized annual net profit and the net profit of tangible and current assets on the one hand, and the capitalization rate of knowledge capital, on the other.

Valuation of intangible assets using these methods is achieved through information and non-monetary valuations based on surveys or special forms of discounted cash flow.

IV. Example of Evaluation of Intangible Assets of Small and Medium-Sized Enterprises from the Countries of the European Economic Area

Due to their ability to generate economic benefits, intellectual property assets today play an important role in the progress and development of small and medium-sized enterprises. The management of intangible resources includes, in a certain form, the identification and analysis of intellectual property assets, that is, the evaluation of intellectual property assets - intellectual capital.

The current quantitative and qualitative valuation methods are the ones most often used in determining the value of intellectual property assets. While quantitative methods evaluate the monetary value of intellectual property assets, qualitative methods evaluate intellectual capital assets using an assessment and scoring system.

Choosing the appropriate method for the valuation of intellectual capital goods depends on its characteristics, the medium of marketing, the target group and the expected results of the evaluation.

The main reason for evaluating the value of intellectual capital is to realize its maximum value and, consequently, the value of the organization by making optimal decisions by managers. There are certain scenarios where valuation is necessary and required: valuation of businesses (transactions, takeovers and mergers, bankruptcy, joint ventures, etc.), sales or licensing deals, financing (bank loans, venture capital, investments), tax planning and tax compliance, external reporting and accounting, dispute resolution and related support, internal management.

The choice of evaluation methods must be in accordance with the intended objective: the right methods for objectives that have non-monetary results (for example, management decisions) are qualitative methods; objectives with monetary results (such as transactions) are suited to quantitative methods. For example, a valuation of intellectual capital for internal management will require an internal value, while a valuation for sale or licensing will require a market value.

These values may differ from each other. Several valuation approaches have been proposed, each with its own strengths and weaknesses. For best results, it is important to choose the appropriate method or set of methods for each individual case. Practically every set of evaluation tools contains one or more described methods.

Important factors that must be considered when requiring intellectual capital evaluation and selecting appropriate tools based on the following questions are as follows:

1) Which intellectual capital assets need to be valued?

Valuation of intellectual capital is possible if it is identified and differentiated from other tangible or intangible assets. In practice, however, it is difficult to separate, for example, two interdependent patents or technological advances from a brand name.

2) What is the purpose of valuation?

The value assessment procedure determines the type of value (internal value, market value) and the type of required value assessment result (qualitative, quantitative).

3) Who is the valuation for?

Different valuation approaches are needed if the target group includes different investors or if the valuation is performed for internal management purposes.

4) Who conducts the value assessment?

The appraiser may have experience in a particular valuation domain and this could influence the choice of valuation methods. This can lead to bias in the valuation.

5) Date of valuation

The valuation date will affect the method chosen and, in the case of income-based methods, will affect discounting.

A. *Qualitative Approach in Evaluation. Methods Applied in EEA Countries*

Qualitative methods provide a guide to the value of IS assets through ranking and scoring systems related to various factors associated with intellectual capital assets. Those factors can have a positive or negative impact on the value of IS goods and cover all aspects that can affect an IS good (legal aspects, technological innovation level, market details and company organization).

Qualitative methods are used at the micro level to analyze the quality of intangible assets, their status and importance compared to other business aspects, the industry within which the company operates and the value of business competitors. At the macroeconomic level, qualitative methods provide a perspective of the useful life of intangible assets within the economic branch in which the company operates. A qualitative study is used to prove the justification of the basic assumptions of financial models for determining the numerical value of intellectual capital goods.

B. *Qualitative Assessment of Patent Value - Value Indicators Based on Patent Information*

When it comes to patents, there is a strong correlation between patent value and standard metrics that can be found in patent information documents. For example, the number of references to earlier patents during the research and examination process and the number of citations of a patent indicate its importance and value. The result is a network of patent citations, which is a useful tool for qualitative value assessment. In addition, the number and quality of applications, the size of the patent family, and the outcome of patent application challenges can be indicators of value.

C. *Evaluation of Value Indicators: IPScore*

IPScore is software created by the Danish Patent and Trademark Office in collaboration with Professor Jan Mouritsen, Copenhagen Business School, and some Danish companies [24] and is used for internal evaluation of the value of technology, patents and patent portfolios within an organization. This tool provides a framework for strategic patent valuation and management. IPScore consists of five categories: legal, technology, market, financing and strategy, each with associated questions. Each question refers to a different value indicator. Each question is scored from 1 to 5 according to the strengths or weaknesses of the patent. The indicators provide a complete picture of the patent and its implicit risks and opportunities. These are then graphically displayed in various forms that are used in management decision-making.

D. Advantages and Disadvantages of Qualitative Valuation Methods

The main advantage of these methods is simplicity. After obtaining the relevant information about the valued intellectual capital assets, it is very easy to perform the classification and valuation of these assets without the need for complex methods. Another advantage is the fact that the evaluated data is available to the public. Qualitative valuation methods facilitate the comparison and classification of intellectual capital assets within a company or comparison with the intellectual capital assets of competitors.

The disadvantages of estimating value using patent information linked to value indicators are that it emphasizes simply counting citations, thereby deliberately ignoring any added value within the citation network. The engaged appraiser must have sufficient experience and decide which indicators are relevant for the valuation and which are not. The quality and realism of value estimation using IPScore software largely depends on the quality of the information used.

Qualitative evaluation methods are used for internal management of intellectual property. They are useful for comparing, categorizing and classifying intellectual capital assets within a company's portfolio or for comparison with intellectual property competitors. They are also useful for evaluating the risks and chances of intellectual capital, i.e. properties.

Some of the models that can be used by both corporations and medium-sized enterprises is the Kaplan Norton model of firm valuation. The four perspectives include financial, customer, internal processes, and learning & growth. A few different objectives will probably emerge as company creates strategy map. [25] Inadequate market research is one of the key reasons why 70% of startups fail. The model that is called the Value Net Model is a strategic framework developed by Adam Brandenburger and Barry Nalebuff [26], primarily introduced in their book “Co-Opetition”. This model helps organizations analyze their business ecosystems by identifying key players and understanding their interactions. There are several key components of the model: players that influence a business (customer, suppliers, competitors, complementors); added values refers to the contribution each player makes to the ecosystem, which can include products, services, knowledge, and resources; rules encompass the regulations, norms, and agreements that govern interactions among players; scope (defines the boundaries of the business ecosystem, specifying which players are included and excluded). Situations when company or start-up could use the model: market entry (before entering new markets, businesses can analyze the existing ecosystem and potential partners or competitors); ecosystem optimization (businesses can optimize their position fostering beneficial partnerships maximizing the value of the market); innovation (introducing new products or services, understanding the value net can guide innovation by considering how it fits into the larger ecosystem).

V. Conclusion

In a knowledge-based economy, the terms knowledge economy and knowledge-based economy are distinguished. The knowledge economy refers to the production of knowledge, while the knowledge-based economy uses knowledge and technology to ensure growth and development and higher engagement of the capacities. However, the way intellectual capital is managed significantly (and sometimes decisively) affects business performance, i.e. the effects of using intellectual capital are not realized automatically, but must be expertly planned and implemented.

The intellectual value of the company is part of the total value, created through the process of accumulation of various intellectual components (expertise of employees, organizational processes, and the sum of knowledge contained within the organization, etc.). Companies with large intellectual capital create new knowledge more easily than companies with little intellectual capital or poorly managed intellectual capital, even when it exists to a significant extent. The wide coverage of intellectual capital affects the perception of the impact on the company's business performance and the complexity of its valuation [27].

The impact of intellectual capital on the business performance of companies is evident and indisputable, but in practice these cause-and-effect relationships are still not sufficiently clearly seen and unified. Professional literature offers numerous researches, models and solutions, however, there is an insufficient number of empirically verified laws that could be unconditionally accepted. The authors gave an overview of the most represented and accepted ones, but also point out significant limitations because potential models should have a holistic character and include other factors, such as national and regional culture, narrower and wider political and legal environment, and others.

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Original Scientific Article

"Distributed" Management of the "Knowledge Economy": "Income – Risk"

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Abstract—**The subject of the study is the "knowledge economy" as an economic sector experiencing the effects of management tools at the macro level. The purpose of the study is to demonstrate the doctrine of "distributed management", which unlike the classical "goals-tools" approach is aimed at taking into account the power of the tool and the cumulative effect of its application. The methodological basis of the research is the theory of economic development and "knowledge economy", elements of mathematical formalization of the "distributed management" principle, ideas about the relationship between income and risk and a taxonomic approach. The result is that the formulation of distributed management has been obtained in relation to the sector of the "knowledge economy", which includes science, education and high-tech sectors of the economy. The need for direct statistical accounting of the "knowledge economy" is indicated for the most adequate identification of the processes taking place in this sector and for substantiating the appropriate economic policy for its development. The pros and cons of the Eurostat methodology for accounting for the "knowledge economy", as well as the author's methodology for evaluating this sector are shown. Models of the development of the "knowledge economy" in the "income–risk" coordinates are presented, according to which it is possible to differentiate the methods of managing the sector development with the use of "distributed management".**

Keywords - distributed management, knowledge, risk, goal principle-tools, income-risk scale

I. Introduction

Knowledge management is usually considered at the microeconomic level, a firm, a corporation using information and communication technologies and learning effects, but the leading role in the generation and dissemination of knowledge is assigned to universities [1]. Their role is leading in the creation of technologies and the acquisition of patents. However, there are studies paying attention to the connection of various macroparameters characterizing the knowledge economy as a macroeconomic sector [2]. At the same time, they investigate correlations or their absence, but the "knowledge economy" is not identified, since indicators of costs for internal research and development, GDP per capita, GDP growth rate, the number of researchers and the human development index, which characterize the economy in general, are introduced. The vast majority of knowledge management research concerns the microeconomic, industry level. Moreover, it is precisely such studies [3] that have expanded, shifting the emphasis from management as such to the application of knowledge and obtaining additional competitive advantages through knowledge. Conceptual approaches in the field of knowledge management are also developing [4], shifting the emphasis from knowledge-intensive industries to knowledge-based service activities.

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II. DISTRIBUTED MANAGEMENT OF THE "KNOWLEDGE ECONOMY": RESEARCH METHODOLOGY

Management consists in the forceful action of the subject on the object in order to change the state of the object or ensure its movement in the required direction [5]. In control theory a function is usually used that describes the state of an object and its change, as well as a control function that provides a change in the state of the object. However, the object moves from one state to another not only under the influence of control actions but also the presence of other objects that also affect the control object in question. These two types of influence are very difficult to separate, which creates great difficulties in interpreting management and selecting management tools – economic policy measures. The rate of change in the state of the object is an important characteristic of management.

Thus, the managed system is defined by the state of the control object and the control function, which reflects the state of the control subject. But in a mathematical sense, in particular, in the functional of L. Pontryagin [6] introduced the control function is not changeable, but in practice it is permanently changing, since the goals of development, the state of the objects of management and the power of the instruments of influence are subject to change.

Of particular note is the possible connection of two functions – the state of the object and management, which depend on time and on the tools used and initial conditions.

Here, direct and feedback links between the subject and the object of management become important. Management as an impact can no longer be considered as an exogenous factor. This is of great importance in knowledge management, which is very heterogeneous and requires the selection of specific incentive tools, since a common set of measures can have a very different impact on each type of knowledge. The goals of influencing knowledge can be to increase their volume, improve their quality, and expand the coverage of this knowledge. But they can be influenced by various tools. If we apply a well-known set, then its impact on the goals of knowledge development will be distributed differently to the specified goals in the field of "knowledge economics". This is what constitutes the so-called "distributed management". The idea of this doctrine, in contrast to Tinbergn's principle of "goals-tools" [7], is that over time the power of influence of each tool affecting the control object changes, and the sensitivity of the goal and object to each tool changes, which forms a cumulative effect for each tool [8]. This approach significantly modernizes economic policy, taking it out of the classical approach, which considers management tools exogenously to the economic system [9].

The principle of "goals-tools" of management can be mathematically represented as follows: let the number of goals be T_k, where $k = 1....N$, the number of tools I_j, where $j = 1... M$, $M \geqslant N$, then the equations connecting goals and tools can be written according to (1):

$$T_k = \sum_{k=1}^{N}\sum_{j=1}^{M} a_{kj} I_j \ . \qquad (1)$$

Having set goals (by setting them), you can create a system of equations, the solution of which will give you the tools that will allow to achieve the set goals [7]. This approach is static, does not take into account either the diversity of goals and their coherence (the structure of goals), or the diversity of policy measures (management) and the structure of tools, which changes based on political preferences. If knowledge–related attitudes are chosen as goals, then it is not possible to see how the same tool affects different types of knowledge and how they, in turn, are related to each other. This creates an inherent difficulty in forming a policy for the development of the "knowledge economy", not to mention influencing the risks of obtaining new knowledge, which can be quite high, as well as the risks of applying already created (open) knowledge.

The development of the principle of "goals-tools" in the form of linking tools to each goal also does not work in the field of "knowledge economics", because it is impossible to see such a link in advance. Unfortunately, this interpretation of the Tinbergen principle does not work in the field of macro management either.

It is necessary to take into account the institutional changes [10], implementation of projects [11], investments [12], reliability of the functioning of management facilities [13], state of information systems [14] and human capital [15], etc., affecting macroparameters, the level of accumulated knowledge and their dissemination. There are so many of these conditions that a distributed management solution is a condition for the formation of a new system of equations linking changing goals, instruments of influence, development factors and changing conditions that determine both conditions, factors, and policy measures and development goals.

Let's show one of the options for "distributed" management. Under it a set of impacts on the management object is considered, taking into account the strength of the influence of tools on the goals and factors of the development of the object. In this case the principle of "goals-tools" is modified and expanded. Distributed management links a change in purpose with a change in tools and factors. If the number of tools (M) and factors (L) do not match, then the system of equations can be written as follows [8]:

$$\frac{dT_k}{dt} = \sum_{k=1}^{N} \{ \sum_{i=1}^{L} b_{ki} \frac{dF_i}{dt} + \sum_{j=1}^{M} a_{kj} \frac{dI_j}{dt} \} \quad . \qquad (2)$$

It is fair to note that the presented system of equations (2) with respect to a_{kj}, b_{ki} has the same disadvantage as the system of equations (1). These coefficients determine the strength of the influence of changing tools and factors on the goals. In Lucas's theory of expectations, the same disadvantage arises when evaluating expectations [9]. When complex goals are considered, for example, building knowledge and its quality, then we have the right to raise the problem of fundamental limitations regarding the assessment of past managerial influences relevant in the current regime and determining the future state of the management object. This basic condition is the basis for the uncertainty of creating – discovering new knowledge, spreading and ensuring high-quality assimilation and replication of knowledge, which is the risk of knowledge activity at various facilities – firms, corporations, regions, and nationwide. However, it is still appropriate to note that the principle of "goals-tools", arising from the mathematical logic of equations (1), which postulates the superiority of the number of tools to the number of goals, is transformed. It turns out a fundamental reservation, reduced to the fact that, according to expression (2), the number of goals should not exceed the sum of the number of tools and active factors. Otherwise, system (2) will not have a solution. Thus, the number of tools may be less than the number of goals. These are the outcomes we have in the practice of macroeconomic management and knowledge management.

The equation coefficient (2) will symbolize the strength of the influence of a factor or a specific tool, the effectiveness of which is determined by the movement towards the goal, the speed of this movement and the achievement of the goal, taking into account the cumulative effect of the tool.

Having presented the "knowledge economy" in the form of a sector consisting of science, education and high-tech sectors of activity, we will show the principle of "distributed management" within the framework of a theoretical scheme. It is reflected in Table I.

TABLE I. "DISTRIBUTED MANAGEMENT" AT THE MACRO LEVEL – "KNOWLEDGE ECONOMY".

Tools	**Added value of the elements of the economy structure, which together give the sector of the "knowledge economy"**		
	Science	***Education***	***"High tech"***
1	+	-	*n*
2	-	-	+
…	-	*n*	-
N	+	+	*n*

Source: compiled by the author.

In Table I "+" means (positive sensitivity of the element to the tool) such an application of the tool that leads to an increase in the added value of the element of the "knowledge economy", "–" (negative sensitivity to the tool) means a distance from the goal, that is, a decrease in added value or the absence of its increase, "n" is element of "knowledge economy" does not respond to the tool. Macroeconomic policy measures (money supply, interest rate, budget expenditures, exchange rate, etc.), as well as measures to influence elements of the "knowledge economy", in particular, stimulating the number of researchers, patents, the number of teachers, teachers, students at universities and schools, industry incentives for the introduction of high technologies, for example, digitalization and much more. All this can increase the knowledge economy, or not affect it, it all depends on the scale and effectiveness of measures in their combined application.

Table I reflects the current situation, which may change if a new, previously unused policy tool is introduced. Then it, like the system of equations, must be rebuilt taking into account such an introduction. This is especially true for the subsequent action of tools that dynamically change their strength. It also matters how this new tool will influence the government's measures already in place – to weaken or strengthen their effect.

The size of the "knowledge economy" as a sector can be estimated by the amount of value added created Y, which consists of similar values for science, education and high-tech sectors. However, it is possible to assess the development of this sector from the perspective of other goals – income, risk, the number of researchers and graduates, the created scientific contribution, patents, etc. Thus, goals can be set that also depend on a certain set of applied and introduced management tools.

Thus, we can write the following: $Y = \sum Y_i$ (i from one to three according to Table I); then $Y_i = a_{o_i} + a_{1_i} I_1 + a_{2_i} I_2 + \ldots + a_{N_i} I_N$ (N is number of tools).

With regard to the goals, the number of which is K, for the j_{th} option, we can write the following: $K_j = b_{o_j} + b_{1_j} I_1 + b_{2_j} I_2 + \ldots + b_{N_j} I_N$.

In practice, it may turn out that the goals are related, that is, $Y = f(K)$, where K, for example, is an increase in the number of researchers, which is relevant, in particular, for modern Russia. In other words, there is a task of increasing – expanding the knowledge economy, at the expense of science and technology, which is problematic to solve without increasing the number of researchers, which has been declining for many years. Having set goals, including structural elements (build–up, gross value added), it is possible to obtain a system of equations from which unknown values of instruments can be distinguished. Mathematically, the number of equations should be equal to the number of unknown tools, then the solution is not difficult. With the nonlinear nature of the equations, the solution can be obtained by numerical methods. With this formulation, optimization tasks are also possible, in particular, conditional optimization, which impose a framework for achieving some kind of optimum. This approach can be included as a block in the input–output method, overcoming its obvious (one of many) drawback when the calculation is based on direct costs – an assessment of their structure and relationship to the output structure. At the same time, it suggests the need to use and take into account policy tools, taking into account the "cumulative effect" of policy and "distributed management". In addition, the elements of the knowledge economy can show a certain coherence, which can be designated as. $K_j = h(K_{j-1})$, for $j > 1$. The cumulative effect can be estimated as follows: $a_N > 0$ is positive cumulative effect, $a_N < 0$ is negative cumulative effect, $a_N = 0$ is neutrality.

Next, we will consider the main models of knowledge management, taking into account the possibility of reducing uncertainty – the risk of reproduction and dissemination, the use of existing knowledge at any management facility and for any scale.

III. Discussion of the Results. Managing the "Knowledge Economy": Models and Risk Reduction

Knowledge is even more heterogeneous than the objects of the economy, and they change faster and on a larger scale. In addition, the goal of developing specific knowledge may be vague, which increases the requirements for the selection of management tools. However, the known, acquired knowledge can be controlled in terms of expanding its application, increasing the coverage of this knowledge and practical implementation – embodiment in the form of a technology or product. The use of a particular tool that affects the introduction, dissemination of knowledge, or its transformation, unlike purely economic objects, is described with great difficulty by the amount of income and risk. The reason is that the profitability of a particular knowledge is not obvious and arises in the current mode of using this knowledge, and the risk arises from the influence of specific tools, but is different, which creates the problem of comparing the risk for the same or different types of knowledge. Even for standard economic objects, risk and income change along their trajectories, often unrelated. However, there may be situations that reveal a connection between the specified parameters.

It is generally believed that the growth of income is accompanied by an increase in the risk of receiving it. However, in relation to knowledge, creation or application, income may be absent in the primary time interval, and the risk may increase as well as decrease. Moreover, each result depends on many conditions and even the content of knowledge itself. If, in relation to standard economic objects, the goal may be to increase income with the least risk, maximize

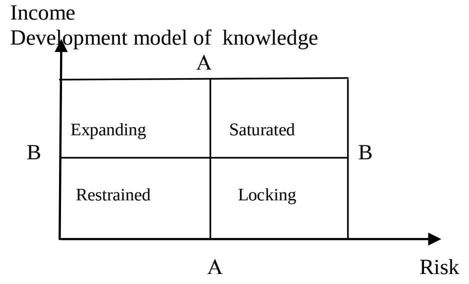

Figure 1. Income-risk matrix knowledge management models

income and minimize risk, then with respect to knowledge, this statement does not work, since the goal is to obtain specific knowledge or apply the knowledge obtained, regardless of how income and risk will change. This is especially true in a situation where knowledge is highly relevant and without it is problematic to imagine the development of some kind of activity.

Fig. 1 reflects general knowledge management models in situations where there is high or low income and risk. The models are separated by lines AA and BB respectively. The four basic situations of income and risk from knowledge management embody management regimes that are characterized by a set of tools designed to either stimulate income, reduce risk, or simultaneously affect both relevant parameters (income and risk).

With low income and the risk of applying knowledge, a model of restrained knowledge management is being formed. This forces the subject of management to look for opportunities to influence both income and risk, increasing the former, restraining the growth of the latter, assuming an established relationship between these parameters. With low risk and high income, there is a model of expanding with high income and risk of obtaining it, a rich knowledge management model is being formed. In this model, high income is reproduced in very risky conditions of applying knowledge, limiting the fact of using knowledge to further increase income. It is important to reduce the risk here. With low income and high risk, a model of locking development develops, since it is problematic to invest in knowledge that provides a high risk of application with a small income, and incentives for such activities are lost.

According to the models in Fig. 1, the following are the best basic situations of income and risk changes in knowledge management:

- growth of income and risk;
- income growth and risk reduction;
- reduced risk with the same income;

The second option is the most acceptable. However, in the reproduction of knowledge, as noted above, not only income is important, but also the content and purpose of the knowledge being created itself.

In general, it is necessary to look for tools that affect risk in the direction of its reduction, and income in the direction of increase (from the applied knowledge). However, the content of knowledge may not allow to reduce risk and increase income. Thus, the composition of the object and its structure brings standard estimates on the income–risk scale to a completely different plane [8]. It is necessary to distribute the tools according to the impact on knowledge itself, and only then on the income and risk from its application.

The change in income and risk for the economy/facility occurs differentially. In any case, the presented models are described exactly like this.

Note that the knowledge management models presented in Fig. 1 assume that the tools affect income and risk separately, not to mention different types of knowledge. However, for a particular knowledge, it may turn out that the risk and income of its application may be related. However, this implies a lack of connection between income and risk. This should be taken into account when making decisions.

Assuming that these parameters are related for the same knowledge, situations arise when achieving one parameter may worsen the second parameter [8]. Fig. 2 reflects the CC line of

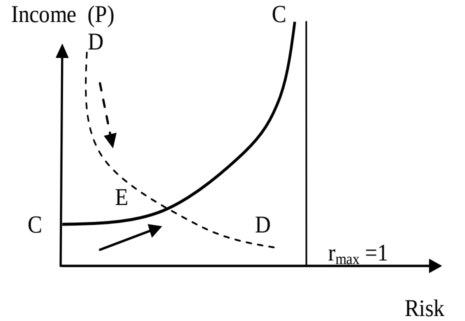

Figure 2. Income-risk dependence options in relation to knowledge management

income growth with increasing risk, and the DD line of income decrease with increasing risk.

Knowledge management should be aimed at changing the law of the relationship between income and risk, which follows from Fig. 2. If an ordinary economic object were considered, this would be achievable (not in all the same cases), but when knowledge is considered, it becomes impossible to provide such an influence to change the law of the relationship of parameters. This is a characteristic property of knowledge, and for each type of knowledge it manifests itself in its own way. Influencing knowledge in order to increase income with increasing risk is a completely natural outcome.

However, reducing the risk of applying knowledge, if it also causes a decrease in income, cannot suit the subject of management. If the risk increases and the income does not increase, then the process of building knowledge and its application may stop according to such an economic criterion. Thus, in the field of knowledge management, it is important to take into account the change in relevant parameters characterizing the economy of knowledge creation and implementation.

Point E in Fig. 2 is of interest, where income and risk are the same, but are given by different types of knowledge and management models, since Fig. 2 embodies all the models of Fig. 1. The power of tools according to the doctrine of "distributed management" is different, but their influence can lead the economy to point E. From this point, it is advantageous to move along the EU line to the left, since income almost does not decrease, and the risk decreases significantly. The option of an increase in income and risk or a decrease in income with an increase in risk are the worst in this case, given the current elasticity of the curves shown in Fig. 2. If the curves under consideration reflected the composition and content of knowledge, then it would be possible to assess how the structure of knowledge gives one or another combination of income and risk. Such a task can be described as promising within the framework of distributed management.

This example reflects the importance of "distributed" management in achieving goals and meeting accepted criteria. The analysis using Fig. 2 proceeds from efficiency, estimated as follows, We introduce an indicator of the efficiency of reproduction and use of k-type knowledge: $E_c = P_k\,(1 - r_k\,)/Z_k$, where P_k is the income from the k-type of knowledge, Z_k is the cost, r_k is the risk of using this type of knowledge. To increase efficiency with income growth, it is necessary to exceed the growth rate of costs (investments) and the weighted growth rate of risk. The weighting coefficient, in this case, will be equal to $r/(r - 1)$ [8]. The vast majority of knowledge management models assume significant limitations due to the fact that "distributed management" is not taken into account. Only it allows to choose the tools to which the goals are sensitive, capable of influencing the relevant parameters of the general economic plan and characterizing the object of management, in this case, knowledge. Thus, distributed management allows to see special risks, their relationship with income, the structure of knowledge and choose tools that can positively affect the change of these parameters in their relationship. Modern approaches in the field of management do not allow to achieve the same result.

Considering the macroeconomic level of knowledge management, although the above statement is valid for any level of management, nevertheless, in the author's opinion, it is necessary to identify the sector of the "knowledge economy", the development of which involves a set of different tools due to its heterogeneity and the differing sensitivity of the elements of the knowledge sector to the tools themselves (distributed management) [16]. Table II gives an idea of the differences in the interpretation of the "knowledge economy" at the level of measurement, which cannot but affect the formation of policies that stimulate this economic sector, which is the backbone for the modern development of society. As we can see from Table II, management tools according to the second method of identifying the "knowledge economy" are distributed systematically across sectors – science, education and high-tech activities, which implies distributed management for the development of science, education and knowledge-intensive types of work. There is only a problem of their coordinated application and determination of the cumulative effect of the goal on the tool, that is, the strength of the management tool acting on a specific goal or element of the economy has changed over time. When identifying the sector of the "knowledge economy", according to the first Eurostat methodology, distributed management can be localized only for the purpose of building educated and competent personnel, which clearly gives a higher assessment when summing up such activities [16], moreover, the quality of training and education (knowledge) is not taken into account.

TABLE II. "KNOWLEDGE ECONOMY" - DIFFERENCES IN MEASUREMENT AND MANAGEMENT TOOLS.

Name of the measurement method	***Content of the measurement method***	***Disadvantages and advantages of identification are the dimensions of the "knowledge economy"***	***Management tools***
1) According to Eurostat	The "knowledge economy" as an economic sector includes subjects and elements of the economy, where the number of employed persons with an established high educational level exceeds the established standard (33%), the type of activity entirely belongs to the "knowledge economy"	A full measurement of the knowledge economy is carried out for employees with a certain level of education, but the disadvantage is that they do not represent the sector as such, since they are dispersed throughout the economy and many types of activities. The measurement is not accurate, because it is included in the knowledge economy, in particular, coke production, petrochemistry, etc., etc., since people with the specified educational level work in these types. Here there is a clearly overestimation of the "knowledge economy"	They are aimed at increasing the proportion of educated people in each type of activity, with education above the established standard, constant retraining, transfer of experience, etc. This will increase the sector measured in the specified way
2) Direct method (author's [16])	The sector of the "knowledge economy" is estimated by the value added created in three basic types of activities – science, education and high-tech sectors of the "high tech" economy	The "knowledge economy" is evaluated in its pure form by activities related to the generation – creation of knowledge (the field of science), replication and dissemination – education (here there is also a partial modification of knowledge) and the application of the most advanced knowledge in highly technological activities. The assessment is also not accurate, because knowledge is also used in other activities. Nevertheless, in its pure form, as a direct value-added method, it gives an idea of the scale of the relevant activities that make up the core of the "knowledge economy".	The instruments are aimed at the development of science, education and high-tech sectors, that is, they include scientific and technical, educational and sectoral policies. Within the framework of educational policy, it is appropriate to influence the expansion of the number of educated and competent workers, which increases the sector of the "knowledge economy" according to the first measurement method and includes its tools within this management approach.

Source: compiled by the author.

According to the second author's assessment method (Table II) of the "knowledge economy", the size of the sector in terms of volume is usually less, making up some kind of pure (although not absolutely accurate) assessment of this type of activity. The "goals-tools" approach in management in general and in knowledge management dominates both standard and classical, but the idea of distributed management, developed here and in other works of the author [16], has not a bad prospect, both at the level of knowledge macroeconomics and in organizations implementing knowledge management – at the microeconomic level. In addition to science and education, the innovation of the economy, the institutional regime, information and communication technologies, as well as the formed incentives for obtaining and introducing new knowledge are important for the knowledge economy development [17-19].

IV. Conclusion

To summarize let's formulate the most valuable conclusions.

Firstly, distributed management involves assessing the strength of the tools used, acting on specific goals and elements of the economy, in particular, the "knowledge economy" sector. In relation to specific knowledge, the use of this approach looks problematic, since it is not easy to identify those tools that will affect this type of knowledge.

Secondly, the macroeconomic analysis of the "knowledge economy" allows to consider the situation in the "income–risk" coordinates, despite the existing limitations of income and risk assessment. The overall management strategy should be aimed at increasing income, possibly with a time lag, and eliminating the risk of generating and implementing knowledge, taking into account the structure of specific knowledge and its content.

Thirdly, the identification of the "knowledge economy" is important for the application of the doctrine of "distributed management", since the option of representing this sector as a set of activities included in it allows for a more adequate application of the distribution of tools, weighing their impact on the structural elements of the "knowledge economy".

Thus, distributed management, unlike the classical "goals-tools" method, is becoming a very promising form of change not only in macroeconomic management, but also in knowledge management, both at the macro and micro levels.

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Original Scientific Article

Importance of Teachers' Digital Knowledge: Prerequisites for Modern Teaching Process

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Abstract—**This paper aims to highlight the need and importance of teachers' digital knowledge and the implementation of digital tools in the teaching process. The fourth industrial revolution and the comprehensive changes it brings require a shift in teachers' approach to the teaching process. This paper shows the importance of the role of teachers in creating pedagogical-didactic models in the digital environment, pointing out the knowledge and skills that teachers need to effectively adapt the teaching process to the needs of modern students. Based on the conducted research on the needs of students in the context of digitization, it can be assessed that the need for digitization exists and that there is significant space for improvement.**

Keywords – digitization, teaching process, digital learning environment.

I. Introduction

The fourth industrial revolution initiated changes in all areas of life and work. The development and mass use of information and communication technology (ICT) have influenced changes in the habits and needs of everyone, especially young people and students. The foundations of the traditional educational paradigm have been shaken because the needs of new generations of students are changing in the direction of digitalization. Therefore, digitization, i.e. the introduction and use of digital tools in the teaching process, is imperative for modern teachers. Digitization of the education system is one of the key components of the Strategy for Education Development until 2030 in the Republic of Serbia [1]. The Strategy aims to improve the educational system through the integration of digital technologies, modernization of teaching, and the introduction of modern digital tools into the teaching process, aiming to bring the quality of the teaching process closer to the needs of contemporary students. The paper presents the current situation and the initiatives undertaken in order to digitize the educational system, as well as the results of research about the needs of students in the context of the use of digital tools in the teaching process.

II. Analysis of Regulations in the Field of Digitization of Education in the Republic of Serbia

According to a survey conducted in 2017 [2], only 47% of teachers estimated that the level of equipment of schools with ICT is satisfactory, while more than half of teachers need regular access to digital cabinets. Regular and high-quality access to digital tools is crucial for effectively integrating technology into teaching and supporting modern education. Since 2018, following the digitization process, the pilot project "Schools for the 21st Century" has been implemented, which aims to provide training and support for teachers to contribute to developing digital students' skills and encourage school networking. In this regard, the specific goals of the Strategy for Digital Skills Development [3] were defined to ensure a timely response to intensive technological changes and thus contribute to developing the individual and society in the new circumstances. As a significant particular goal of the Strategy, the *Improvement of digital competences* in the educational system is defined, which implies the implementation of basic digital competences and the introduction of programming and computer-based problem-solving in curricula at all levels of education. To successfully integrate digital competencies into the educational process, it is necessary first to define the specific areas of competence and the levels of expertise, knowledge, skills, and attitudes required for each area. In this sense, the basis for improving digital competences in the education system in the Republic of Serbia is the Digital Competence Framework - Teacher for the Digital Age [4], by which applying teachers directly contribute to developing a digital teaching environment. At the same time, the development of teachers' digital competences not only means the technical application of information and communication technologies in the teaching process but also the development of conceptual solutions and the creation of an innovative educational environment to improve the teaching process. In this way, technology should enable the teacher to contribute to raising the quality of education, making it more relevant and efficient. Further development of the Digital Competence Framework - Teacher for the Digital Age 2023 [5] introduced novelties related to the application of artificial intelligence in education with a greater focus on the well-being of students in the digital environment. On that occasion, 25 digital competencies desirable for the teaching profession were classified into six categories: (1) digital environment; (2) digital resources; (3) teaching and learning; (4) development monitoring; (5) supporting students in the learning process; and (6) professional engagement and development. In this way, the process of classifying and identifying desirable digital competencies is not finished; on the contrary, it has just begun, opening up space for further modification by the specifics of a particular educational context.

In order to further align education policies with scientific, technical, and technological development, the Strategy for Education Development until 2030 aims to improve the education system by integrating digital technologies and introducing modern digital tools into the teaching process. Within the framework of the Strategy, the obligation of educational institutions is defined in terms of undertaking activities related to the design and introduction of digital platforms into everyday teaching practice. The activities of this type, institution should align with their strategic goals by adhering to the standards for ensuring the quality of education to ensure consistency and quality in applying digital solutions.

The Action Plan [6] follows the Strategy by providing concrete steps and measures for implementing digital solutions in schools and providing suggestions and ways of training teaching staff to use new technologies. The action plan defines particular goals that, among other things, relate to establishing foundations for developing digital education at the pre-university level (Special goal 1.3) and digitizing higher education (Special goal 2.4). The achievement of this goal is foreseen through the introduction of digital platforms, the development of the register of competences and the register of qualifications [1]. In this sense, it is envisaged that designing and introducing digital platforms will be undertaken with a pre-defined dynamic while respecting quality assurance standards and within the institutional framework. When it comes to developing the register of competences and the register of qualifications, the first step will be drafting legislation in this area and providing appropriate guidelines for their use.

In this way, it is envisaged that the continuity of the application of digital solutions will be ensured through all levels of the teaching process.

III. The Role and Tasks of Teachers in the Digital Age

The role of the teacher is crucial in designing the digital form of the educational process because the development of pedagogy and teaching methodology in the digital age is still in its initial phase. Research shows that the traditional approach to the teaching process, in which the teacher is the central figure and the only source of knowledge, does not give satisfactory results. However, applying digital tools enables and encourages placing students at the center of the teaching process while the teacher's role is transformed into an advisory, moderating and collaborative one. Within this new educational paradigm, the role of teachers is to find a way to encourage students to independently study relevant digital content, which allows class time to be used for heuristic discussion that enables the maximum development of student's potential and adequate preparation for business in the digital age.

Such a change in approach requires teachers to change their thinking and engagement in accepting dynamic technological changes, which implies the continuous improvement of professional knowledge and skills and the acquisition of other knowledge and skills [7]. In this way, the possibility of developing digital didactics and creating new principles and approaches to teaching and assessing achievements is opened [8].

Effective technology integration for topic-specific pedagogy requires developing a sensitivity to the dynamic relationship between the following knowledge components situated in unique contexts: content knowledge, pedagogical knowledge, technological knowledge, pedagogical content knowledge, technological content knowledge, and technological pedagogical knowledge [9].

When it comes to the European framework, of particular importance are DigCompEdu [10], which is primarily designed to help teachers and other stakeholders in education to develop their models of digital competences at all levels of education, as well as DigComp 2.2 [11], designed to support the development of digital competences of individuals through adequate examples of competence areas at all levels of development.

Fig. 1 shows the essential elements of the DigiComp framework in 5 areas. This important tool helps European citizens and the workforce evaluate their digital skills, set learning goals, identify training opportunities, and enhance career prospects.

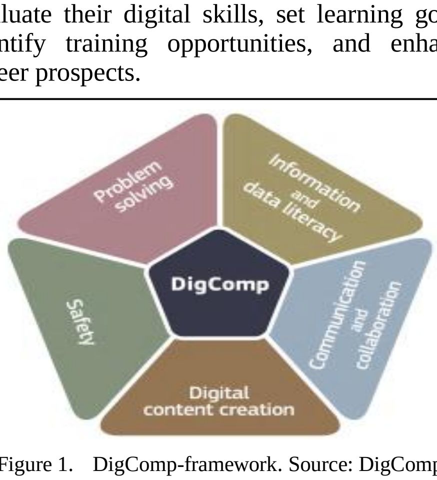

Figure 1. DigComp-framework. Source: DigComp Framework, 2023. [12].

However, the integration of digital tools in teaching faces numerous challenges. The biggest is the lack of teachers' motivation to acquire digital skills, particularly among teachers of older generations who rely predominantly on traditional pedagogical and didactic methods in their work. The next factor that slows down the digitization of the teaching process is insufficiently developed technical and technological infrastructure in schools (weak internet connection, outdated equipment, etc.). It is necessary to make additional monetary investments to acquire the prerequisites for effectively implementing modern digital tools in teaching. Finally, it is essential to systematically organize additional training for teachers, enabling them to see the possibilities of primary digital tools and acquire technical and transversal knowledge, skills and competencies necessary for the effective digitization of teaching.

IV. Analysis of the Current Needs of Students within the Digitalization of the Teaching Process in the Republic of Serbia

To assess the current quality of the application of digital tools in the teaching process, a survey was conducted on a representative sample of students of the Autonomous Province of Vojvodina. The survey was conducted using a Google questionnaire. Two hundred and twenty-one respondents participated in the survey. Of all respondents, 51.4% are undergraduate students, 24.6% are master's students, and 23.9% study distance learning programs (DLS).

The general goal was to examine the needs of students for digitization of the teaching process. The analysis of the results of the conducted research aims to find adequate pedagogical-didactic models, which can serve as guidelines for teachers to effectively integrate digital teaching tools (chosen by the respondents) to better prepare students for business in the digital age.

In addition, the goal was to determine the extent to which students are satisfied with the current teaching models used in practice, as well as which digital tools students consider the most useful for improving the quality of the teaching process.

Based on the research conducted among randomly sampled students, it can be seen that 93% of the total surveyed students attended classes in which digital tools were applied. From their experience, digital tools were used within synchronous and asynchronous learning. The digital tools used the most for synchronous learning are Zoom, Google Teams, and applications such as Slido and Kahoot for conducting quizzes during class. On the other hand, recorded video lectures and applications for collaborative learning and developing critical thinking, such as Padlet and Kialo.Edu, are the most used for asynchronous learning.

Research results have shown that 79% of respondents expressed an opinion in favor of the fact that due to the use of digital tools, they feel that they are actively participating in classes and that they are more connected with colleagues and teachers.

Quizzes stand out as a favorite digital tool because 73% of students preferred them over other digital solutions, primarily due to the possibility of interactively checking the material covered, the feeling that through the game, they gain knowledge and correct mistakes, learning simultaneously, but also gain the points necessary to form the final grade. Video lessons in the learning process also play a significant role since 76% of respondents think that video materials facilitate learning.

At the same time, 88% of students declared that the use of digital tools in class significantly helps them master and better understand the material, while as many as 91% claim that the use of digital tools in class raises the level of attention and makes the class more attractive (69% strongly agree with this statement, while 22% agree), as shown in Fig. 2. Only about 2%

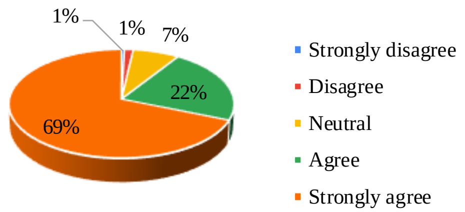

Figure 3. Students' assessment of the impact of the use of digital tools in teaching.

of respondents do not find this issue meaningful (0.45% strongly disagree, and 1.36% disagree).

Also, the possibility of direct communication with the teacher is essential for students since 87% claim that the existence of some direct communication channels is important. In the end, according to the opinion of the surveyed students, 48% believe that, ideally, organized teaching would be a combination of live teaching with digital tools, while 33% claim that it would be important to include an online teaching method (Fig. 3).

Finally, regarding the effects of using digital tools in teaching, 75.5% of respondents said that using digital tools in teaching reduced their exam preparation time by 50% or more. In addition, 95.4% said that using digital tools in teaching contributed to the acquisition of permanent functional knowledge, as well as the development of critical thinking and soft skills such as collaborative learning, teamwork and so on.

The research results support the claim that implementing digital transformation in education is essential for improving the quality of teaching

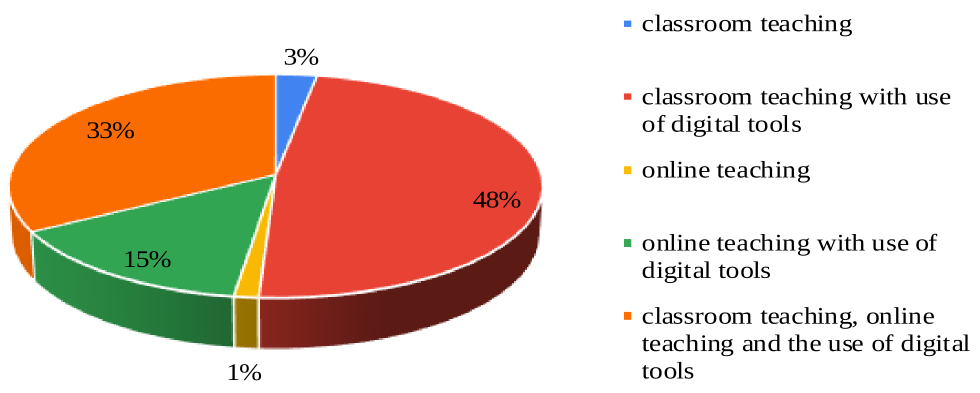

Figure 2. Students' opinion about ideally organized teaching. Source: Authors' calculations.

and learning. The modernization of the educational system through the introduction of digital tools enables teachers, students and pupils at all educational levels to have better access to materials, more efficient mastering of the material and greater interactivity. Also, training of teaching staff in digital tools and ensuring adequate technical infrastructure are essential steps in this process. In the Republic of Serbia, as in many other countries, investing in the digital transformation of education can significantly improve educational and scientific research results and thus prepare educational institutions for the challenges of modern society.

V. Conclusion

The traditional concept of teaching does not give satisfactory results. Changes in the educational paradigm, stimulated by the fourth industrial revolution, place the imperative of implementing digital tools in the teaching process before teachers. In the digital age, they must be prepared for constant upskilling and reskilling. In the Republic of Serbia, this initiative is supported by the Strategy for Education Development until 2030, where one of the goals is that through continuous improvement of professional and other necessary knowledge and skills, teachers will fully meet the challenges of digitization of education and training. The research on students' needs in the context of digitization showed that students fully accept the use of digital tools in teaching and that better access to educational materials and greater interactivity help them acquire professional knowledge and skills necessary for successful business in the modern age.

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Original Scientific Article

Digital Engineering and its Impact on Biomedical Technologies: Theoretical Overview

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Abstract — **Nowadays, digital engineering is an important discipline in biomedical engineering where complex numerical methods, engineering computational models and medical technologies are involved. The application of digital engineering in biomedical gives a good ground in the aspect of the design of the device, diagnostic techniques, and development of healthcare systems. Software such as MATLAB, LabVIEW, Computer Aided Design/Computer Aided Manufacturing, and Finite Element Method have maintained high precision and time effectiveness in solving issues in biomedical engineering. Thus, this paper focuses on the theoretical part of digital engineering in biomedical engineering.**

Keywords - Digital engineering, biomedical engineering, integration and innovation

I. Introduction

The concept of digital engineering in biomedical engineering incorporates the essentials from electrical engineering, computer science, and mechanical engineering with medical sciences to introduce novelty into the healthcare domain. This enables modeling, simulating, and prototyping of complicated biomedical systems-from organ functionality to the interaction of medical devices with biological tissues-through an integration of the core elements of engineering with information technology and control systems, which are basically intrinsic in the development of more sophisticated medical equipment and systems. Biomedical engineering has always depended on the newer technologies provided by the engineering field. Now, however, biomedical engineering enters a totally new dimension with the development of digital systems and technologies such as AI, IoT, and 3D modeling. This opens totally new frontiers in patient care, diagnostics, and medical treatments.

Specific digital engineering allows for the development of more sophisticated computational models, simulating real-life biological processes, predicting outcomes, and designing highly customized medical solutions [1].

II. Digital Engineering with Biomedical Engineering: Importance and History

Digital engineering marked a real turning point in the evolution of biomedical systems. It began with digital control systems that allowed both continuous and discrete-time processing, thus opening new methodologies for modeling complex systems such as cardiovascular flow or neural networks [2].

Digital engineering is an increasingly established academic and research discipline at many universities today, one of which is TU Graz; it is presently taught on both undergraduate and graduate levels [1,3].

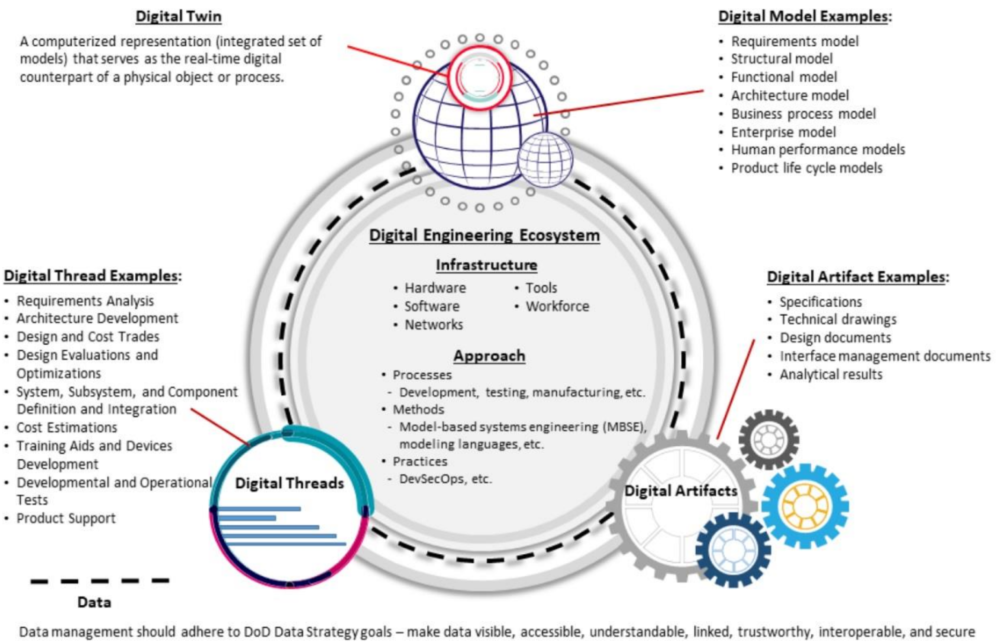

Figure 1. Digital engineering, [4]

For these reasons, biomedical engineering has developed in parallel with the advancement of these technologies. Classically, biomedical engineering was closely related to mechanical and electrical devices, but in the modern context, the scope of this discipline has expanded significantly. Initially, it was focused on electronic components at the micro and nano level but also on information technologies. Today, biomedical engineering includes digital technologies in all its forms. Digital engineering enables today's engineers and clinicians to co-design and simulate complex medical systems, from artificial organs to real-time health monitoring solutions. The possibilities brought about by digital engineering are reflected in faster and more accurate prototyping and testing of new medical devices. The European Union's strategic plan for the "Digital Decade" until 2030, involving medicine and biomedical and clinical engineering [5], indicates that the same digital engineering technologies have important significance regarding industries and industrial transformation. The concept of "digital twins" becomes central to medicine since one can analyze and simulate a specific patient in a virtual environment, which will be the key factor to more precise diagnosis and personalized treatment. In the future, the health system needs to work on improved digital infrastructure and innovation in developing solutions for medicine.

III. Digital Engineering in Medical Applications

The basis of digital engineering combined with biomedical engineering is certainly the precision of mathematical and computational modeling. Techniques within control systems and computational engineering allow the simulation of biological systems, tissues, and organs, giving much more profound insights into their functionality under various conditions. Tools like MATLAB and LabVIEW help develop digital models, which are vital for engineers and researchers in processes developing medical devices like pacemakers or insulin pumps [6,7].

The examples of physiological processes necessary for modeling by the FEM approach are blood flow, bone stress, and tissue elasticity. Such models can improve implant and prosthetic designs while more accurately practicing their in vivo performance [7,8]. Biomedical devices are often prototyped through CAD/CAM software packages; these are invaluable to test and refine designs before clinical use [8].

Figure 2. Basic Structure of a Dental Implant and implant models, [9]

IV. DEVELOPMENT OF MEDICAL DEVICES

Research and development of medical devices plays a crucial role in healthcare systems. Digital engineering brings designing, simulating, and (pre)testing of new medical device. The 3D printing technology allows implants and prosthetics to be customized to each patient following its anatomy. This flexibility enhances the functionality of the implant itself, it also enhances patient comfort, which is of high importance for its recovery and further quality of life [10].

3D printing in biomedical engineering, e.g., complex tissue structures, represents the next generation in developing functional tissue replacements and organ prototypes. These innovative technologies have opened an entirely new subfield of regenerative medicine, whereby the fabrication of biological structures that can be implanted in the body may contribute to healing and functionality.

One application is that researchers from the University of Wisconsin managed to 3D print biohybrid tissue substitutes for burn treatment by enhancing the proliferation of the patient's cells [11]. Besides, researchers from MIT have created significant structures within regenerative medicine: printed cartilaginous structures replace the lost part of the knee [12].

Nowadays, Control systems are an inseparable part of most medical devices. Constructing autonomous medical devices that can adapt in real-time to the needs of a patient using knowledge from adaptive control systems. Exemplar devices may include insulin pumps that automatically regulate blood sugar levels using appropriate insulin therapy based on the decision of a medical doctor. The following example is robotic systems that assist surgeons during complex operations. For example, the da Vinci Surgical System [13], which belongs to robotic systems, grants surgeons precision and control over their operations when dealing with patients in minimally invasive surgical procedures. This reduces complications that would otherwise have arisen due to such operations, offering quicker patient recovery.

Advanced sensor technology, combined with algorithms for an algorithm of control, enables such precise and minimally invasive medical intervention. Hence, interventions improve treatment results and decrease the time spent recovering from them, something quite critical in today's healthcare system [14].

V. AI AND IOT IN MEDICINE

Artificial intelligence revolutionizes the application of digital technologies in medical and healthcare systems. Machine learning is becoming integral to medical devices and health monitoring systems. Analyzing a large amount of data enables predictions, for example, about the patient's future condition based on the measured parameters.

AI supports diagnostics by comparing databases, images, or genomic information faster than conventional methods [6]. This enables specialist doctors to diagnose the patient and prescribe appropriate medical therapy. In addition to AI, IoT is crucial in medicine and the health system because it enables the connection of various devices around patients, connection to the monitoring room, and connection of different medical institutions, e.g., primary and tertiary. Doctors can monitor the state of health continuously, which is extremely important, e.g., postoperative recovery. Wearable devices with biosensors can monitor all vital signs and send data to healthcare professionals for early intervention before the condition worsens. Electronic Health Records (EHR), Electronic Medical Records (EMR), telemedicine, and decision support systems supported by the use of AI are becoming the new standard in patient management, improving the outcomes of personalized treatment and data-driven care [15,16].

Deep learning algorithms are adept at processing the increasing amounts of data provided by wearables, smartphones, and other mobile sensors for monitoring in various fields of medicine. While AI-powered medical technologies are currently used in particular clinical settings, the potential for their more comprehensive application is immense [17]. The ethical aspects of AI use in medicine and the formulation of strict rules are ongoing. They are set to become integral parts of the legal regulations in the medical sector.

VI. Conclusion

Digital engineering has carried certain aspects of the Industrial Revolution to medical technologies involving engineering, computer, and medical sciences. Modeling, simulation, and prototyping of complex biomedical systems and digital medical twins have advanced medicine and made it easier for doctors to diagnose and decide. Digitization in medicine enables, among other things, faster and more precise prototyping, but also the personalization of medical solutions using advanced mathematical and computer models and suitable simulations. With the growing application of artificial intelligence (AI) and the Internet of Things (IoT), biomedical engineering is entering a new era. New possibilities for diagnosis, treatment, and care of patients have been made possible. The critical role of digital twins in medical/healthcare systems, e.g., hospitals or clinics, and 3D printing in personalized medicine, further emphasizes the importance of digital engineering in the future development of health systems and technologies. Dental medicine today is unimaginable without digital engineering. The future is undoubtedly seen in real-time artificial organs using digital engineering involving 3D models, mechatronic components, control algorithms, modern biomedical materials, and adaptability to each patient.

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Original Scientific Article

The Significance of Simulation in Mining as a Conseque of Industry 4.0

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Abstract—**Industry 4.0 has become global strategic stimulation for realization of science-technological development. Although Industry 4.0 presents complex concept, it could be defined as completely new approach and appliance of information-communication systems with integration at different levels with purpose of increasing of product`s quality and service quality. Industry 4.0 permeates all pores and spheres of modern society. One of those spheres is mining. Mines, surface mines, hard mechanization and other present specific manufacturing systems with lot of products and production waste. Appliances of Industry 4.0 for those systems must be well planned, organized and realized, including all specifications related to mining. Complete planning of exploitation, application of maintenance related to condition, analyses and prediction of benefits and problems are only some of them. The appliance of the new technologies in mining and design of Mining 4.0 concept and standard demands many preparations and purports many benefits, but also and many problems. This paper was written to show the influence of Industry 4.0 and new technologies, especially simulation as a very important benefit in the sense of safety, costs and realisation.**

Keywords - Industry 4.0, mining 4.0, concept, management, simulation, evacuation

I. Introduction

Generally, Industry 4.0 presents huge digital transformation in many spheres, with the special environment, consisted from huge amount of data, Internet of things, systems, processes and lot of others. Complex systems such as industrial property, smart production systems, ecological environment, mine transport and lot of others different systems must be connected in real time and communicate for each other. Mining also presents the sphere where Industry 4.0 has been realizing huge changes, with involving of totally new technologies, principles and concepts.

Industry 4.0 concept in appliance was based at realization on four operative levels (operational, methodical, technical and virtual). Noted operational levels with determined principles (accessibility, multilingualism, safety, open code software, different solutions) enable realizations of smart cities, smart factories, smart manufacturing, smart electrical nets, smart mining etc. Related to mining, all of noted refers to smart cities, smart manufacturing, smart products, smart electro-nets, smart buildings and objects, smart plants, smart transport and logistic, smart highways and smart surface mines.

In detail analyses, model of Industry 4.0 related to mining purports manufacturing transformations on the complete new digital-machine level. That model presents the constitutions from cyber physic systems (CSP), cloud computing (CC), big data analytics (BDA), internet of things (IoT), enterprise resource planning (ERP), business inelegancy (BE), augmented reality (AR), artificial intelligence

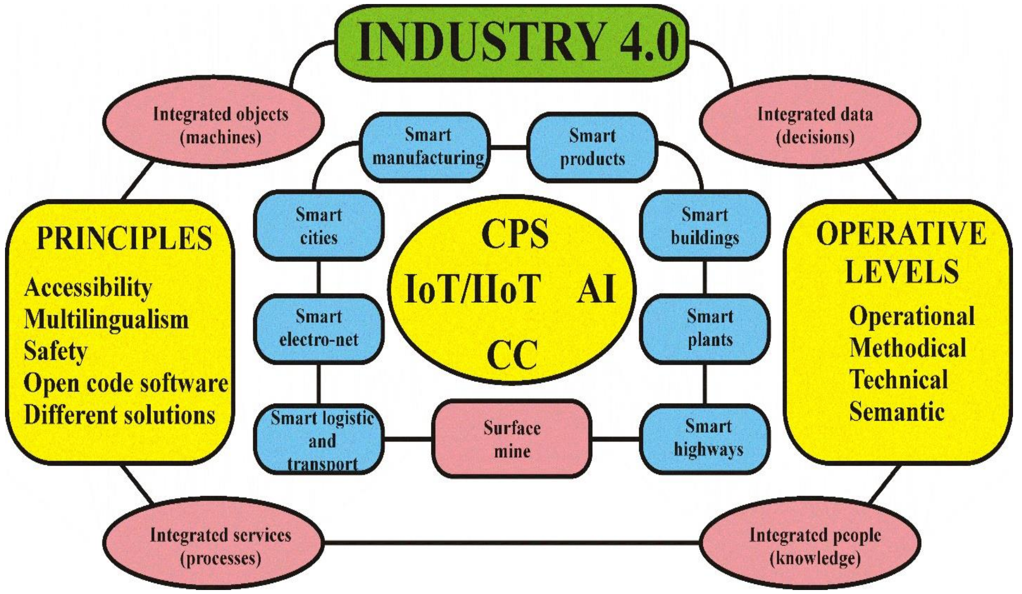

Figure 1. Industry 4.0 concept in mining

(AI), advanced manufacturing (AM), simulations, machines, robots and many others. With the appliance of noted, many additional benefits are possible: ecological sustainability, resources saving, systems tracking and monitoring etc. Industry 4.0 applied concept in mining, based on four operations level and five principles and is presented on Fig. 1.

With the appliance of noted, many additional benefits are possible: ecological sustainability, resources saving, systems tracking and monitoring etc. [1-3].

II. MODERN TECHNOLOGIES USED IN MINING

Noted operations levels and principles were used that models of smart factories, smart cities, smart electrical nets and similar should be designed and realized.

These realizations for mining are possible with the use of different modern technologies, grouped in different areas, such as: communication, embedded systems, interface man-machine, sensors and actuators,

standardizations and regulations, software and technology systems.

Used technologies are different and numerous, such as communication nets, mobile systems, environment modeling, sensors net intelligent systems, simulations, cloud computing etc. Of course, the use of new technologies provides many benefits but also many problems. One of the most important problems is the way of appliance and realization. This problem purports education and training of human`s component in the purpose of easy and efficiently acceptance and appliance of new technologies. For some spheres, it is particularly hard to solve this problem. Some of new technologies can be applied immediately, but for some of them, very serious preparations must be provided and realized. Education and training can be extremely hard and expensive. Sometimes it is very difficult to accept and to apply the new technologies. Also, one of the most important factors is safety. Only well trained and educated worker, engineer, technician or similar can do some work with maximal professionalism, efficiency and safety. Previous experience and examples have confirmed the presented facts many times.

Communication presents extremely important area in many spheres, so as in mining. Wireless net in real time enable high performance in the sense of maintenance, production, management, tracking and safety.

Embedded systems, that present computer systems with special purpose, completely incapsulated with the supervised device. Their dimensions are getting smaller but their possibilities are getting bigger. There are many benefits from these systems, such as energy optimization.

The possibilities to design environment, the new and optimized presentation of information, semantic visualization, remote maintenance and many other present technologies used in the areas of interface man-machine.

Very important technologies present the sensors and actuators technologies. New families and types of sensors with significantly smaller dimensions and much greater possibilities enable design of sensors and actuators nets with new concepts and unexpected achievements.

All of these demands involving of new standard, regulations, regulates and similar, needed for normal, rational, determined and legal functioning.

The use of new software presents very important step in the sense of involving of new technologies. The possibilities of big data processing and storage, easy and fast accessibility, potentials of robots and machines learning and recognition enable new and unseen achievements not only in mining but in many other spheres significant for people and society. The use of modern technologies in mining is presented in Table I [1,3-5].

There are many different concrete examples how technologies such as artificial intelligence (AI), robotics, or Internet of things improving mining. One of very specific example is the maintenance of mechanisation condition. Mining as a specific sphere must use different forms of mechanisation, especially hard mechanisation. Different technologies, including sensors, detectors, processors, computers, robots, wireless Internet and similar tracking work of hard machines in real time and tracking determined parameters crucial for their functioning. Tracked and supervised machines can spend optimal quantities of fuel or energy, with precise and optimal moving. Malfunctions are summoned on minimum, and their elimination is fast, flexible and effective. Analyses are realizing related to parameter of normal functioning, deviation from prescribed values, decisions are making on the basis of which the work is not interrupted or interrupted and all of that in the purpose of normal, safe and economically approved manufacturing. All of information are stored and easily accessible for analyze or recommendation. Based on that facts, artificial intelligence can plan optimal and achievable economics or other strategies. There are many known cyber physical models capable to manage with exploitation of mechanization in mine. They are mostly designed at two different

TABLE I. INDUSTRY 4.0 TECHNOLOGIES APPLIED IN MINING.

Communication area	
Applied technologies	Self-organized communication net
	High communication performance
	IT security
	Channel of mobile communication
Embedded systems area	
Applied technologies	Miniaturized embedded system
	Energy optimization
	Intelligent embedded system
Interface man-machine area	
Applied technologies	Environment modelling
	Presentation of information
	Semantic visualization
	User interface
	Voice/movement management
	Remote maintenance
	VR/AR
	Intuitive elements
Sensors and actuators technology area	
Applied technologies	Miniaturized sensors
	Intelligent sensors
	Sensor`s net
	Intelligent actuators
	Actuator`s net
Standardizations, Regulations areas	
Applied technologies	Communication standards
	Standard elements
	Identification standards
Software and Technological systems area	
Applied technologies	Simulation of environment
	Multi-criteria analyse
	Machine learning and recognition
	Multi-agent systems
	Big data analyse
	Cloud computing
	Web and cloud services
	Ontology

levels. One level is strictly physical level, while the second level presents virtual level that consisted of software systems and applied and developed simulation models.

Many complex and demanded processes, such as mine melting, mine filtering, waste separation and many other are significantly improved. Artificial intelligence and robots are present at places and positions where humans could not be because of different ambient and work conditions; decisions are making very fast, safe and economically optimised, because processes itself demand such conditions. Specifically, for this part, autonomically robots are frequently used. They communicate between themselves and with humans, learning from them. They can be used as independent cyber systems for manufacturing at places or positions where humans have health or physical limitation.

Methods of additive manufacturing are also widely used, solving different problems such as manufacturing of small series of complex prototypes. There are three known methods used for these purposes: deposit material fusion, selective laser melting and selective laser sintering. Of course, there are many others examples [1].

III. The Appliance of Simulation in Mining

The use of simulations in production, technological and other processes enables great possibilities and benefits. That is the way with the mining, too. Generally, simulation in the sense of Industry 4.0 presents digital presentations of production and processes with purpose to identify any kind of potential problems, without costs and waste generation in manufacturing. At this moment, the use of 3D simulation of environment, different conditions, manufacturing, products development and technological processes are widespread. Also, the use of simulations decreases needed times and improves the quality of the products.

One form of simulation in mining is the modeling of machines, procedures and processes, with the use of data in real time. The use of smart sensors, smart cameras, smart measuring devices with the combination of powerful computers and software enable design of virtual world identic as real world. With the use of modern technologies, it is possible to design the virtual reality of the mine and predict many, in real mine, hard predicted events or consequences that can lead to jam in the production, transport problem or fatal epilogue for humans inside. Design of digital twins enable prediction and tracking of many different events or occurrences in virtual world, without consequences, such as costs and risk. On this way, it is possible to design complete mine environment, such as simulated virtual presentation of machinery, simulated production and technological phases, with maximal control, tracking, analyze and optimization.

Almost any mine process can be simulated: transport, casting and deformation processing, energy control and distribution, maintaining of transport and production machines etc. As an example, complete transport in mine can be controlled, analyzed and managed with total insight in safety, costs, human and machine activities etc. Internecine connections between vehicles, machines, robot and other elements that take part in the transport, provided by sensors, central computers and Internet robots enable precise, economic and safe loading, transport, unloading, garbage delay etc. Machines, vehicles and robots are getting “smarter”, more intelligent, more communicative, more flexible with better and better options for learning. These elements can be used in transport or some other mining area, as completely independent cyber physic systems, especially at the places and locations where human factor has limitation to work, for some reasons. Anyway, simulation can provide any necessary changes of any parameter or factor with the final epilogue-the realization of real, optimized model in the sense of production, safe, costs and others.

The example of simulation appliance in mining is presented on Fig. 2.

Augmented reality has a great role in the collaboration with simulation. Systems based on augmented reality are capable to realize and support many different services, such as recognition and selection of different parts or elements important for manufacturing or processes; 3D analyze of different machine structures in the cases of malfunction, stoppage, termination, repair, maintenance or similar. Augmented reality enables different information in real time for workers, important for many processes, such as process of decision in working procedures or similar.

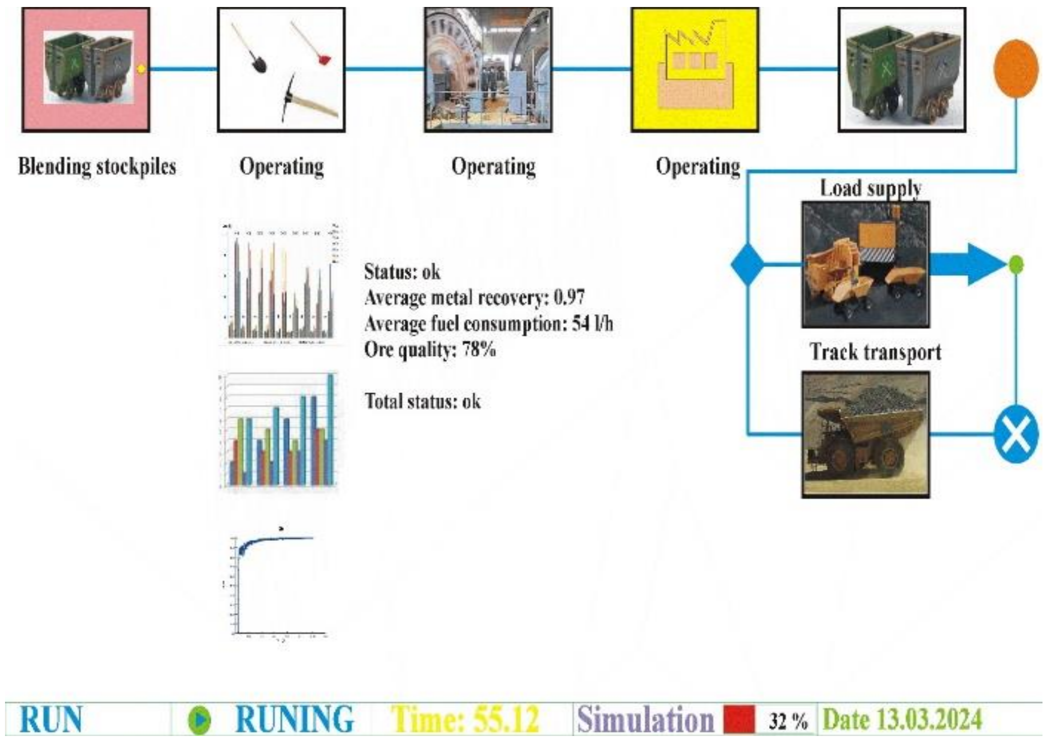

Figure 2. An example of simulation in mining with analysing and parameters changing

Augmented reality has a great role in the collaboration with simulation. Systems based on augmented reality are capable to realize and support many different services, such as recognition and selection of different parts or elements important for manufacturing or processes; 3D analyze of different machine structures in the cases of malfunction, stoppage, termination, repair, maintenance or similar. Augmented reality enables different information in real time for workers, important for many processes, such as process of decision in working procedures or similar.

The limitation of this paper of course doesn't allow to present every benefit of simulation appliance in mining, but related to many different criteria, the protection of human life's and safety should always present benefit number one. With the appliance of simulations and use of virtual reality, there is no any kind of risk for humans; furthermore, it is possible to predict many events, problems and similar that can endanger human life's and safety.

As it was noted, one of the most important benefits of the use of modern Industry 4.0 technologies is safety. Mines and surface mines present object with high risk for employees. Handling with huge work machines, moving the huge quantity of load (ore, chats, cargo etc.), work and stay in the different natural conditions (underground tunnels, wastelands, melting objects etc.), contact with dust, fumes and different chemical compounds (carbon monoxide, carbon dioxide, hydrogen sulphide, phosphor derivates, sulphur derivates and lot of other poisons compounds), high possibilities of explosion and fires, evacuation of employed ad material properties show the facts that safe for employees in mines and surface mines present always serious, open and demand problem. One of the best solutions for those and similar examples is the use of virtual reality and simulations.

The use of virtual reality and digital twins enable design of the "virtual" model of the mine or similar object with virtual conditions, machines and humans. It is possible to simulate complete real work at the mine and to notice important problems that may occurred in real model, without any threat for human safety. A new concept of visualization provided with the use of new technologies enables complete insight

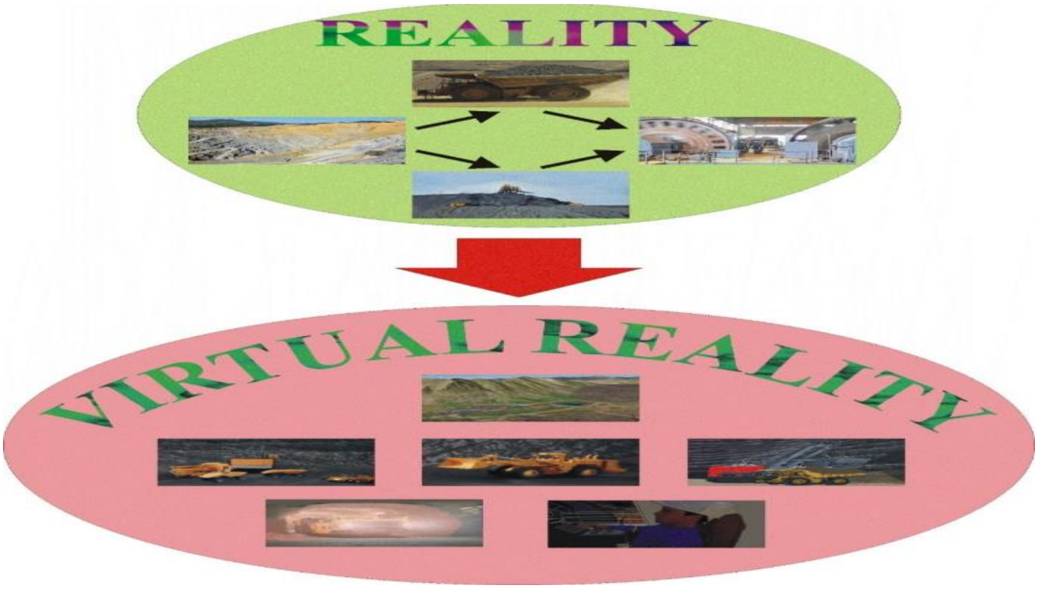

Figure 3. The relationship between reality and virtual reality in the case of mine

in the any kind of problem related to production, research, exploitation and safety [6-9].

The relationship between reality and virtual reality is presented on Fig. 3.

One of the particularly complex problem in mines is, of course, the evacuation problem. Generally, evacuation presents always open problem for many different objects. Although many safe precautions, the problem can occur from nowhere and cause many difficulties, including tragic epilogue. Related to evacuation, mine as object presents very complex task. Many mines are deep underground (very often, more than several hundred meters), with very limited space for machines maneuvers and human`s movement. Elevators are the only connection between outer world and halls deep underground. In the case of elevators failure or some other problem, such as soil erosion, humans are stuck deep underground, without help, food and air.

There are many examples that accidents in mines were finished with tragic epilogue and human victims (France, Japan, Great Britain, former SFRJ, Zimbabwe etc.). Related to some sources, the twelve the biggest accidents in mines in the world took 6811 human lives. In former SFRJ, there were several accidents in mines with huge number of killed miners (the worst case was in mine was in Mramor, in Bosnia and Herzegovina, in 1990, in in the “Dobrnja Jug” pit, in Kreka mine with 180 victims) [1,7].

So, the best possible way for successful evacuation, at the first place, is prediction. With the good and detailed prediction, it is possible to prepare place, object and humans for potential occurrences and on that way enables realization of needed and obligate measurements. Of course, it is almost impossible to predict every potential scenario, but it is possible to predict and to analyse the most likely scenarios by the use of simulation software.

Simulation software for evacuation enables calculation of evacuation times and analyse of evacuation scenarios for different parameters and in different conditions. It is possible to determine the speed of humans (occupants), their gathering points, dimensions of important structural parts and elements-width and length of stairs, the dimensions of risers and treads, the dimensions of elevators, movement of elevators-speed and movement directions, etc. Simulation software enables 2D and 3D view of evacuation. One of the very important parameters in evacuation situations is the human`s behaviour.

Behaviour in simulation software purports the sequence of actions that humans (occupants) undertake in the simulation. Behaviour generally presents parameter impossible to be predicted-every human presents unique unit and their behaviour under stress, panic, flame, smoke, water, earthquake or something else related for evacuation situations is very complex and unpredictable. In the simulation software, occupants can go to some specific area, room, elevator or similar. They also can wait for determined time, assist to other occupants, wait for assistance or detach from assistance. It is also possible to simulate injured occupants (with smaller speed or with need for assistance).

One of the best simulation software for calculation of evacuation times and analysing of different evacuation scenarios is the Pathfinder. This software works in two different modes ("Steering" and "SFPE") and has a lot of possibilities. The first simulation mode purports that occupants use steering way of moving and interaction with other occupants. The second simulation ode purports occupants moving without attempts to avoid each other and with some limitations related to doors and exits flows. As a result, complete visual simulation for some specific object is obtained. The presentation of simulation results can be in 2D or 3D. Of course, this and similar software demands strong hardware configuration (strong processor, strong graphic card with lot of RAM memory) for continual, undisturbed, fast and cosy work.

An example of evacuation simulation from mine where simulation scenario purported specific corridors arrangement and possibilities for use with different miners (occupants) and elevators speeds is presented on Figs. 4 and 5. The mine was presented as object at different depths (150, 450 and 750 meters), with different number of available corridors with length of 4 km, width of 2 m and height of 2 m. Maximal number of available corridors was four and minimal was one. Maximal capacity of two available elevators was 25 persons.

Realized simulations showed that the shortest evacuation time from mine was 89.07 minutes, (the depth was 150 meters) while the longest evacuation time from mine was 672.3 minutes (the depth was 700 meters). Also, the appliance of simulation software in this case determined the occupant`s speed at which delays, jams and similar potential events can occur [10,11].

Based on simulation results at noted example, it is possible to design the proper and the most effective evacuation strategy with complete insight in the needed evacuation times and potential critical points (doors, elevators, passages, stairs or similar) where jams, delays or similar events or accidents can occur. Simulations software has not a standard level yet; almost any firm developing its own software for specific manufacturing and operations, but, related to technological improvement, it is only a matter of time when simulation software become generalised for any part or sphere of mining [10-13].

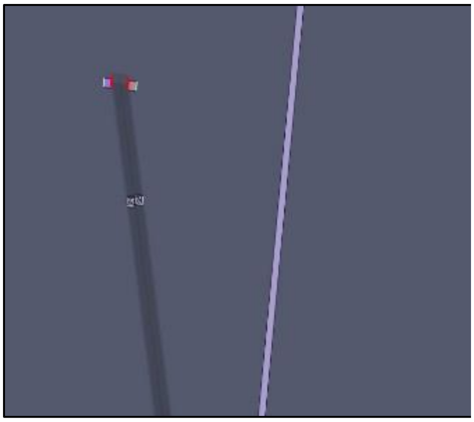

Figure 4. Simulation moments from the mine evacuation, for the occupant speeds from 0.5 m/s and depth from 700 meters [13]

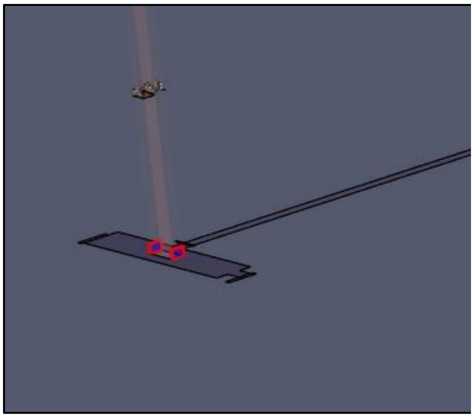

Figure 5. Simulation moments from the mine evacuation, for the occupant of 0.7 m/s and depth from 700 meters [13]

IV. CONCLUSION

The influence of Industry 4.0 present huge penetration of different new and modern technologies in many different spheres. Mining presents sphere where the influence of Industry 4.0 made large, unseen and deep changes, at every level and element. Although the influence of new technologies brings great benefits in many senses (economy, costs, speed, productivity, autonomy, digital presence, digital control, digital management, flexibility, sustainability, integrity, safety, ecology, waste management and many others), the most important task should be the protection of human life. So, the safety must be at the highest level in any aspects of Industry 4.0 influence and use.

Of course, there are many other different questions and challenges related to consequences of Industry 4.0 use that have great importance and that can cause potential problems. The next one is only some of them.

It is very important, in the mine manufacturing, to group machine equipment, because of design of modular and smart transport units that can configure different manufacturing routes. Researches with digital twins can be very complex and demanded. Analytics of big groups of information in mining must be constantly improved with developing of new and new models, because of high quality, integrity, availability and safety of information. Smart technological manufacturing systems demand more autonomy and possibilities of decisions. All of noted demand drastic cyber security.

Education, training and possibilities of retraining for new technologies and demands are complex and special problem. Although many benefits will be achieved, there are many work positions that will be closed. Will it be economically approved? Whether and how these workers will be able to join new workplaces and accept new technological challenges? Finally, can be achieve the balance between benefits and potential problems in technical, economical and safety sense? Of course, these are question for future research.

However, the use of simulation as a consequence and technology of Industry 4.0 in mining, but not only in mining, enables very important benefit-prediction. With the use of simulation, it is possible to choose the best way for production, transport, safety and other parameters, without any costs-economy and human. But the greatest benefit is, of course, human life. Mining presents very danger and unpredictable sphere in the sense of safety. There are many different unpredictable things and events that can be happened. Simulation software can help in predictions of these events and realisation of the best solutions related to human safety. Noted example for use of simulation software in mine evacuation enable the view in crisis and critical situations and the shortest time needed for human`s evacuation to safe location.

Because of all noted, especially because of safety for human live, the use of simulation software and other simulation tools should and must be obligate part of future engineers' knowledge and work.

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Original Scientific Article

A Note on Some Aspects of Capacitated Transportation Problem

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***Abstract*—In this paper, we have presented various aspects of bounded transportation problems. It includes different types of objective functions such as fractional objective function, indefinite quadratic transportation problem, linear plus linear fractional objective function, time minimization and cost minimization problems etc. The objective function is subjected to different types of constraints such as rim conditions, enhanced flow constraint, restricted flow constraint and specified flow. Mathematical formulations under different scenarios are developed.**

Keywords - transportation problem, indefinite quadratic, time minimization, fractional programming

I. INTRODUCTION

The simplex technique, created by George Dantzig [1] in 1947, is the most organized, effective, and popular approach for resolving linear programming issues. Any linear programming issue can be solved exactly in a finite number of steps using this algebraic iterative method, or it can indicate that there may be an unbounded solution. When a homogenous commodity that is available at several warehouses needs to be transported to multiple markets and depots at the lowest possible cost and time of transportation, it gives rise to transportation problems. Pioneer work was done by Hitchcock [2] and Koopman [3] on these problems. Hitchcock formulated the transportation problem, and later on, Koopman took advantage of its unique matrix structure to construct a computationally more efficient solution approach that essentially follows the steps of the simplex method. Appa [4] studied transportation problem along with its variants. A transportation problem refers to a class of linear programming problems that involves selection of most economical shipping routes for transfer of a uniform commodity from a number of sources to a number of destinations. A necessary and sufficient condition for the existence of feasible solution of a transportation problem is that total demand is always equal to total supply. But in real world situations, there is a limited capacity of resources such as vehicles, docks, equipment etc. This gives rise to a capacitated transportation problem with bounds on rim conditions. Dahiya and Verma [5,6] studied a class of capacitated transportation problem with bounds on rim conditions where only variable costs are taken in to account. Adlakha [7] studied transportation problem where the costs of transportation consist of both variable and fixed component. This gives rise to fixed charge transportation problem. Later, Gupta and Arora [8-10] worked extensively on various aspects of bounded transportation problems. Indefinite Quadratic transportation problem is a class of non-linear programming problems where the objective function is a product of two linear functions. This gives more insight in to the situation than the optimization of each criterion. Fractional transportation problem [11] is an another interesting class of non-linear programming problems where the objective function is a ratio of two linear functions. Optimization of a ratio of criteria often describes some kind of an efficiency measure for a system. Arora and Gupta [12] developed an algorithm to find optimum cost time trade off pairs in a fractional capacitated transportation problem with restricted flow. Dahiya and Verma presented a note on two stage interval time minimization transportation problem. Some researchers [13,14] gave equal importance to both cost and time minimization. This dual objective give rise to optimum cost-time trade-off pairs in transportation problem. This paper is an attempt to summarize various aspects of capacitated transportation problem which finds its applications in real life.

II. Defining Transportation Problem

A. Classical Transportation Problem

A transportation problem may be described as follows: Let there be *m* sources with a_i ; $i = 1, 2, 3, ...m$ units of supply of a particular commodity and n destinations having b_j ; $j = 1, 2, 3, ...n$ units of demand respectively. It is assumed that $a_i, b_j > 0$. Let c_{ij} be the unit cost of transportation from source i^{th} source to j^{th} destination. Since there is only one commodity, a destination can receive the demand from one or more sources. The problem is to determine the feasible shipping pattern from sources to destinations that minimizes the total transportation cost. The basic assumption here is that the transportation cost of a given route is directly proportional to the number of units transported. The definition of "unit of transportation" will vary depending on the commodity transported. Let x_{ij} be the number of units transported from source *i* to destination *j*. Assuming that the total supply equals the total demand, that is:

$$\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j \,, \tag{1}$$

the mathematical formulation of the standard transportation problem is:

$$\min z = \sum_{i\in I}\sum_{j\in J} c_{ij}x_{ij} \text{ subject to} \tag{2}$$

$$\begin{aligned} &\sum_{j\in J} x_{ij} = a_i ; i \in I \\ &\sum_{i\in I} x_{ij} = b_j ; j \in J \\ &x_{ij} > 0; i \in I, j \in J \end{aligned} \tag{3}$$

where $I = \{1, 2, 3...m\}$ and $J = \{1, 2, 3...n\}$. However, in real life, it is not necessarily true that the total supply equals the total demand. In such situations, source and/or destinations constraints are in equations as opposed to the usual equations. Such unbalanced transportation problems can be studied by developing equivalent standard transportation problems.

B. Capacitated Transportation Problem

The standard transportation problem, known as "Hitchcock – Koopmans Transportation Problem" is mathematically given by (4). The total flow in the problem is (1). But in real world situations, there is a limited capacity of resources such as vehicles, docks, equipment etc. This gives rise to a capacitated transportation problem with bounds on rim conditions. A capacitated transportation problem is a distribution model with upper and lower bounds on the number of units shipped from an origin to a destination. This problem differs from the classical distribution model in which the node shipping amounts are, by contrast, specified exactly. This generalization of the classical distribution problem not only makes the model versatile from the theoretical stand point but also makes the model more usable from an application view point. In many applications of the distribution model, the firm is only interested in shipping exact number of units from each origin and in receiving an exact number of units at each destination. Mathematically stated, the problem at hand is:

$$\min z = \sum_{i\in I}\sum_{j\in J} c_{ij}x_{ij} \text{ subject to} \tag{4}$$

$$\begin{aligned} &a_i \le \sum_{j\in J} x_{ij} \le A_i ; i \in I \\ &b_j \le \sum_{i\in I} x_{ij} \le B_j ; j \in J \quad , \\ &l_{ij} \le x_{ij} \le u_{ij} ; i \in I, j \in J \end{aligned} \tag{5}$$

and integers, where $I = \{1, 2, 3...m\}$ is the index set of *m* origins; $J = \{1, 2, 3...n\}$ is the index set of *n* destinations; x_{ij} denotes the number of units to be transported from i^{th} origin to j^{th} destination; c_{ij} is the cost of transporting one unit of commodity from i^{th} origin to j^{th} destination; l_{ij} and u_{ij} are the bounds on number of units to be transported from i^{th} origin to j^{th} destination; a_i

and A_i are the bounds on the availability at the i^{th} origin; $i \in I$, b_j and B_j are the bounds on the demand at the j^{th} destination, $j \in J$.

III. Aspects of Capacitated Transportation Problem

A. Fixed Charge Capacitated Transportation Problem

Capacitated transportation problem finds its application in a variety of real-world problems like telecommunication networks, production – distribution system, rail and urban road system. But many distribution problems in practice can only be modelled as fixed charge transportation problems. For example – rails, roads and trucks have invariably freight rates which consists of fixed costs and variable costs both. The transportation cost in many distribution problems consists of fixed costs, which are independent of the amount transported and the variable costs, which are proportional to the amount shipped. For example – rail, road and truck companies invariably use freight rates that comprise both fixed costs such as permit fees and property taxes and variable costs, such as direct equipment and personnel usage. Capacitated fixed charge transportation problem finds its application in warehouse location problem, in fleet routing, in scheduling problem etc. Capacitated transportation problem is solved by upper bounded simplex technique. The inclusion of upper bound in the transportation table requires modification in the feasibility condition of the simplex method because a basic variable can become a non-basic variable at its upper bound or lower bound. Moreover, when a non-basic variable becomes a basic variable, its value should not exceed its upper bound and should not be less than its lower bound. In addition to this, its value should not disturb the non-negativity and upper bound conditions of all existing basic variables. Mathematically, a fixed charge capacitated transportation problem is represented by:

$$\min\left(\sum_{i\in I}\sum_{j\in J} c_{ij}x_{ij} + \sum_{i\in I} F_i\right), \qquad (6)$$

subject to the constraints (5). Here, F_i represents the fixed cost associated with i^{th} origin. For the formulation of $F_i; i \in I$, we assume that $F_i; i \in I$ has p number of steps so that:

$$F_i = \sum_{l=1}^{p} F_{il}\delta_{il};\ i \in I, \qquad (7)$$

where:

$$\delta_{il} = \begin{Bmatrix} 1; \sum_{j\in J} x_{ij} > a_{il} \\ 0; otherwise \end{Bmatrix} \forall l = 1,2,3...p;\ i \in I, \quad (8)$$

$0 = a_{i1} < a_{i2} < ..... < a_{ip}$; $a_{i1}, a_{i2}, ..., a_{ip}; i \in I$ are constants and F_{il} are the fixed costs for all $i \in I; l = 1,2,...p.$

B. Bottleneck Capacitated Transportation Problem

A special class of transportation problem called bottleneck transportation problem is considered where the objective is to minimize the maximum time of transporting all supply to the destinations under certain conditions. In a bottleneck transportation problem, the time of transporting items from origins to destinations is minimized, satisfying certain conditions in respect of availabilities at sources and requirements at the destinations. Time minimization is more important than cost minimization in certain situations such as when military units are to be sent from their bases to certain fronts within the shortest possible time. Another situation concerns the transportation of perishable goods. From practical point of view, the problem consists of supplying certain consumers with the necessary quantity of items (goods, military equipment, aircraft and so on) in such a way that the total time from the starting of the operation until its completion should be minimal. This section studies the objective function of time minimization in a capacitated transportation problem when decision variables are bounded. A technique for minimizing time in a capacitated transportation problem with bounds on rim conditions is developed. The procedure involves finite iterations and is based on movement from one extreme point to another extreme point until an optimal solution is reached. The technique is based on certain assumptions such as the carriers have sufficient capacity to carry goods from an origin to a destination in a single trip. Moreover, they start simultaneously from their respective origins.

The mathematical model of the problem is:

$$\min T = \max\{t_{ij} / x_{ij} > 0\} , \tag{9}$$

subject to the constraints (5). Here, t_{ij} is the time of transporting goods from i^{th} origin to the j^{th} destination. For any given feasible solution, $X = x_{ij}$ satisfying (5), the time of transportation is the maximum of t_{ij}'s among the cells in which there are positive allocations i.e. corresponding to the solution *X*, the time of transportation is:

$$\left\{\max_{(i,j)}\left(t_{ij} \mid x_{ij} > 0\right)\right\}, \tag{10}$$

C. *Cost-time Trade-off in a Capacitated Transportation Problem*

The fixed charge transportation problem can be stated as a distribution problem in which there are m suppliers (warehouses or factories) and n customers (destinations or demand points). Each of the m supplies can ship to any of the n customers at a shipping cost per unit c_{ij} (unit cost for shipping from supplier *i* to customer *j*) plus a fixed cost F_i. Sometimes, the total capacity of each route is also specified by some external decision maker because of budget or other political consideration. This gives rise to capacitated time minimizing transportation problems. Moreover, sometimes a fixed cost (like set up cost for machines, landing fees at an airport, cost of renting a vehicle) is also associated with every origin due to which fixed charge must also be taken in to account along with variable cost of transporting goods from various origins to different destinations. Normally, bi – criterion problem arises when the user has to compromise between two criteria. In emergency situations such as fire services, ambulance services, police services etc., when the time of transportation is more important than cost of transportation. If the total flow in a transportation problem with bounds on rim conditions is also specified, the resulting problem makes the transportation problem more realistic. Moreover, if the total capacity of each route is also specified then optimal solution of such problems is of greater importance which gives rise to capacitated transportation problem. From the practical point of view, the cost minimizing transportation problem and the time minimizing transportation problem cannot be viewed as two independent problems. The mathematical model of the problem in which the two objectives of minimizing cost and time are unified is given below.

$$\min\left\{\sum_{i\in I}\sum_{j\in J} c_{ij}x_{ij} + \sum_{i\in I} F_i, \max_{i\in I, j\in J}\left(t_{ij} \mid x_{ij} > 0\right)\right\}, \tag{11}$$

subject to (5). These types of problems have practical importance in real life. This is clear from the real-life problem discussed in next section.

D. *Problem of Supplying Medicine for the Treatment of Swine Flu at Villages in Haryana.*

An epidemic disease called swine flu spread in three villages- Bahadurgarh, Bhiwani and Karnal of Haryana. One medicine is particularly needed for the treatment of swine flu which is not available in these villages. CMO of the C.H.C (Community Health Centre) in these villages purchases this medicine from a pharmaceutical company having its distribution centres in two cities–Kolkata and Chandigarh. Total number of cartons of medicine that can be supplied from Kolkata and Chandigarh lies to three destinations ranges between 5 to 30, and 10 to 40 respectively. The demand of medicine in Bahadurgarh, Bhiwani and Karnal varies between (10,30), (7,20), (5,30) respectively. The lower and upper bounds on the number of cartons to be supplied from Kolkata to Bahadurgarh, Bhiwani and Karnal are (1,10), (2,10), (0,5) respectively. Similar figures for Chandigarh are (0,15), (3,15), (1,20) respectively. The fixed cost from Kolkata to Bahadurgarh, Bhiwani and Karnal are 150, 50 and 50 respectively and the fixed cost incurred while supplying goods from Chandigarh to three villages are 200, 100 and 50. The problem of the pharmaceutical company is to determine the optimum cost-time trade off pairs which minimize the cost and time simultaneously. Let x_{ij} denotes the number of cartons of medicine transported from i^{th} distribution centre to j^{th} village. Let c_{ij} be the cost of transporting one carton of medicine from i^{th} distribution centre Kolkata and Chandigarh to j^{th} village is given by $c_{11} = 5,\ c_{12} = 9, c_{13} = 9, c_{21} = 4, c_{22} = 6, c_{23} = 2$ and the corresponding time values are given by $t_{11} = 15, t_{12} = 8, t_{13} = 13, t_{21} = 10, t_{22} = 13, t_{23} = 11$. Let F_i be the cartage of delivery vans used for transporting cartons of medicine from i^{th}

distribution centre. Let t_{ij} be the time of transporting the cartons of medicine from i^{th} distribution centre to j^{th} village. Then the problem can be formulated as:

$$\min\left\{\sum_{i=1}^{2}\sum_{j=1}^{3}c_{ij}x_{ij}+\sum_{i=1}^{2}F_i, \max_{i,j}\left(t_{ij} \mid x_{ij}>0\right)\right\}, \quad (12)$$

subject to:

$$\begin{aligned} 5 \le \sum_{j=1}^{3} x_{1j} \le 30, \\ 10 \le \sum_{j=1}^{3} x_{2j} \le 40, \end{aligned} \quad (13)$$

$$\begin{aligned} 10 \le \sum_{i=1}^{2} x_{i1} \le 30, \\ 7 \le \sum_{i=1}^{2} x_{i2} \le 20, \\ 5 \le \sum_{i=1}^{2} x_{i3} \le 30, \end{aligned} \quad (14)$$

$$\begin{aligned} 1 \le x_{11} \le 10, \\ 2 \le x_{12} \le 10, , \\ 0 \le x_{13} \le 15, \end{aligned} \quad (15)$$

$$\begin{aligned} 0 \le x_{21} \le 15, \\ 3 \le x_{22} \le 15, . \\ 1 \le x_{23} \le 20. \end{aligned} \quad (16)$$

On applying the algorithm for solving the bounded transportation problem described by Gupta and Arora [11], the decision maker can obtain three cost-time trade off pairs as (508,15), (555,13), (555,11).

E. Indefinite Quadratic Capacitated Transportation Problem with Restricted flow

In linear programming, the values of decision variables are to be determined so as to optimize the value of the linear objective function subject to linear constraints. However, when either objective function or constraints or both are not expressed in terms of linear relationships among decision variables, we take the help of non -linear programming methods to solve such non-linear programming problems. A special class of transportation problems called indefinite quadratic transportation problem consist of the objective function as the product of two linear functions. One of the linear-function represents the total variable cost of transporting goods from various supply points to various demand points. Another linear function represents the total damage cost or depreciation cost which is incurred while transporting goods. Practically, a fixed cost called set up cost is also incurred when a commodity is transported. The objective function discussed in this section considers fixed charge also. In addition to cost, a time is also associated with each shipping route. A business man must be interested in minimizing the maximum time of transporting all supply to the destinations. From the practical point of view, the cost minimizing transportation problem and the time minimizing transportation problem cannot be viewed as two independent problems. This gives rise to efficient time cost trade off pairs which minimizes cost and time simultaneously in a capacitated fixed charge bi–criterion indefinite quadratic transportation problem. The mathematical model of such a problem is:

$$\min\left\{\begin{array}{l}\left(\sum_{i\in I}\sum_{j\in J}c_{ij}x_{ij}\right)\left(\sum_{i\in I}\sum_{j\in J}d_{ij}x_{ij}\right)+ \\ \quad +\sum_{i\in I}F_i, \max_{i\in I, j\in J}\left(t_{ij} \mid x_{ij}>0\right)\end{array}\right\}. \quad (17)$$

subject to (5). In any transportation problem, the total quantity supplied by the various supply points and consequently received by the various destinations is the total flow in the system. This flow is different for different combinations of supply points and destination constraints. Sometimes, situations arise where either reserve stocks have to be kept at the supply points say, for emergencies or there is a shortfall in the production level. In such situations, the total flow needs to be curtailed. This gives rise to a new restricted flow constraint given by $\sum_{i\in I}\sum_{j\in J}x_{ij}=P$ in the transportation problem where:

$$P<\min\left(\sum_{i\in I}a_i, \sum_{j\in J}b_j\right). \quad (18)$$

This gives rise to a capacitated fixed charge b_i – criterion indefinite quadratic transportation problem with restriction on total flow.

F. *Fractional Transportation Problem*

There is a wide scope of fractional transportation problem in practice such as stock cutting problem, resource allocation problems, routing problems for ships and planes, cargo loading problem, inventory problem and many others. The standard transportation problem aims at minimizing the total cost of transporting a uniform product from various supply points to various destinations. But the objective function of profit maximization is not considered so far. We now consider an objective function which minimizes the total variable cost of transporting goods from various sources to different destinations and simultaneously maximizes the total variable profit earned when goods are transported. In addition to this, the objective function maximizes the rate of return on a fixed capital investment. The mathematical model of such a problem is given by:

$$\min\left\{\frac{\sum_{i\in I}\sum_{j\in J}c_{ij}x_{ij}}{\sum_{i\in I}\sum_{j\in J}d_{ij}x_{ij}}+\frac{\sum_{i\in I}F_i}{\sum_{i\in I}G_i}\right\}. \tag{19}$$

subject to (5).

G. *Paradox in a Capacitated Transportation Problem*

A paradoxical situation arises when value of the objective function falls below the optimal value and this lower value is attainable by transporting larger amount of quantity. The source of the so- called transportation paradox is unclear. Apparently, many researchers have discovered independently from each other the following behavior of the transportation problem. In certain cases of the transportation problem, an increase in the supplies and demand may lead to a decrease in the optimal transportation cost. In other words, by moving bigger amount of goods around, one may save a lot of money. This surely sounds paradoxical. The more for less paradox in a transportation problem occurs when it is possible to ship more total goods for less (or equal) total cost, while shipping the same amount or more from each origin to each destination and keeping all shipping costs non negative. The information of occurrence of a paradoxical situation is useful to a manager in deciding which warehouse or plant capacities are to be increased and which market should be sought. It could also be a useful tool in analyzing and planning company acquisitions, mergers, consolidations and downsizes. If a paradox exists, one would obviously be interested in the best paradoxical pair.

H. *Model Comparison*

The classical and capacitated transportation problems prioritize minimizing transportation costs. These models are more suitable for logistics problems where costs are the primary concern. The bottleneck and time-minimization models prioritize reducing transportation time, making them critical in emergency response or time-sensitive deliveries. The fixed charge, cost-time trade-off, indefinite quadratic, and fractional transportation models incorporate multiple objectives, adding complexity but offering more realistic solutions where multiple factors (cost, time, profit) influence decision-making. Each model has its strengths and limitations, depending on the specific constraints and objectives of the transportation scenario being addressed.

IV. CONCLUSION

In this paper, various aspects of the capacitated transportation problem were explored, including models with fractional, quadratic, and linear objective functions. The study presented different types of constraints such as rim conditions, restricted flow, and specified flow in order to make transportation models more realistic. The mathematical formulations of these problems and their applications in real-world scenarios, such as telecommunication networks, warehouse management, and emergency response, were discussed. Techniques for finding optimal cost-time trade-off pairs were also examined, particularly in cases where minimizing transportation time is critical, such as in military operations and perishable goods transportation. Overall, this paper provides a comprehensive summary of the capacitated transportation problem, with an emphasis on its practical applications in logistics and resource management. Despite the extensive analysis presented, there are certain limitations. First, the mathematical models developed in this paper are based on simplifying assumptions, such as simultaneous dispatch of carriers and sufficient carrier capacity. These assumptions might not always hold in real-world transportation systems. Moreover, the study does not account for dynamic or stochastic variables, such as uncertain demand or transportation delays, which could significantly affect the outcome of transportation planning. As future work is intended, we can extend the models to accommodate multi-modal transportation systems or integrating them with modern technologies such as blockchain or AI for real-time optimization. This could further improve the practical applicability of these methods in diverse sectors.

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Original Scientific Article

Advanced Analytics and Machine Learning Transforming Industry 5.0

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Abstract—**This paper analyzes the transformative impact of advanced analytics and machine learning on Industry 5.0, highlighting the integration of these technologies to improve productivity, efficiency, and innovation. The integration of real-time data processing and predictive analytics enables informed decision-making and proactive issue management, creating agile and responsive manufacturing environments. Human-machine collaboration, augmented by AI, uses the strengths of both human creativity and machine precision, improving operational efficiency and workplace safety. A theoretical model is proposed, detailing the relationships among data collection, advanced analytics, human-machine interfaces, and decision support systems. The model aims to present how machine learning and advanced analytics can contribute to transformation of enterprises in the context of Industry 5.0.**

Keywords – advanced analytics, machine learning, Industry 5.0, transformation

I. Introduction

Industry 5.0 represents the next evolutionary stage of industrial development, building upon the principles of Industry 4.0. While Industry 4.0 focused on the digitization and automation of manufacturing processes through the use of cyber-physical systems, the Internet of Things (IoT), and advanced computing, Industry 5.0 emphasizes the collaboration between humans and machines. This new paradigm integrates human creativity and significant thinking with the precision and efficiency of smart machines and advanced technologies, aiming to create more personalized and sustainable manufacturing processes [1]. The concept envisions factories where human workers and intelligent systems work together seamlessly to achieve higher levels of productivity and innovation. The integration of advanced analytics in Industry 5.0 plays a important role in transforming traditional manufacturing processes [2]. Advanced analytics involves the use of sophisticated data analysis techniques to extract actionable insights from vast amounts of data generated by industrial operations. In the context of Industry 5.0, advanced analytics facilitates real-time monitoring and optimization of production lines, predictive maintenance of machinery, and improved decision-making capabilities. Leveraging big data and real-time data processing can help companies to identify patterns, trends, and anomalies that inform strategic decisions, reduce downtime, and improve overall operational efficiency. The integration of these analytical tools is fundamental to achieving the smart, responsive, and adaptive manufacturing environments envisioned by Industry 5.0 [3,4]. Machine learning applications are at the heart of the technological advancements driving Industry 5.0. Machine learning, a subset of artificial intelligence, involves training algorithms to learn from data and make predictions or decisions without being explicitly programmed. In industrial settings, machine learning can be applied to various aspects of the manufacturing process, including quality control, supply chain optimization, and predictive maintenance [5].

This paper includes six main sections: Introduction, Integration of advanced analytics and machine learning applications, Human-machine collaboration and ethical considerations, Theoretical model, Suggestions and guidelines, and Conclusion.

II. Integration of Advanced Analytics and Machine Learning Applications

The integration of advanced analytics in Industry 5.0 is transforming how businesses operate and make decisions. Advanced analytics encompasses a range of techniques, including data mining, predictive analytics, and machine learning, which are used to analyze large volumes of data and extract valuable insights. In Industry 5.0, these insights are pivotal for enhancing efficiency, productivity, and innovation across various sectors [6]. Real-time data processing allows for the continuous monitoring of manufacturing processes, enabling businesses to quickly identify and address any issues that may arise. Predictive analytics can forecast future trends and potential problems, allowing companies to proactively manage resources and optimize production schedules [7]. This level of insight and foresight is essential for creating more agile and responsive manufacturing environments. Moreover, advanced analytics enables more effective predictive maintenance strategies. Traditional maintenance approaches often rely on scheduled checks and reactive repairs, which can lead to unplanned downtime and increased operational costs. Predictive maintenance, on the other hand, uses data from sensors and machinery to predict when equipment is likely to fail, allowing for maintenance to be performed just in time to prevent breakdowns. This not only extends the lifespan of equipment but also ensures that production processes are not interrupted, leading to significant cost savings and increased efficiency. Advanced analytics also facilitates better supply chain management by providing visibility into every aspect of the supply chain, from raw material sourcing to product delivery, enabling businesses to make more informed decisions and optimize their operations [8,9].

Machine learning applications are integral to the advancements seen in Industry 5.0, driving significant improvements in automation and process optimization. Machine learning algorithms can analyze vast amounts of data to identify patterns and make decisions with minimal human intervention. In manufacturing, this can translate to improved quality control, where machine learning models can detect defects in products at a much earlier stage than traditional methods. This early detection allows for corrections to be made before defective products reach the end of the production line, reducing waste and ensuring higher quality outputs [10]. Additionally, machine learning can be used to optimize production processes by continuously analyzing data from various sensors and adjusting parameters to maintain optimal conditions [11].

Another important application of machine learning in Industry 5.0 is in the realm of personalized manufacturing. With the growing demand for customized products, machine learning algorithms can analyze consumer data to predict preferences and tailor production processes accordingly. This enables manufacturers to produce goods that meet specific customer needs without the inefficiencies typically associated with mass customization [12,13]. Furthermore, machine learning can improve supply chain operations by predicting demand more accurately, optimizing inventory levels, and reducing the risk of overproduction or stockouts. These capabilities allow businesses to be more responsive to market changes and customer demands, ultimately leading to better customer satisfaction and increased competitiveness [13,14].

Overall, the integration of advanced analytics and machine learning in Industry 5.0 represents a significant leap forward in industrial capabilities. These technologies provide the tools necessary to create more efficient, responsive, and personalized manufacturing processes, paving the way for a new era of industrial innovation.

III. Human-Machine Collaboration and Ethical Considerations

Human-machine collaboration in Industry 5.0 is greatly improved by advancements in artificial intelligence (AI), facilitating a synergy between human creativity and machine efficiency. AI-driven technologies enable machines to understand, learn, and respond to human commands more intuitively, creating a more seamless interaction between workers and intelligent systems. This collaboration is evident in various aspects of industrial operations, such as in manufacturing environments where robots work alongside human employees on production lines. AI systems can take on repetitive, physically demanding, or dangerous tasks, allowing human workers to focus on more complex and strategic activities. This not only improves overall productivity but also improves workplace safety and job satisfaction. One of the key benefits of AI-improved human-machine collaboration is the ability to use real-time data and insights for decision-making. AI systems can process and analyze vast amounts of data at speeds beyond human capability, providing workers with actionable information that can inform their decisions and actions [15,16]. For example, in quality control processes, AI can quickly identify defects or irregularities that might be missed by human inspectors, ensuring higher standards of quality. Additionally, AI can assist in training and upskilling workers by providing personalized learning experiences and real-time feedback, helping employees to adapt to new technologies and processes more effectively [17].

Despite the significant advantages offered by AI and advanced technologies in Industry 5.0, several challenges and ethical considerations must be addressed. One major challenge is ensuring data privacy and security in an environment where vast amounts of data are continuously generated and processed. Protecting sensitive information from cyber threats and unauthorized access is important to maintaining trust and integrity within industrial operations. This requires robust cybersecurity measures and adherence to strict data governance policies to prevent data breaches and other security incidents. Ethical considerations also play a important role in the deployment of AI and machine learning technologies. There is a need to ensure that these technologies are developed and used in ways that are fair, transparent, and accountable. Bias in AI algorithms is a significant concern, as biased algorithms can lead to unfair treatment of individuals or groups and perpetuate existing inequalities. Ensuring that AI systems are designed with ethical principles in mind, including fairness, accountability, and transparency, is essential to mitigate these risks [18].

Additionally, there are concerns about the impact of automation on employment, as machines take on tasks previously performed by humans. It is important to consider strategies for workforce transition, including reskilling and upskilling programs, to help workers adapt to the changing industrial landscape and ensure that the benefits of Industry 5.0 are shared broadly. Another ethical consideration involves the environmental impact of advanced manufacturing technologies. While Industry 5.0 aims to create more sustainable and efficient processes, the increased use of data centers, AI, and other technologies can lead to higher energy consumption and resource usage. It is essential to develop and implement sustainable practices and technologies that minimize environmental impact and promote long-term ecological balance [19]. Navigating these challenges and ethical considerations requires a comprehensive approach that balances technological innovation with societal needs and values. Establishing clear regulatory frameworks and guidelines, fostering collaboration between industry stakeholders, and engaging in ongoing dialogue about the ethical implications of new technologies are all important steps toward creating a responsible and sustainable future for Industry 5.0 [20].

IV. Theoretical Model

The analyzed literature provided significant insight into the complex dynamics of analytics, machine learning and collaboration between humans and robots. These insights helped in the development of a theoretical model for transforming of enterprises in the context of Industry 5.0 through advanced analytics and machine learning. The model is presented on Fig. 1.

Data collection and Integration is foundational for the entire model, as it involves gathering and consolidating data from various sources. Sensors and IoT devices play a important role in real-time data acquisition, capturing detailed information about operational conditions and environmental factors. This data is transmitted to Data lakes and Warehouses, where it is stored in both structured and unstructured formats, enabling comprehensive data analysis. Data integration platforms are then used to process and harmonize this data through ETL processes, ensuring that disparate data sources are combined into a cohesive dataset that can be effectively analyzed.

Advanced analytics and Machine learning are directly influenced by the quality and comprehensiveness of the data collected and integrated. Predictive analytics uses the data to forecast trends and detect anomalies, providing valuable insights that can preemptively address

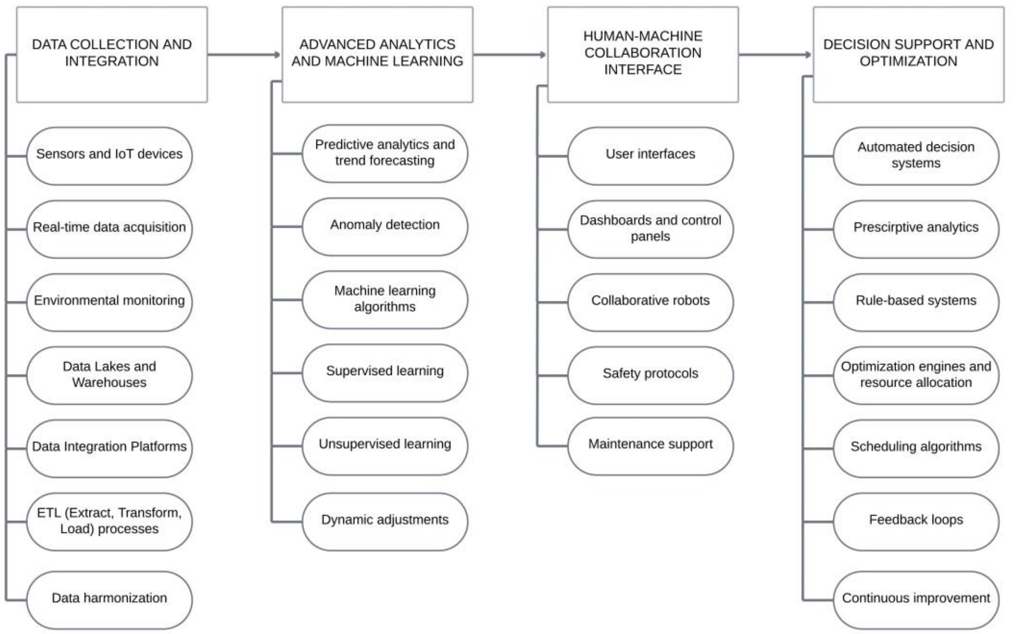

Figure 1. Model of machine learning and advanced analytics for transforming Industry 5.0

issues before they escalate. Machine learning algorithms, including both supervised and unsupervised learning, rely on the integrated data to learn patterns and make accurate predictions.

Real-time analytics uses stream processing capabilities to analyze data as it is generated, enabling dynamic adjustments to processes and operations based on real-time insights. The Human-machine collaboration interface is improved through the insights derived from advanced analytics and machine learning. User Interfaces, such as dashboards and control panels, present these insights in an accessible and actionable format for human operators. Collaborative robots (Cobots) utilize the data to safely share tasks with humans, following safety protocols and optimizing task distribution. Augmented reality (AR) and Virtual reality (VR) technologies further support human-machine collaboration by providing immersive training simulations and real-time maintenance support, informed by the analytical insights. Decision support and Optimization systems are heavily influenced by the advanced analytics and machine learning outputs, as well as the human-machine interactions. Automated decision systems use prescriptive analytics and rule-based systems to provide recommendations and automate decisions, optimizing operational efficiency. Optimization engines apply these recommendations to allocate resources and schedule tasks in the most efficient manner. Feedback loops, informed by continuous monitoring and performance data, allow for ongoing improvements to processes and systems, ensuring that the entire operation remains adaptive and responsive to changing conditions.

The proposed theoretical model includes several key components: data collection and integration, advanced analytics, machine learning, real-time analytics, human-machine collaboration, decision support, and optimization systems. Data collection is achieved through IoT devices and sensors, storing data in warehouses and lakes for structured analysis. Advanced analytics and machine learning rely on this data for predictive insights, while real-time analytics enable immediate adjustments to processes. Human-machine collaboration is enhanced through user interfaces, AR/VR, and collaborative robots (Cobots), and optimization systems use prescriptive analytics to allocate resources efficiently. These components interact in a feedback loop where data is continuously collected and processed, providing real-time insights to humans and machines for decision-making. Machine learning models analyze data to predict trends and anomalies, and humans interact with the system through dashboards or Cobots. Enterprises can implement the model by first establishing data collection systems and investing in data integration platforms. Developing machine learning capabilities and training staff on human-machine interfaces is essential, along with embedding real-time analytics into their operations.

V. Suggestions and Guidelines

Based on the developed model the following suggestions and guidelines for improving business performance through machine learning and advanced analytics applications in the context of Industry 5.0 transformation, are noted:

- Promote education and training programs in AI and data science.
- Establish clear regulatory frameworks for AI and data usage.
- Invest in research and development (R&D) initiatives for advanced technologies.
- Integrate machine learning and analytics into core business processes.
- Foster a culture of continuous learning and innovation.
- Collaborate with tech companies and startups to adopt cutting-edge solutions.
- Pursue education and certification in machine learning and data analytics.
- Stay informed about the latest trends and developments in AI and Industry 5.0.

VI. Conclusion

The integration of advanced analytics and machine learning within Industry 5.0 represents a transformative shift in industrial capabilities, fostering improved productivity, efficiency, and innovation. Through the strategic application of these technologies, businesses can optimize their operations, reduce downtime, and respond dynamically to changing market demands. Real-time data processing and predictive analytics empower organizations to make informed decisions, foresee potential issues, and implement proactive measures. This, in turn, facilitates the creation of agile and responsive manufacturing environments that are important for sustaining competitive advantage in the modern industrial landscape.

However, the deployment of these technologies also presents several challenges and ethical considerations. Ensuring data privacy and security is paramount in an era of pervasive data collection and real-time analytics. Robust cybersecurity measures and stringent data governance policies are essential to protect sensitive information and maintain trust. Additionally, addressing ethical concerns such as algorithmic bias and the impact of automation on employment requires careful planning and the implementation of fair, transparent, and accountable AI systems. It is important to consider strategies for workforce transition, including reskilling and upskilling programs, to ensure that the benefits of Industry 5.0 are equitably distributed.

The proposed model could be validated empirically by implementing it in real-world industrial settings and measuring key performance indicators (KPIs) such as efficiency, productivity, and downtime reduction. Empirical validation would involve comparing performance before and after the integration of advanced analytics and machine learning, as well as benchmarking against industry standards. Longitudinal studies could track improvements over time.

The paper emphasizes the need for reskilling and upskilling, suggesting that businesses should implement AI and data science training programs. Specific strategies include offering certifications in machine learning and predictive analytics, and providing continuous learning opportunities through collaboration with academic institutions or online platforms. Workforce transition programs could also focus on developing digital literacy and human-machine collaboration skills. The adoption of these technologies will vary based on industry readiness, technological infrastructure, and regulatory constraints. Industries like manufacturing and logistics may benefit most from predictive maintenance and supply chain optimization, while service-oriented sectors may prioritize customer data analytics and personalized services. In manufacturing, the challenge lies in balancing automation with workforce management, while healthcare must address data privacy and the complexity of medical data in implementing analytics. The energy sector faces opportunities in improving grid management but must contend with integrating disparate data sources from renewable energy systems. Each sector has unique regulatory and operational considerations that affect how the model is applied.

Future research could focus on industries with high potential for automation, such as automotive manufacturing or logistics. Empirical studies should investigate the scalability of machine learning models across different operational sizes. A roadmap for further research might include pilot projects in sectors like healthcare, testing predictive analytics in patient management, or in smart cities, where real-time data from IoT devices could be used to improve urban infrastructure and sustainability.

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Original Scientific Article

The Impact of the COVID-19 Pandemic on the Business Result of the Snapchat Platform

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Abstract—**The aim of this paper is to investigate and analyze the impact of the COVID-19 pandemic on the operations of the Snapchat platform. The analysis uses selected financial parameters from the profit and loss account and the trend of the number of users. Financial analysis and statistical regression models are used in the analysis of selected business parameters. The results of the research indicate that the global pandemic did not have a significant impact on the operational business of the Snapchat platform. On the contrary, gross profit grew during the pandemic, as did the number of platform users. With the end of the pandemic, the platform achieved the highest gross profit in the analyzed period of seven years. Research and analysis of business results and the trend of the number of users proved that the pandemic did not have a significant impact on the overall business result, but what is even more significant than that, after the end of the pandemic, revenue growth fell below the average for the analyzed period. The platform continuously achieved a negative financial result, which did not significantly affect the interest of investors. All of the above proves that doing business in the platform economy model is completely different from the classic "pipeline" model.**

Keywords – COVID-19, digitization, digital transformation, platform economy, Snapchat**.**

I. Introduction

The Snapchat platform was founded in 2011, and developed as an entrepreneurial project of students from Stanford University. The basic idea of the applications was the exchange of short messages and digital contents that disappear very quickly after opening. Snapchat allows users to send and receive text, images and video content, which can only be opened once or twice for a very short time (1 to 10 seconds). Once the time is up, the content disappears permanently [1]. The platform also developed the "My Story" application, where users can post content that disappears after 24 hours [2]. The idea of disappearing thumbnails was quickly accepted among teenagers, and the platform began to develop a user community. The growth and development of business activity based on the development of the user community and building the network effect is a fundamental attribute of the platform economy model [3,4], and also uses the zero marginal cost effect [5,6]. The basic service of the platform, i.e. communication within the user community, takes place in a freemium model, but a premium service model has also been developed for users who want to individualize part of the communication options provided by the platform.

The platform was developed as a communication infrastructure where individuals exchange short media content, but very quickly built user communities that are very interesting to global corporations. Research has shown that the platform attracts young people because the system of "disappearing" images is quite beyond the control of parents [7]. The content that is sent most often are selfies, that is, it is 50% of the distributed content. Content exchange is most common between friends and accounts for 55% of sent content [8], while 18% of distributed content is exchanged between partners [9]. In 2018, the platform became a "unicorn" with more

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than a billion dollars in revenue [10]. The number of users of the platform grew continuously, except for a short pause in 2018, when the platform achieved more than one billion dollars in revenue for the first time. In 2015, after four years of existence, it had more than 100 million active users, and at the end of 2022, that number increased by more than three times, i.e. the platform had 375 million users [10].

The application was produced by students from the age of 22, and shortly after they left Stanford and Silicon Valley. Everything about the platform looked like a student party, and even the logo of the platform, which, at the beginning of the activity, was more about than technical support on the platform and technological development. The logo of the platform is actually a little good ghost that hints that "snaps" disappear like ghosts. According to the repeated statements of one of the owners of the "code", the ghost was named "Ghostface Chillah" after the singer "Ghostface Killah", the leader of the hip hop band Wu-Tang, which was the favorite band of the founder of the platform. Disappearing messages, technical support far below the level of similar platforms, a user community built around a teenage population, "code" owners dropping out of an elite university to pursue an entrepreneurial project from their parents' house in an elite neighborhood, etc. In 2022, the platform generated $4.6 billion in revenue and has more than 375 million active users. The paper analyzes the business result of the platform in the period before and after the end of the COVID-19 pandemic. Financial parameters and the trend of the number of users are investigated and analyzed in order to answer research questions that are aimed at analyzing the impact of the COVID-19 pandemic on the business result of the Snapchat platform.

II. Literature Review

Social networks are used by more than 4.48 billion people, and Snapchat is in 12th place according to the number of active users in 2022. From the beginning of 2022, more than 6 billion different digital contents are created daily on social networks. According to the results of a survey made in Belgium, 91% of young people between the ages of 13 and 17 had Snapchat installed on their mobile phone [7], while in Great Britain 78% of young people of that age have Snapchat installed on their mobile phone [11]. In the USA, it is used by 90% of the population between the ages of 13 and 24 [1]. Snapchat’s exponential development is a very rare case even among corporations in the platform economy model [8]. Young people were attracted to the platform by topics about pop culture, rappers, celebrities, hip hop music, fashion films, education, food and the like, but also topics related to feminism, indigenous languages and music, violence against women, xenophobia, Latin American problems, debunking stereotypes and the like [12]. The Snapchat user community is dominated by women with 54% of the user population [13].

The platform has developed various models of user community development in order to continuously strengthen the network effect. One such model is the use of gamification to engage users in communication. In order to maintain daily communication, the platform awards different types of rewards to users who communicate daily [14]. One of the forms of gamification is the "Snapchat Streak" model, in which "torches" are assigned next to the names of users who exchange at least one picture in 24 hours [15]. Facebook has three billion profiles, but does not provide similar gamification opportunities [11]. Research has proven that students used Snapchat more for communication than Facebook, and the reason for this is found in a greater degree of fun, practicality and attraction to messages that have personal characteristics [16].

Snapchat's unique configuration may make it a powerful platform for improving learner knowledge by leveraging its unique ability to capture attention of the user. This idea is supported by a conceptual framework of memory termed the “stage theory [17]. Snapchat users are more inclined to share relaxed content and humor than Facebook and Instagram users. Pictures on Snapchat are relaxed in contrast to pictures on Instagram where users want to show "their better selves" [18,19]. The transient nature of Snapchat messages means that the platform is often considered more private and is likely to contain sensitive, highly personal activities such as messaging and flirting [20]. Messages on Snapchat are more personal and confidential, therefore more intimate, and the use of emoji allows for layering and better understanding, as well as avoiding ambiguity and embarrassment [21]

Studies have revealed a positive relationship between problematic use of social networks and one's need to belong, and one's need to be admired [22]. In this context, Snapchat is a platform that is very often the subject of such research. In 2017, Snapchat developed an application for uploading media to its own map or "Snap map". Snapchat users could tap the screen to find out where other users were uploading from. The images that were uploaded to Snap Map had a dubious character, and the peak of the problem occurred during the riots over the death of George Floyd [23]. Research has shown that the term sexting is associated precisely with the development of the Snapchat platform, which was accepted by adolescents due to rapidly disappearing messages [2,24,25].

The platform is very often mentioned in cases of investigations into the sharing of explicit content, especially the sharing of personal images out of revenge [26]. Research related to drug dealing placed the platform in a high place according to the indications of the existence of contacts of interested parties in the sale of various types of drugs [27]. The platform is associated with the term "Snapchat dimorphic", and it is associated with a sudden increase in the number of selfies and image filtering, especially among young women, and subsequently an increased demand for surgical operations according to the appearance from the photos [13].

Snapchat opens up a lot of room for image processing with its tools and filters, and research shows a strong link between dissatisfaction with one's own appearance and the use of filters to process selfies. All this leads to an increased level of anxiety in society [28]. Millennials alone are predicted to take more than 25,000 selfies in their lifetime. A large part of these photos will be processed with different image filters, and women are at the forefront of this as well. Instagram was primarily used for public sharing, while Snapchat was used for sharing private images. This highlights the various motives and possibilities of the ephemeral nature of Snapchat communication [29,30]. Snapchat, like Tinder, discovered the problems of geolocation photos using the triangulation model, which is a contribution to the theories of "surveillance capitalism" [31], and the role of various government bodies in this process is often mentioned [23]. Despite the fact that Facebook dominates among social networks according to the number of users, research has shown that users who have profiles on Facebook and Snapchat spend the same amount of time a day on both networks [16].

III. Methodology and Research Questions

The research and analysis are based on selected data from the corporation's audit report [10]. In the research, data from the profit and loss account and the trend of active users of the platform were selected. Data from the audit report were selected according to the criteria set in the research questions:

1. How strongly did the COVID-19 pandemic affect the financial results of the Snapchat platform?

In the first quarter of 2020, the corporation generated $446 million more in advertising revenue than in the first quarter of 2019 [32]; the number of searches is not the highest for already established corporations such as Facebook, Instagram and Snapchat, but Tik Tok is in the first place, which will subsequently be reflected in revenues and stock prices [33]; research has proven a particularly increased activity of students on social networks, including Snapchat, during the pandemic, but also after 2020 [1].

2. How did the COVID-19 pandemic affect the trend of users of the Snapchat platform?

In the first quarter of 2020, the number of active users increased by 11 million; communication between friends increased by 30%, and in the countries most affected by the virus by 50% [32]; the number of group video chats has grown beyond any platform expectations during the pandemic [34]; the ephemeral properties of the platform have triggered entirely new user behaviors. While previous generations preserved the memory of people and events in the past, Snapchat users define what they do not want to preserve, and have established the "Internet of Forgetting"[35].

Selected financial parameters will be processed using methods of financial analysis and statistical regression. The trend of the number of users will be processed by statistical analysis and regression models so that they can be compared with the results of the analysis of financial parameters. The research and analysis are presented in the Results Analysis chapter, and the final results and interpretations in the Conclusion chapter.

IV. Data Analysis

The research is divided into two areas, namely the analysis of financial parameters and the analysis of the trend of the number of users. For research purposes and for easier comparison of results in all research areas, the same seven-year period was chosen.

A. *Financial Data Analysis*

In the selected analysed period from 2016 to 2022, platform revenues grew by 1,037.7%, which is a growth that corporations from the classic linear business cannot boast of. Revenues have grown continuously from year to year, and they have achieved particularly large growth with the emergence and development of the pandemic. After the development of the pandemic, revenues began to grow exponentially, from which it could be concluded that the pandemic had a positive effect on the platform's revenues. In the same analysed period, direct production costs increased by 302%, which is far less than the growth of income, which was reflected in the growth of gross profit of 4,081.3%. Direct production costs grew continuously, except in 2018 when they were lower than the previous period, which directly affected the almost fourfold increase in gross profit. The share of gross profit in total revenues increased from year to year, and in the last period it amounted to 60.6% of total revenues. The results of the analysis are presented in Table I.

Table I. Selected financial parameters (000; $) [10]

	2016	2017	2018	2019	2020	2021	2022
Revenue	**404.482**	**824.949**	**1.180.446**	**1.715.534**	**2.506.626**	**4.117.048**	**4.601.847**
Cost of revenue	451.606	717.462	708.865	895.838	1.182.505	1.750.246	1.815.342
Gross profit	-47.124	107.487	471.581	819.696	1.324.121	2.366.802	2.786.505
%	-	13,0%	39,9%	47,8%	52,8%	57,5%	60,6%
Total costs	924.867	4.310.525	2.448.896	2.818.862	3.368.698	4.819.117	5.997.153
Operating loss	**-520.385**	**-3.485.576**	**-1.268.450**	**-1.103.328**	**-862.072**	**-702.069**	**-1.395.306**
Net loss	**-514.643**	**-3.445.066**	**-1.255.911**	**-1.033.660**	**-944.839**	**-487.955**	**-1.429.653**

The results of the research using the regression analysis model determined an average annual growth of total income of 49.5% ($s = 0.4952$) interpreted by the exponential regression equation $y = 491035e0,4023x$, with a coefficient of interpretation of 97.78% ($R^2 = 0.9778$). The independent variable is the number of users, while the revenue is the dependent variable in the model. In the same period, direct production costs grew at an average annual rate of 26% ($s = 0.2598$) interpreted by the exponential regression equation $y = 481969e0,231x$, with a coefficient of interpretation of 95.79% ($R^2 = 0.9579$). On the total income curve, the inflection point in the last period is below the average growth curve. This indicates an increase in income below the average growth rate. The same is true for the curve of direct production costs. The results of the regression analysis prove the positive impact of the COVID-19 pandemic on the platform's revenues, and the drop in revenues below average growth after the end of the pandemic.

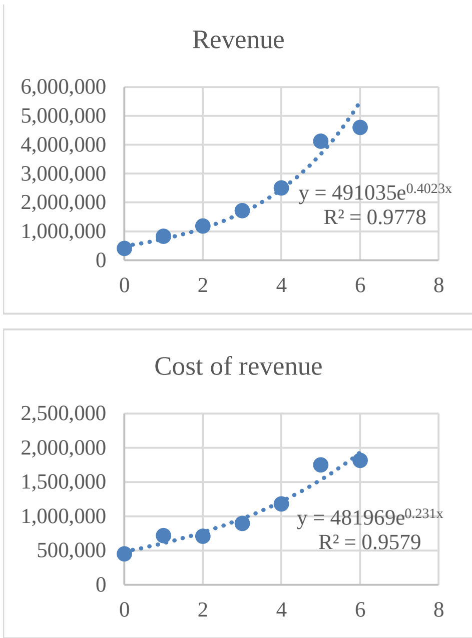

Figure 1. Regression analysis

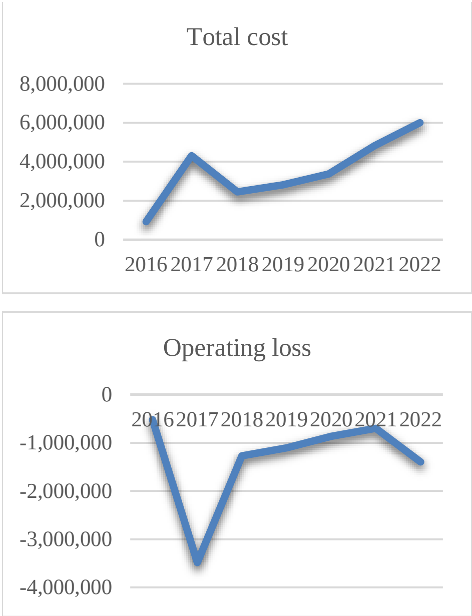

Figure 2. Overview of total costs and operating losses

Despite the growth in income, total production costs are higher than income in the entire analyzed period. In the last analyzed period, the corporation realized almost one and a half billion dollars in losses from regular operations. Total revenues were 4.6 billion dollars, and total costs were almost six billion dollars. Total costs rose sharply in 2017, and thereafter fluctuated depending on the amount of financial activity in research and development. Since 2019, that is, with the continuous increase in income, the total costs of production have been continuously increasing. The increase in production costs was directly reflected in operating losses, that is, the corporation was never positive in the category of operating profit in the analyzed period. The curves of total costs and operational losses are shown in Fig. 2.

In the entire analyzed period, the platform recorded operating and net loss from business. The trend of operating and net losses is the same, i.e. losses will increase sharply in 2017, and after that the platform will increase revenues and reduce losses. However, with the end of the pandemic, the total losses increased sharply again. The corporation had no profit in any of the analyzed periods, and in the last period it has sharply increased its losses. As with total revenues, the pandemic had a positive effect on the overall financial result. A similar situation with the impact of the pandemic on the financial results of corporations from the platform economy model happened with other corporations as well. Shopify and Etsy increased revenues during the pandemic, only for revenues to fall in 2022 [36,37], while Netflix, Tinder and the global music industry in the streaming model continuously increased revenues during the pandemic [36,38].

B. User's Trend Analysis

The movement of the number of users indicates the beginning of the saturation of the platform in the existing user communities. In 2018, the number of users of the platform decreased compared to the previous period, after which the number of users continued to grow. However, in the last two analyzed periods, the number of users has been increasing digressively. As with total revenues, with the end of the pandemic, that is, in the last analyzed period, the increase in the number of users is lower than the increase in the two previous periods.

C. ANOVA Analysis

In the period of the pandemic, after 2019, Snapchat increased the number of users, but advertising revenues slowed down. The same processes took place on the Facebook platform. During the pandemic, the platform laid off 2,300 employees in order to reduce costs, and developed a premium package in the subscription model [26]. The platform increased profits, capitalization grew, but still had losses from operational business. Facebook and other unicorn platforms went through this development. Investors believed in the return of investments because the number of users was continuously growing, which strengthened the network effect [39]. In order to analyze this phenomenon, which appears very often in corporations from the platform economy, the ANOVA analysis model was used. In the model, the relationship between the influence of the growth in the number of users, an independent variable, and the movement of income, i.e. the dependent variable, is analyzed. An overview of the results is shown in Table II.

The results of the analysis using the ANOVA model proved that there is a correlation between the dependent and independent variables, that is, there is a strong connection between the analyzed variables – *MultipleR* = 0.96352. The coefficient

TABLE II. ANOVA ANALYSIS

SUMMARY OUTPUT						
Regresion Statistics						
Multiple R	0.9635242					
R Square	0.9283789					
Adjusted R Square	0.9140546					
Standard Error	413772.92					
Observations	7					
ANOVA						
	df		*SS*	*MS*	*F*	*Significance F*
Regression	1		1.10963E+13	1.10963E+13	64.8118002	0.000478549
Residual	5		8.5604E+11	1.71208E+11		
Total	6		1.19523E+13			
	Coeff.	*St. Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-2211436.5	541589.1769	-4.08323622	0.00950963	-3603635.846	-819237.245
Users	17108.06	2125.072311	8.050577631	0.00047855	11645.38733	22570.7319

of interpretability of the regression model, for strings of less than 30 frequencies, is 0.91405, that is, the regression model is statistically significant because *Adjusted R Square* > 0.8. The coefficient of significance of the statistical model is 0.0005, or Significance $F = 0.000479$, which is less than 0.05. The result of the significance analysis proves that the model is statistically significant, that is, at least one regression variable significantly affects the value of the dependent variable. In the analyzed model, the P-value is 0.0005, with a risk level of $p < 0.05$, which proves that the independent variable, in the model they are Users, has a statistically significant effect on the value of the independent variable, in the model they are Revenue. The results of the analysis using the ANOVA model prove the differences in the analysis methodology between corporations in the linear model and in the platform model. The regression model proved a statistically significant relationship between the dependent and independent variables, although the majority of users are in the freemium model, and the income comes from different sources.

V. CONCLUSION

The Snapchat platform has achieved global success even though it started as an entrepreneurial project that didn't promise too much. This could be the conclusion of an analyst from classic pipeline economics, but not an expert in platform economics. The results of research and analysis using classic tools from the linear business model indicate business results that are completely different from efficient and financially successful corporations from the classic economic model. The results of research and analysis, in the context of the development of the global COVID-19 pandemic, can be summarized in four basic points. First, platform revenues began to grow exponentially with the emergence and development of the pandemic, so it can be concluded that the pandemic had a positive effect on the corporation's revenues. Second, the share of gross profit in total revenues is 60.6%, which is unimaginable for corporations from the "pipeline" business model. Third, total production costs are higher than total revenues in the entire analyzed period, which indicates high research and development costs for each new product or application on the platform, and fourth, the average annual growth in the number of users is lower than the average annual growth in revenue, which indicates an efficient diversification of the platform's business activities.

In the context of the first research question, the results of the analysis proved that the COVID-19 pandemic did not have a significant impact on the platform's financial results. During the pandemic, as well as after the pandemic, the platform's revenues grew continuously. The platform's gross profit continued to grow, which is even more significant than revenue growth. In the last analyzed period, gross profit was 60%. The results of the financial analysis indicate a positive impact of the COVID-19 pandemic on the financial result of the platform. A similar financial result was achieved by a large number of corporations from the platform economy model during the global pandemic. In the context of the second research question, the results of the survey and analysis showed very similar results. With the onset of the pandemic, the number of users grew rapidly, and after that it grew digressively. Revenues grew faster than the number of users, but the number of users continues to grow continuously. The COVID-19 pandemic had a positive effect on the user trend, as the number of people interested in communication during the "lock-down" increased, and the platform became globally popular among teenagers.

The growth of total revenues in the last analyzed period is below the average for the analyzed period, which proves that the COVID-19 pandemic had no impact on the business result of the platform. On the contrary, during the pandemic, incomes grew continuously, and this growth fell below the average only in the last period. The number of users grew gradually, but the trend of using the platform spread globally. All this convinced investor to continue to believe in the Snapchat project, even though the platform was continuously making operational losses. The strength of the network effect is growing day by day, and this is the only guarantee for investors in the project. Everything is different from the classical linear economy, but it still increases its value. The impact of the COVID-19 pandemic was exactly the opposite of what happened in global linear business models. For future research, the question of what the trend of total income will be, or whether the average annual growth rate will begin to fall, remains an open question. Moreover, the potential long-term implications of the slowdown of the revenue growth will be tackled in future research.

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Original Scientific Article

Innovations in Risk Management - Integration of Neural Networks in Boilers with Automatic Firing

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Abstract—**Already at the beginning of the first quarter of the twenty-first century, we are witnessing the increasing application of artificial intelligence in all stages of life. The paper you are reading highlights the importance of implementing neural networks on boilers with automatic firing and is the result of a project that is entering its fifth year of experimental verification. The application of neural networks in boilers with automatic firing gives good results in risk management, through the prediction of system failures and their early software elimination. Artificial intelligence systems applied to boiler systems can reduce the harmful effects of the systems themselves, but also prevent accidents that can threaten people's health and safety, as well as cause material damage.**

Keywords - neural networks, risk management, automatic boilers.

I. Introduction

Risk management in industrial systems is a key aspect for ensuring the safety, efficiency and reliability of their operation. As boilers with automatic firing are complex electronic energy systems, risk management becomes even more important due to the specificity of the systems themselves and all potential hazards.

Increasing boiler efficiency through controlled operation can lead to energy savings and reduced pollutant emissions. Scheduled maintenance activities can improve operations and reduce running costs. However, the time interval between recommended maintenance varies from boiler to boiler. Therefore, it is necessary to choose a suitable early detection system that uses algorithms that will improve efficiency, operability and security [1].

Boiler systems operate at high temperatures and pressures, which can lead to serious accidents if adequate risk management measures are not taken. Risk management in these systems enables the identification of potential hazards, which occur due to overheating caused by various failures or anomalies in the fuel they use. Neural networks can significantly improve the risk management of auto-fired boilers in several ways. Primarily, they can analyze large amounts of data generated by sensors in boilers in order to predict possible failures and enable timely intervention. Then, their implementation for optimization of the combustion process and temperature control can significantly reduce the risk of improper operation and increase efficiency, i.e. the degree of beneficial effect, which directly leads to a reduction in energy consumption, and thus directly reduces harmful effects on the environment. With the proper use of intelligent systems, we detect potential problems and risks at an early stage, which leads

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to a timely reaction, both of the management system and the operators of these systems. We know that the diagnosis of system failures is of great importance for saving energy. The latest studies propose a new approach to energy-saving fault diagnosis based on the deep learning method,[2]. In order to minimize the number of system downtimes, and thus the maintenance costs, manufacturers of modern boiler systems have adopted advanced fault detection and diagnosis techniques. These techniques can be divided into three main categories: model-based methods [3-5], data-based methods [6] and statistics-based methods [7,8].

Model-based methods are effective solutions to simple fault detection problems. However, they can be challenging to apply to complex industrial processes because working with them requires quite expensive and powerful computers. In such cases, data-driven approaches and statistical methods have become popular. These methods include the use of machine learning algorithms [9], ANN [10] and multivariate statistical techniques, such as PCA [11]. Also, they use real-time data from data collection systems to detect and diagnose errors. Boiler stations are equipped with various acoustic emissions [12,13] and process monitoring sensors [14], which generate a large amount of data.

II. Application of Neural Networks in OZON 55 Type Boilers

Neural networks have a very wide application, both in complex security systems, improving the quality of life through applications used in everyday life, and in industrial plants. [15] Recurrent Neural Networks (RNN) are suitable for working with time series and sequential data, because they retain information about the previous states of the system. [16-20] To control the combustion parameters of auto-fired boilers, the key models and architectures used are the basic RNN model. We note here that the basic architecture of a recurrent neural network includes. Recurrent nodes that receive an input signal, as well as a return signal from the previous state (hidden state), which processes time dependencies and weights that are shared at each time step, which allows modification of the network's behavior based on previous data. With the basic RNN architecture, there is a problem with long-term dependencies, because it is difficult to remember information from the distant past due to the gradient quenching problem during training. After this, LSTM (Long Short-Term Memory) was resorted to, which is a more advanced type of RNN, designed to solve the problem of long-term dependencies. Its architecture contains special mechanisms, such as memory cells, that can store information for long periods of time. The main elements of an LSTM network include Input gates that determine what new information will be added to a memory cell, Forget gates that determine what information from memory should be deleted, and Output gates that control which portion of memory will be used as output in the current time step. LSTM мреже су посебно корисне када је потребно задржати и користити информације из претходних временских корака, што је веома важно у сложеним процесима као што су промене у квалитету горива, притиску или мешању ваздуха у котловима. [21,22] So, Parameter Prediction Model: RNN or LSTM is used to predict future combustion parameters based on data sequences that include temperature, pressure, air and fuel flow. This is followed by a real-time adjustment: The network would dynamically adjust its prediction based on new sensor data, ensuring efficient combustion, regardless of changes in fuel quality or environmental conditions.

In order to better approach the problem that arose during the control of one of the OZON 55 type boilers, it was decided that it was necessary to collect data experimentally. An Arduino Uno was used for collection, to which type K temperature probes, humidity meters and gas meters were connected. Temperature probes are placed at the probe points that control the operation of the boiler, but also directly under the firebox, in the smoke channel one meter above the smoke exit from the boiler, as well as for measuring the external and internal air temperature. Humidity sensors monitor the relative humidity of air and pellets. Gas sensors are placed in the chimney to measure the amount and type of gases that are a product of combustion. By May 2022, the system has undergone a series of hardware and software changes to adapt for more accurate and purposeful measurements. Experimental measurements for the research part are carried out from October 2022 [23].

In parallel with the construction of the measuring system, the invention of the

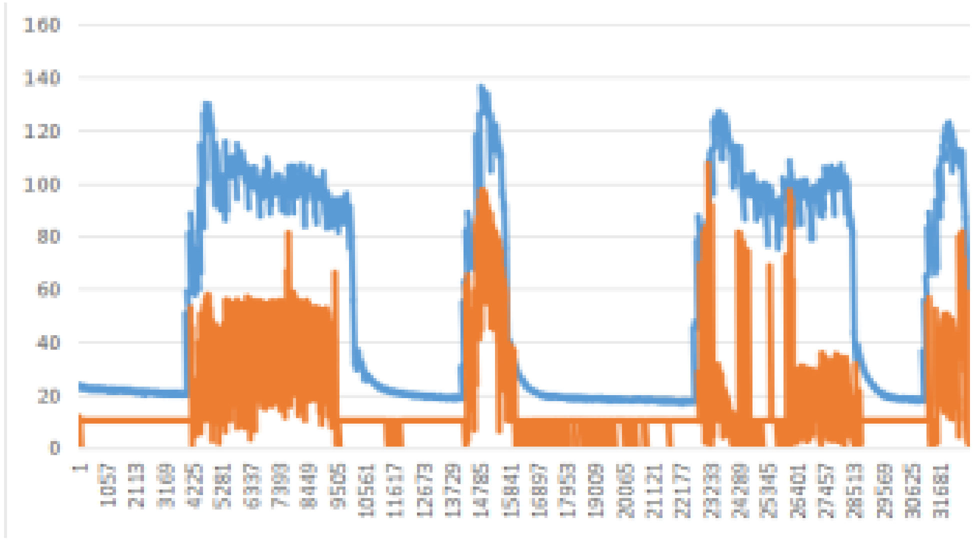

Figure 1. Comparison of measured values and values obtained by calculation.

mathematical model began. By searching for possible mathematical models, we came to the conclusion that, the model to be used is multivariate and non-linear. On the other hand, the nature of the collected data in the form of time series imposes a dynamical discrete time model for this system. For this reason, the required model is of the following form:

$$y(x) = \\ = f\left(Y\left(t,D_y\right),X_1\left(t,D_1\right),X_2\left(t,D_2\right)\ldots\right), \quad (1)$$

where $f:\mathrm{R}^{D_y+D_{x_1}+D_{x_2}+\ldots}\to\mathrm{R}$ is a continuous non-linear map representing the required model. The problem solved initially is the determination of the dimensions of vectors $Y, X_1, X_2,\ldots i.e. D_Y, D_1, D_2,\ldots$ which are the orders of the models autoregressive and transregressive dependencies of the system. The method used for this has been described in [24]. The essence of this method consists in computation of probability that the collected data are produced by a system whose model is a linear map.

The synaptic and the activation coefficients of the neural network, represented by matrices, have been optimized using the method of back-propagation of the error gradient.

The entire system is conceived as a recurrent neural network that determines one sequence element at a time. We introduce a set of measured values to the input and after that we start the calculation. The next mesh is added only after the calculation for the previous mesh has already been performed. A recurrent network maintains a so-called hidden state and has the current hidden state at each step. For a given input, given that input and the current hidden state, it computes a new hidden state as a linear combination of the matrices with the vectors of the current hidden state and the current input. An activation function is applied to the obtained result and thus a new hidden state is obtained. An activation function is applied to the obtained result and thus a new hidden state is obtained. After that comes a new set of measurements, based on the current state and representation of the set, with the help of the same matrices, linear transformations are performed, activation functions are applied and a new state is obtained, and so on for all sets of measurements. At each step, some output can be generated from the hidden state.

III. Analysis of the Obtained Values

The discussion of the results cannot begin before we point out that the neural network training phase incorporates several internal processes and elements, which ensure proper handling and parametrization of the training phase.

1. Number of epochs – Each epoch represents passing the entire dataset forward and backward through the neural network once. Number of epochs is set to 100 for the purposes of the training outlines by this approach.

2. Batch Size – Number of instances processed together before the update of neural network's parameters [18]. Batch size is set to 256, due to the large number of network flow instances.
3. Callback for Learning Rate Reduction – Learning rate influences the size of adjustments made to the model weights based on the calculated gradients. This callback ensures dynamic reduction of learning rate, enhancing and speeding up model's convergence.
4. Callback for Early Stopping – Callback which prevents unnecessary computations and therefore overfitting. After 7 unsuccessful epochs, training phase is terminated and weights from the model's best performing epoch are selected and restored as they encapsulate model's optimal state achieved in the training phase, for further model's performance evaluation.

The carefully designed methodology integrates multiple components to ensure correct and effective neural network's training and evaluation in case of network intrusion detection. The strategic combination of parameters such as the number of epochs, batch size and callbacks ensure both effective and performance-oriented training phase.

By using this model, and after comparing the results, deviations between the computationally obtained hidden states and the actual measured values were seen. By increasing the number of measurement points, the error decreased.

The Fig. 1. shows the relationship between measured values and values obtained by calculation, it can be seen that the calculated value generally follows the measured value, but there is an error. In this research, the neural network obtained an approximate value to the measured value. The error decreased with the number of measurements. And in some cases, the neural network of this type gave results that are not in agreement with the measured results.

A big problem in the development of this model is the short period of operation of the boiler, which is contributed by uneven weather conditions. We see the need to develop a model that, in addition to the parameters necessary for fire maintenance and pellet quality monitoring, will also include parameters related to the climatic conditions of the microregion where the measurements are made.

At this point, we must mention that the introduction of these systems requires costs and hardware modifications of conventional boilers. First, it is necessary to prepare a study of the profitability of the system implementation. Specifically for boilers of the OZON class, which vary in power, ranging from 25 kW to 75 kW, the system itself is profitable to install, since the investments are of the order of magnitude of the annual energy savings. Namely, OZON boilers have a microcontroller in them that can support the aforementioned additions and modifications. Namely, OZON boilers have a microcontroller in them that can support the aforementioned additions and modifications. In addition, they have a set of sensors that satisfy the measurements of the temperature of the exhaust air and the exhaust smoke. Therefore, it is only necessary to place one humidity and temperature sensor inside the pellet tank, for example. DHT 11 and particle sensor PM 2.5. The modification itself does not require large financial investments for hardware modifications. After that we have the new software loading.

IV. Conclusion

Today, when we are faced with uncontrolled pollution, and at the same time the sale of boilers with automatic firing is expanding, we must take care of saving the fuel that the boiler consumes. By increasing the degree of fuel utilization, we reduce the emission of harmful gases into the atmosphere, reduce the consumption of biomass or fossil fuels used, and thus have a positive impact on the environment and increase the quality of living conditions [25]. By introducing intelligent systems that use neural network models, we can improve risk management through prediction, prevention and optimization of the operation of boilers with automatic firing. Rapid diagnosis and repair of faults can be difficult, due to lack of information and manpower, leading to prolonged downtime and increased production losses [26]. The development of a model of neural networks that will be applied to optimize the control parameters of boilers with automatic firing can lead to a significant reduction in fuel consumption and an increase in the degree of fuel utilization. The prediction of the temperatures of the combustion chamber, the energy power of the pellets, the amount of oxygen in the air mixture can significantly improve the operation of the heating system, thereby increasing the comfort of the population and contributing to the protection of the environment [27]. With this, we come to the conclusion that the introduction of neural networks in this area significantly reduces the risk of any kind.

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Original Scientific Article

Developing a Personal Financial Assistant MobileApp: A Comprehensive Approach to Expense Management and Financial Goal Achievement

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Abstract—**The majority of personal financial management systems rely on manual data entry, limiting their effectiveness in real-world applications. In this study, we introduce Genie Savings, a comprehensive mobile financial assistant designed to automate expense tracking and goal achievement. The model was trained using a dataset of 1,000 real-world receipts and 5,000 bank SMS messages to extract financial data using OCR technology and Machine Learning (ML) algorithms. Unlike previous systems that depend heavily on user input, Genie Savings automatically categorizes expenses into key areas such as Food, Transport, and Personal Care, using a Support Vector Machine (SVM) based classifier algorithm with an accuracy of 91.58%. Additionally, the app provides personalized financial recommendations through an anomaly detection model, helping users reduce expenses in high-spending categories. The system's recommendation model achieved a 75% success rate in guiding users toward their financial goals. The study further explores the integration of advanced models for SMS data extraction and automated bill analysis, enhancing the app's accuracy and usability. Genie Savings demonstrates the potential of AI-powered financial tools in automating budget management. It offers significant benefits for personal finance, enabling users to take control of their spending habits and meet their savings goals effectively.**

Keywords - personal financial assistant, expense management, OCR, machine learning, expense tracking

I. INTRODUCTION

Financial goals are targeting an individual set to achieve financial milestones or plans. In other words, they are financial objectives an individual wishes to accomplish within a certain time frame. For example, it could be setting up a fund for their children's education, travel, emergency, health care, etc. [1]. Goal setting is important in achieving an individual's financial goal [2]. A study by Nations Bank and the Consumer Federation of America found that aside from income, [3] the critical factor distinguishing successful people is preparing a comprehensive financial plan. No matter what their income is, people with a plan save more money or invest in more innovative ways and feel better about their progress than those without a plan. The two basic ways to achieve a financial goal are reducing expenses and investing. However, people often face challenges when it comes to reducing expenses. They may not clearly understand which expenses to reduce and how much to reduce for a given time frame. This lack of clarity can lead to misguided actions and ineffective financial decisions. Tracking expenses and understanding spending patterns is essential to reach a financial goal successfully. While various expense tracking apps are available, manually entering expense data into these apps can be inefficient. People may be reluctant to do so due to the effort involved. Additionally, human errors can occur in data entry, leading to misunderstandings of their spending patterns. Accurately identifying spending patterns is critical as these patterns form the basis for making informed financial decisions. Therefore, obtaining accurate and reliable expenditure details is essential to financial goal setting.

A. Problem Definition

Time, Mind, and finances are the three types of freedom in the world [4]. In the process of achieving financial freedom, people run across a variety of issues. Thus, maintaining and pursuing financial goals is essential for reaching financial success. Achieving financial objectives involves dealing with numerous obstacles. The primary methods for achieving a financial objective are to maintain a record of expenses, categorize them, and reduce them with the most effective reduction amounts based on the categories of expenses [5]. Individuals records expenses without seeing the categories. Effective spending tracking is hindered. People lack sense pattern and financial goal knowledge. We found that people lack financial advisers to achieve goals. Personal expense reduction advice is also lacking, hindering financial decision-making. People follow others' needs over their own. Then financial confidence falls. Unfortunately, many struggle to meet financial goals on time.

B. Aim and Objectives

The primary goal of this research is to direct individuals toward achieving their financial objectives by creating a financial assistant. The objectives are to explore effective techniques for extracting expense data from bills without relying on manual input, which is often cumbersome and error-prone. This involves identifying spending categories suitable for reduction to achieve financial goals. Instead of determining optimal reduction amounts for each category, we focus on establishing maximum spending limits for each. This approach allows users to understand how much they can spend in each category while still progressing towards their goals, giving them the flexibility to spend up to or below these limits. The research aim is to provide an alternative to manual expense management by leveraging methods that accurately extract expense data from bills, enabling users to analyze their spending patterns and make informed decisions on where to allocate their funds effectively.

II. Literature Survey

In this section, we delve into a comprehensive review of related works in financial management and expense control. Our exploration is categorized into several areas of research, each contributing to the development of a financial assistant application.

A. Receipt and Bill Extraction

In the first category of research, we examine the aspect of extracting financial information from bills and receipts. Pandey, Vardhan, Verma, Pathak, and Kushwah introduced "XPENSE Tracker," an expense tracking application that utilizes OCR and machine learning technologies for efficient bill and receipt extraction [6]. By employing cutting-edge Optical Character Recognition (OCR) and machine learning, the application recognizes and extracts essential expense data from scanned receipts, including transaction dates, item names, and costs. Additionally, *XPENSE Tracker* offers user-friendly categorization of expenses, allowing users to gain insights into their spending habits across different categories and visualize their financial behavior through various charts. To further enhance receipt capturing accuracy, Kr¨uger and team developed "*Expense Control*," a gamified, semi-automated, crowd-based approach [7]. The study's workflow includes photographing receipts, recognizing general information, and crowdsourcing data correction and enhancement. Gamification encourages users to enrich the database actively.

B. Expenditure Categorization

This section explores methods for categorizing expenses into specific expenditure categories. Effective categorization provides users with a clear overview of their spending habits. Sabab, Islam, Rana, and Hossain developed the *eExpense* application, providing users with the capability to efficiently record and categorize their expenses into various categories such as *food, entertainment, transportation,* *education, healthcare, clothing, bank, and groceries* [8]. The application calculates monthly and yearly balances, considering both income and expenses. Users can conveniently record expenses by scanning their bills and receipts. The *"eExpense" application,* with its intuitive organizational structure, simplifies expense tracking, offering four major sections: Debit, Credit, Balance, and History. *Household Expenditure Patterns - The Effect of Age of Family Head*, conducted by Kwangwen and Chen, explored the relationship between the age of the family head and expenditure patterns [9]. This study demonstrates how perceived economic behaviour varies in the different age brackets, especially the heads of families. The findings indicate that the age of the family head significantly influences consumption expenditure in all the specified categories. This work reveals that family head age is a significant determinant of expenditure, indicating that household financial decisions are not mere simplification.

C. Expenses Controlling or Reducing

This focuses on controlling and reducing expenses. While not all studies offer automated recommendations, they provide insights into managing financial resources effectively. Yan, Wei, Ho, and A. Yap presented an inventive approach to address the financial challenges encountered by the young generation in China [10]. Their creation, the "BUDG" app, allows users to set daily budgets and monitor daily spending, ensuring adherence to user-defined limits. This app acts as a financial compass, promoting self-control and helping users make more informed spending decisions, effectively working towards their financial goals. From a distinct perspective, K. Prochaska - Cue emphasized the significance of creating a cash flow plan for farm and ranch families [5]. This cash flow plan enhances managerial skills and offers a structured approach to managing family living expenses. By carefully strategizing expenses in terms of amount and timing, families can achieve better financial stability and gain control over their expenditures. Additionally, the Timor-Leste Household Income and Expenditure Survey, conducted by the National Statistics Directorate General Directorate for Analysis and Research Ministry of Finance, comprehensively identified key budget categories and essential expenses. The insights drawn from this survey empower researchers and policymakers to assess whether households have experienced improvements in their economic situations over time or are grappling with financial challenges. This data is invaluable for designing targeted economic policies that support the financial well-being of the population [11]. Maulian and Juwono introduced an Expensify Android mobile application [12]. This is a crucial tool for individuals looking to enhance their financial management skills, especially the younger generation. It offers transaction, category, and budget management features to cater to a wide range of financial needs. The primary outcome of this system is to empower users to manage their finances effectively by recording income and expense transactions and providing essential expense statistics. This information enables users to take control of their expenses by identifying exceeded expense categories and making informed financial decisions, fostering financial stability and goal attainment. "IMONEY Manager: Student Accountability Application for Money Management," authored by Tundrea and Barna, addresses the financial challenges frequently encountered by students. This innovative application equips students with tools to balance their financial books and encourages them to adopt a more responsible approach to managing their financial resources. By prioritizing financial well-being and promoting informed financial decision-making, "IMONEY Manager" supports students in efficiently managing their finances. It aims to empower students with the skills and knowledge needed to make wise financial choices during their academic journey [13]. Finally, the "Family Expense Manager Application in Android," as presented by Rajaprabha, serves as a modern-day expense diary that you can carry in your pocket. It facilitates the tracking of daily expenses and settlement details, provides a comprehensive overview, offers detailed reports, and covers periodic expenses. This application is well-suited for middle-class individuals who purchase without relying on settlements or credits. It helps users efficiently record and manage their family's bill settlements and pending expenses. It works as a digital ledger to empower users to keep a close eye on their expenses and easily maintain financial records, fostering financial management and accountability [14].

D. Expenses Controlling or Reducing

OCR technology has gained significant attention and has been applied to various domains for information extraction from text. It plays a crucial role in automating data entry tasks, particularly in handling complex documents. The study of Rekha et al. [14] explores the application of Python-Tesseract OCR in processing invoices, with a specific focus on vendor identification and payments. According to the paper, Tesseract OCR's accuracy with distorted invoices makes it ideal for extracting text from complex documents. The researchers also note that Tesseract OCR is open source, providing reliable OCR technology.

Python compatibility makes it simpler to integrate into projects, especially invoice automation, for efficiency. Tesseract OCR's multilingual capabilities, preprocessing compatibility, customization potential, and strong community support are also highlighted in the study. Budi, Purwandari, and Ramdhani [15] focus on assessing the performance of various OCR engines in the context of information extraction, especially for government human resources documents. Paper automates manual data entry using Named Entity Recognition (NER) and Optical Character Recognition (OCR) techniques. Evaluating multiple OCR engines, the study finds Tesseract excels in preprocessing time, NER time, and precision, while PDF2GO and Foxit perform better in entity extraction. Tesseract is the fastest engine, processing documents in 0.044 seconds on average, slightly ahead of PDF2GO and Foxit.

Figure 1. A) Original Billing Image, B) Preprocessed Image removing wrinkles and shadows, C) Finalized Processed image for using OCR

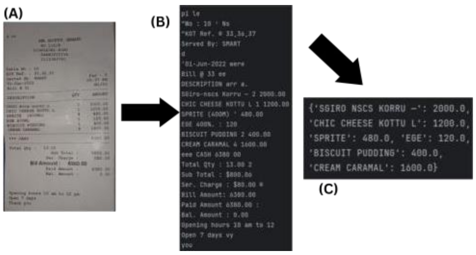

Figure 2. A) Single line bill, B) Tesseract output for single line bill C) Final output with item description and amount

Kumar et. al [16]. Highlight the effectiveness of Tesseract OCR in extracting information from bill receipts. The paper underscores Tesseract OCR's high accuracy in recognizing printed text, making it a valuable tool for preserving the formatting and structure of output text and ensuring the integrity and context of bill and receipt information. Its multilingual support ensures adaptability to diverse documents with text in various languages. For long invoices (longer than 26cm in length), the algorithm divides the invoice into two parts, as shown in Fig. 1, to make extracting data convenient. The algorithm scans the invoice and calculates the dimension of the entire invoice. For the bifurcation process, the invoice is divided into two parts: the first 55% of its length and the last 50% of the length. The 5% in the middle is reserved for information retention. Schouten, Wolf, Nolan, Joshi, and Benedikt [17] research dives into OCR and machine learning classification for shopping receipts. The paper emphasizes the significance of image processing and Natural Language Processing (NLP) in enhancing OCR accuracy.

Fig. 2 shows the challenge of selecting the appropriate image resolution for optimal OCR accuracy, with 300 dpi being the standard. This study shows the image resolution-OCR performance trade-off. The research also shows that font size affects OCR accuracy, especially when dealing with receipt issues like low-quality photos, faded prints, stains, and shadows. Image resolution is crucial for OCR accuracy. The research findings demonstrate that extremely high resolutions, such as 1200dpi, tend to yield worse OCR results while increasing processing time. The main reason character recognition performs poorly at high resolutions is image noise. Given the resolution-OCR performance trade-off, 300 dpi is recommended for maximum accuracy. Font size and a recommended lowercase letter "x" height of 20 pixels also affect OCR accuracy. To maintain recognition quality, smaller font sizes require higher resolutions.

III. METHODOLOGY

A. Data Collection and Labeling

1) Categorized Bill Dataset (Dataset1)

The dataset contains bill images categorized by condition: good-quality, shadows but no wrinkles, and bad-quality, shadows and wrinkles. Categorization allows customized preprocessing for OCR data extraction. The dataset was diverse and comprehensive because images were taken from supermarkets in different districts, including Cargills and Keels. This study examines these categories

- Good-quality bills,
- Bills with shadows but no wrinkles,
- Bad-quality bills with shadows and wrinkles

2) Categorized Expenses Dataset (Dataset2)

This dataset categorizes expenses, automatically classifying user input expenses and OCR extracted bills. It combines data from previous research studies and Kaggle, refined into a structured repository with expense categories such as *"Medical", "Housing and Bills", "Food", "Personal Care", "Transport", and "Other"*. The expenditure data for the Sri Lankan Household Income and Expenditure Survey (HIES) was meticulously categorized to add to the dataset. This rich dataset improves expense categorization accuracy and awareness, boosting research efficiency.

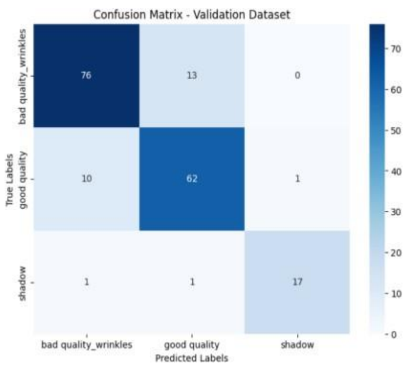

Figure 3. Confusion Matrix of Bill Classification Model

3) Bank SMS Dataset (Dataset3)

This dataset comprises SMS notifications from users across various banks, focusing on electronic card payments and online transactions. The collection process involved using the "SMS Backup and Restore" application to extract SMS data into Excel sheets from diverse users associated with different banks. The dataset serves as a foundation for analyzing bank-related information, particularly in identifying payment transactions and obtaining expenditure amounts accurately.

4) Day-to-Day Expenses Dataset (Dataset4)

This dataset documents one person's spending habits over about four months. It's used to examine past spending to find unusual patterns or unexpected expenses. We got this data from Kaggle. It tells us exactly what was spent and helps us understand how money was used over time.

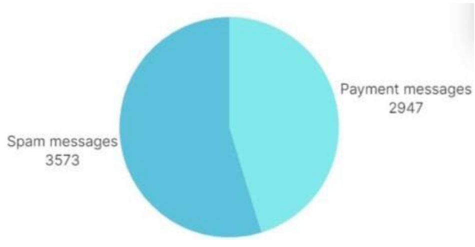

Figure 4. Distribution of SMS dataset

B. Methodology and System Design

Our research methodology for the financial app project follows the design science research approach. This method emphasizes creating and evaluating innovative artifacts to address real-world challenges. In our case, we are developing a financial assistant app to help individuals efficiently reduce expenses and achieve their financial goals.

1) Expenditure Data Extraction

The diagram below illustrates the architecture of a financial assistant system designed for automated management of personal expenses. Bills are input into the system either directly or via SMS, which undergoes a three-tier preprocessing sequence to address various quality issues, such as wrinkles or shadows in the bill images.

Preprocessed bills are fed to Model 1 for initial data extraction. The extracted data is categorized into Food, Transport, Personal Care, Housing Bills, and Medical Expenses. Model 2 refines this classification. Finally, the categorized data is stored in a database and accessed via a smartphone GUI, allowing users to track and manage their spending.

a) Categorizing Bills as Good Quality, Shadowed, or Shadowed with Wrinkles for Precise Data Extraction

When a user scans a bill and submits it to the system, the system uses a VGG16 model to classify the bill into one of three categories: good quality, with only shadows, or wrinkled with shadows. This classification is based on visual features and features detected in the scanned image, allowing the system to apply specific prepossessing steps tailored to each category for accurate data extraction. The accuracy of this model is 0.8741.

b) Automated-Expenditure Categorizing

In the context of classifying user expenditure into predefined categories such as “medical,” “housing and bills,” food,” “personal Care,” “transportation,” and “other,” the study conducted an extensive exploration of classification models. The study aimed to correctly assign the expenditure data to the appropriate category based on the item details. In this research, evaluated *SVM* and *Naive Bayes classification* algorithms to identify the most suitable model for our task. With an accuracy of 91.58%, SVM was chosen as our primary classifier over Naive Bayes, which achieved an accuracy of 83.51%.

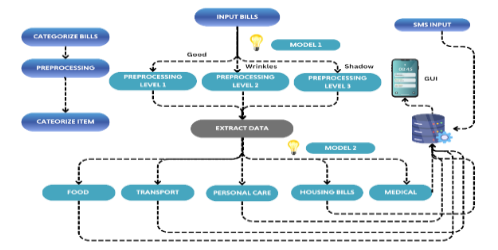

Figure 5. Architecture Design for Expenditure Data Extraction Section

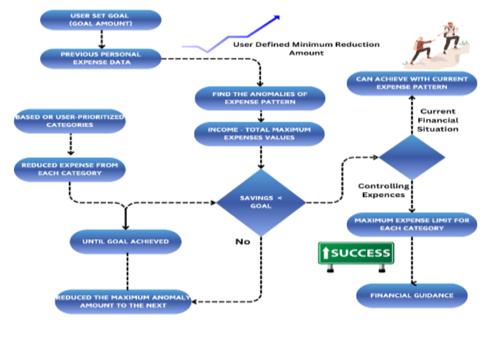

Figure 6. Financial guidance for goal achievement workflow

c) Reward Mechanism for User Interaction

In implementation, we used a neural network model for binary classification. This model uses the labelled dataset of SMS messages labelled “spam” or “bank.” Based on message content, the model learns to distinguish the two categories using neural networks. Once an SMS message is marked "bank," the research team extracts financial data like the amount paid.

2) Track users’ daily and monthly expenditures

The system also stores daily and monthly user expenses for each expenditure category. Set daily or monthly costs with this feature. If these recurring expenses don’t start at the specified time or month, the system will prompt the user to add them.

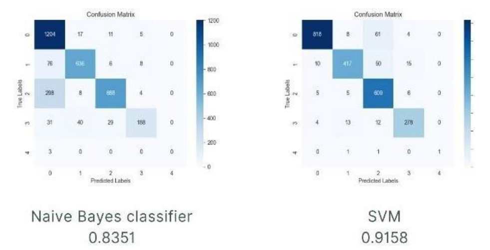

Figure 7. Confusion Matrix of Bill Classification Model

3) Financial Recommendations

The Financial Assistant Mobile App helps budget, save, and manage money. Enter your savings target and deadline. The app finds unusual spending. The user’s income and highest expenses are compared iteratively to cut priorities. If savings aren’t enough, the app suggests cutting the most unusually high expenses first, then repeating until the goal is reached.

The app produces financial recommendations to help users make smart spending decisions. If the user can reach their goal with their current financial habits, it acknowledges success without suggesting further reductions [18,19].

4) Reward Mechanism for User Interaction

Suppose the user follows the spending limit and recommendations. In that case, the system assigns user reward values. Apps offer gold and silver rewards based on context if the user meets their financial goals within the specified time [20].

IV. Results Evaluation

A. Bill Extraction

In the evaluation of bill extraction feature using Tesseract OCR on *1.000 diverse physical receipts*. These bills varied in quality layout to test the OCR’s adaptability and accuracy. Precision, recall, and *F*1 scores were used to assess text extraction accuracy and efficiency.

The results demonstrated that Tesseract OCR achieved an average *precision of 92%, a recall of 89%, and an F1 score of 90.5%* across the dataset.

B. SMS Extraction

For the SMS extraction feature, we developed a machine learning model trained on a dataset comprising 5.000 SMS messages from *three central banks and financial institutions*, annotated with transaction details such as date and amount. A predefined test set of 500 messages was used to evaluate the model's accuracy, precision, and recall. The model scored *95% accuracy, 94% precision, and 93% recall*. This high level of performance signifies the model's effectiveness in accurately categorizing and extracting relevant financial data from SMS messages.

C. User Goal Achievement

In assessing the impact of our Financial Assistant Mobile App on user financial goal achievement, we conducted a practical study involving 20 participants. These individuals were instructed to use the app over a set period, during which they inputted their financial data and defined short-term financial goals. The app provides personalized financial advice based on user inputs to help them reach their goals. At the end of the study, 15 of 20 participants met their financial goals, a 75% success rate. Our app's financial advice helped users make smart spending and budgeting decisions, contributing to this success.

Five participants failed to meet their goals, prompting an analysis of the causes. Complex financial situations, app advice, or external economic factors may explain this variance. These results demonstrate *Financial Assistant Mobile App's* potential to help users achieve their goals while also highlighting areas for improvement, particularly in tailoring advice to different user needs.

V. Discussion and Conclusion

This paper demonstrates how crucial OCR and machine learning are for personal financial management. Genie Savings is a groundbreaking leap in financial technology and expense management that modern society wanted. As a researcher, one cannot underestimate the time factor in changing technologies and user anticipation. Advanced technology is needed to solve personal finance problems. Considering *Genie Savings* automatically categorizes *receipts and SMS* formats using ML, increasing savings. This novel approach and diverse data collection ensure accurate and efficient data management.

As major challenges: Receipts and SMS messages in various formats share common structures, making accurate data extraction and transaction categorization difficult. Receipts that are heavily damaged, poorly printed, or have unusual layouts may pose challenges for accurate data extraction. Variability in how different banks format their *SMS notifications* can lead to inaccuracies in identifying and categorizing transactions. To test the Genuine App for the study selected, three banks' alert formats (Bank of Ceylon, Peoples Bank, National Savings Bank) and three supermarkets (Keels-Super, Arpico, and Cargills) were selected for the implementation. To minimize the limitation by preprocessing images to improve clarity and reduce noise, the system adapts to different layouts and formats to extract financial data accurately. The ML models are trained on a diverse dataset of receipt types and SMS messages, allowing the app to recognize and categorize expenses from any source. This adaptability lets Genie users track their financial activities across platforms and formats, improving the user experience.

OCR systems are essential for extracting data from receipts, but this study faces challenges in text clarity and formatting. Issues include *faded, smudged, low-resolution* receipts, confusion from different fonts, complex data structures, background noise, handwritten notes, language and character sets, and environmental factors. OCR systems may struggle to recognize and extract information from receipts printed in multiple languages or using special characters. To ensure accuracy, data validation is necessary, and developers often pre-process images, use ML models, and use user feedback to correct extracted data errors.

In the Genie Savings app, several steps are taken to ensure the privacy and security of users' financial data. In transit and at rest, financial data, which are receipts and SMS messages, is encrypted in the Genie App. To prevent unauthorized access, data sent over the network and stored data are encrypted using *HTTPS* in the Genie App. The access control app restricts financial data to authorized users. Passwords and biometrics are used in the app (fingerprint or facial recognition) for authentication. Relevant data is collected using the Genie app and reducing sensitive data storage reduces data breach risk ensure privacy.

Real-time feedback and live financial data synchronization (e.g., bank account syncing) in future Genie Savings app versions are possible and could improve user experience. *Genie Savings can integrate APIs to access real-time bank account transaction data, ensuring secure access to user data while adhering to GDPR and PCI DSS standards*. Using alerts and notifications, *Genie users* could receive real-time alerts for low balances or upcoming bills.

More users and real-time feedback can improve app recommendations and functionality. Advanced technology affects financial decisions, as shown on Genie Savings. AI, ML, and user-centered design can make financial tools more accessible and practical, setting a new PFM app standard.

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Original Scientific Article

Big Data and the Circular Economy: Synergy for Sustainable Growth

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Abstract—**Transition from linear economy to circular economy (CE) is very important to meet sustainable development goals, taking into account the resources scarcity and environmental degradation. This paper highlights the pivotal role Big Data will play in enabling Circular Economy practices within various business sectors. The paper elaborates on the ways in which big data has advanced resource management, supply chain visibility, and sustainable business practices through a comprehensive analysis of the basic concepts of circular economy and big data. We open the possibility for a view into synergy between digital technologies and circular strategies to use transforming power of big data to enhance the efficiency of the circular business model. This integration offers organizations a better competitive advantage in the environmentally conscious market, besides increasing efficiency and minimizing waste. The conclusion emphasizes the vital role big data plays in accelerating the process of global transition to circular economy while also calling for more studies and advancements that can help to utilize its benefits maximally.**

Keywords - Circular Economy, Big Data, Sustainability, Digital Transformation, Sustainable Business Practices

I. Introduction

Circular economy is fast coming forward to be a complement to the resource-intensive and polluting linear economy. Reuse, recycling, and regeneration are cornerstones of the CE aimed to minimize generated waste and prolong product lifecycles. The modern digital technology that has been integrated with the CE, especially Big Data, is an important means to realize major goals in sustainability when global enterprises are increasingly practicing CE.

Big data, in terms of volume, diversity, velocity, and authenticity, has really transformed many industries in a way that facilitates data-driven decision-making and improves the effectiveness of value-added operations. In terms of the context circular economy is based upon, Big Data can contribute to a great degree in resource management, supply chains, and environmentally friendly corporate practices. The interaction between a circular economy and big data is essential in making the transition to alternative, more sustainable economic models, since data analysis can raise product transparency, traceability, and material flow forecasts. This paper focuses on the synergy between big data and a circular economy with respect to how precisely BD could instrumentally help in progressing and operationalizing circular business models.

This paper aims to deepen the concepts and practices of the circular economy, to study big data potential and applications in several industries and to analyze relations between big data and the circular economy, explaining how BD can make circular practices more effective.

II. Transition from Linear to Circular Economy

Based on a take-make-use-dispose cycle, linear economy model has been defining current economic practices, very often related to huge waste and environmental degradation. Thus, with the model's impact on consumer behavior, adopting sustainable strategies for the restitution of ecological balance and social well-being is becoming very important [1-6]. The circular economy is based on a take-make-use-recycle approach wherein, at every successive stage of production, wastes or by-products from the previous one are used as raw materials, hence reducing wastes and conserving resources [7-8].

During July 2024, we conducted research on the territory of the Republic of Serbia on familiarity with the concept of circular economy. The results show that 50% of respondents are familiar with this term, which is an extremely good indicator of the population's awareness of the circular economy concept. Nevertheless, the results show that there is a great need for education about the circular economy, bearing in mind that even 60% of respondents never had any education about the circular economy or attended a training or workshop on this important topic. As many as 76.7% of the respondents believe that the circular economy is an extremely important concept, and as many as 86.7% of the respondents emphasize that the implementation of the circular economy in practice can have an extremely positive impact on the social community.

The circular economy is such a novel system in which companies' economic procedures prioritize sustainability by following and initiating regenerative concepts. Therefore, this approach has the aim of enhancing the sustainable performance of organizations by using a regenerative pathway of material recycling and preserving natural resources. It focuses on reducing the waste of resources as opposed to the standard business procedures. CE designs inherently self-contained systems promoting recycling and reusing paradigms and takes precedence over acting reactively to environmental degradation [9-10]. In the contemporary business world, sustainability has become a critical success factor for the growth and development of any company. The trend of integrating CE practices has been an outcome of the inclusion of the sustainability factor among the various corporate strategies and policies, particularly by large firms, whose operations are focused on environmental protection. Effective waste management is important to reduce pollution and preserve resources, especially as far as plastics are concerned. By encouraging the concept that waste may be managed without being released into the environment, CE supports Sustainable Development Goals (SDGs).

However, there are certain challenges that the enterprise faces in adopting a CE business model. Systemic improvements might be required while creating stakeholder advantages and aligning all the relevant systems and networks with the existing business models [11-13]. The optimization of performance along with system externalities reduction requires proper decisions that demand accurate data collection and analysis. Challenges to the adoption of CE are many, especially for SMEs, with barriers including a lack of funding, government support, and technical capacity. Policy drivers, such as environmental commitment and green economic incentives, have been recognized as some of the key enablers for CE [14]. The way that consumers understand CE is also crucial. Consumer engagement with CE is influenced by variables such perceived economic benefits, environmental awareness, and willingness to make sacrifices for the environment [15]. Research indicates that consumers who prioritize environmental concerns are more inclined to find recycled products interesting. Contextual factors such as brand image and price may influence consumption within circular economies, but they do not act as a deciding factor [16-17].

According to Gupta et al. [7], the core of CE is restorative and regenerative economic practices that seek to increase resource efficiency while enhancing the value of end-of-life products. For successful implementation, CE demands a collaborative approach to sustainability and active participation by stakeholders at multiple levels. It is an established fact that circular economy cannot be obtained in isolation; businesses have to change their operations based on changing stakeholder expectations and dynamics of the external environment [18]. The global corporate world is increasingly focusing attention to the circular economy model to reduce resource consumption, enhance sustainability, and financial performance to benefit all the participants along the value chain [19].

III. Leveraging Big Data Analytics for Sustainable Growth

The problems of unsustainable production and consumption in emerging economies are largely dependent on big data analytics and disruptive technology. These technologies present viable options for improving competitive advantage, sustainability, and productivity in large corporations and SMEs as they develop further. However, for implementation to be effective, an extensive understanding of all factors impacting the adoption of big data and the development of plans to address related obstacles are necessary. Big Data (BD) analytics has attracted a lot of interest in emerging economies because of its potential to provide new opportunities and offer significant advantages. It has been acknowledged that, regardless of necessity, the production and consumption of goods and services have become increasingly inefficient and unsustainable. As a result, addressing circular economy issues has become a fundamental approach to tackle these problems and pursue resource efficiency [20].

Significant amounts of data are being produced by both individual and group operations because of the quick development of technologies like the Internet and cloud computing. Big Data is a sort of data that is distinguished by its volume, diversity, and frequency of production [21]. Big Data, however, is more than just a gathering of data; it also entails real-time, comprehensive data management from several sources. To obtain a competitive edge, this presents new difficulties for maintaining and collecting useful information from the data [22-23].

Big Data analytics is a new method that identifies patterns in particular data sets over time, which helps in making wise decisions, increasing productivity, and generating new knowledge [24-25]. Through timely information collecting, BD analytics can greatly improve a firm's competitiveness by reflecting the relationships between employees, consumers, suppliers, and distributors. It frequently provides descriptive and predictive results [26]. Big Data has been used by large organizations for a variety of objectives, including predicting market trends and finding opportunities for progress. Big Data adoption has been modest despite its apparent potential; many businesses have had difficulty progressing from the earliest stages of adoption into integrated use [27]. The literature is still developing regarding the use of big data in small and medium-sized businesses (SMEs) [28]. Due to a lack of funding and knowledge of the primary obstacles to adoption, SMEs remain behind in the implementation of Big Data, despite their considerable contributions to national economies [29-32].

Due to the exponential growth of business data from the spread of social media, e-commerce, mobile technologies, and search engines, among other digital developments, businesses today can collect and analyze such data for better performance. Major factors driving the adoption of Big Data have been organizational readiness, management support, and technology characteristics [33]. Big Data generated in a various format by technologies like IoT, Mobile Communication Platforms, and social media can be used by businesses for obtaining insights into performance using data and statistical methods. Big data analytics can massively facilitate stakeholders involved in the circular economy through informed decision-making, which is inves-tigated based on patterns, correlations, consumer preferences, and market trends.

In recent decades, industrialization has been largely responsible for the growth in living standards, but it has also resulted in an increase in carbon emissions and unsustainable consumption habits. Organizations have a responsibility to recognize and address the negative environmental impacts of excessive consumption due to the expanding carbon footprint and the increasing demand for natural resources [8].

Hence, the development of organizational processes integrating concepts of I4.0 and circular economy is necessary to solve these problems [34-35]. I4.0 technologies such as robotic systems, additive manufacturing, smart industries, Internet of Things, Big Data, and robotics hold a high potential for solving the issues associated with unsustainable patterns of production and consumption. According to Frank et al. [35], these technologies are expected to enhance resource efficiency, productivity, and flexibility. They equally remain relevant to overall sustainability.

Big data is a critical technology enabler for predictive maintenance improvement, rapid reconfiguration of industrial systems, and reduction in energy consumption, waste generation, and overproduction. Despite the described advantages of big data for companies, several major challenges still need to be faced concerning their technology adoption and digital shift in management and operational contexts [36].

IV. Big Data Adoption in Circular Economy

Big Data (BD) is becoming a major role in this transition when businesses investigate data-driven choices in the modern corporate landscape are driven by the objectives of efficiency and growth [37]. Business activities and operations stand to benefit greatly from BD, which could have long-term effects [38]. The relationship between Big Data (BD) and the Circular Economy (CE) is examined in this chapter, with a focus on how BD might be used to advance the ideas and practices of CE. Asserting the key principles of CE, BD facilitates the creation of sustainable business systems and simplifies decision-making [7,28,39].

For production to be profitable and sustainable, BD and CE integration is becoming more and more important. [40-42] Despite strong promotion, the adoption rates of BD and recycling are currently quite low, with less than 10% of businesses using BD extensively and only around 9% of waste being recycled [43]. This underlines the need for a better understanding of human behaviours influencing recycling and the factors promoting the uptake of BD [20]. A new industry revolution, Industry 5.0, has emerged with an agenda on sustainability and building on Industry 4.0 technologies including BD and IoT [44].

CE practices greatly rely on this new digital technology including BD, IoT, AI, and blockchain. These technologies facilitate the efficient circulation of resources within organizations adhering to CE principles, thereby enhancing corporate operations [7]. This is very important in relation to BD analytics as they ensure the normal CE practices through management of resource flow [45]. This closely relates to BD analytics that are crucial drivers of an organization's ability to handle resources effectively and maintain a good CE through increased organizational efficiency and a competitive advantage that is maintained over time [46]. The BD analytics will also maintain the practices for CE, management systems, eco-design, and the investment recovery practices by providing imperative insights for the decision-making and development of strategies [47-48].

Despite the potential benefits of BD in CE, the adoption of these technologies presents challenges. The heterogeneous nature of digital technologies and the varied business models in which they are implemented make the choice and suitability of these technologies complex for businesses [49]. The disconnection between industrial initiatives and the available scientific research on the application of IoT and BD to CE further complicates the widespread adoption of these technologies [50]. The rise of digitalization as an enabling factor for CE, however, opened significant opportunities. Digital technologies advanced product life cycles, resource use transparency, and enabled a transition to CE by facilitating data collection and analysis at a detailed level both for products and resources [22,51]. Companies implementing circular business practices collect vast amounts of data from production to recycling, and there are concerns about unauthorized access or misuse of important data. It is necessary to ensure compliance with legal regulations on data privacy, especially when it comes to personal data concerning the customers. Cyber security measures that companies can implement include: encryption, multi-factor authentication, regular security audits, etc.

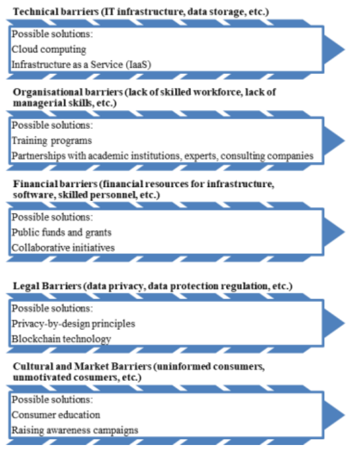

Figure 1. Key barriers for adopting Big Data in Circular Economy and possible solutions (Source: Authors)

Big Data offers the immense potential of giving a massive thrust to the transition toward the Circular Economy, by providing more efficiency in managing resources, which leads to improved supply chain performance and adoption of sustainable business practices. Integration of BD with CE principles should lead to a substantial improvement in organizational efficiency and competitive advantage. Even with all these technologies ready, there still are huge challenges in their adoption and actual implementation in digital technology with varied business models and in overcoming the existing disconnection between initiatives in industry and scientific research. Further exploitation of BD capabilities in CE is the precondition for harnessing its full potential to contribute to sustainable economic development.

Digital technologies, some of which include blockchain, IoT, AI, and BD, are required to support CE processes. These technologies enhance the business processes through the ease of resource distribution in organizations that adhere to CE principles [7]. For example, BD analytics are necessary for controlling resource flows and ensuring homogeneity in performance regarding CE procedures. The capabilities of BD analytics can directly influence the effectiveness of an organization to manage its resources efficiently and to maintain a strong competitive advantage, possibly leading to increased organizational effectiveness and long-term competitive advantage [46].

Businesses aiming to implement sustainable and circular business models can make radical change through the integration of Big Data into circular economy activities. Big data allows businesses to reduce their ecological impact while maximizing the use of resources, improving operational effectiveness, and innovation. Besides attaining goals on sustainability, big data could help businesses gain a competitive advantage. The following are some of possible effects of big data usage on circular economy and circular business models:

1. Reduced Environmental Impact. Big Data reduces companies' ecological footprint by optimizing resource use and reducing waste, thus promoting sustainability goals of companies.

2. Improved Waste Management. Big Data can optimize the use of resources, creating less waste and more efficient material use. Accurate tracking and analysis of material flows made possible by big data results in more economical use of resources and a decrease in waste.

3. Informed Decision-Making. Big Data helps companies reach informed decisions regarding circular strategies, like usage of most sustainable materials, optimization of workflows, and new circular opportunities.

4. Regulatory Compliance and Reporting. Big data assists firms in complying with environmental regulatory needs and reporting exact measurements of material consumption, waste production, and emissions.

5. Increased Transparency in the Supply Chain. Big Data gives insight into each step of supply chain process, which in turn helps to trace the materials more efficiently and fosters transparency in sourcing and recycling processes.

6. Risk Mitigation: Big Data assists in detecting possible hazards in circular processes, such interruptions in the supply chain or shortages of materials, enabling companies to proactively handle these issues and preserve continuity.

7. Increased Profitability. Big Data may be used by circular business models to find cost-saving options, such reducing the cost of material inputs or finding markets for recycled products, which will ultimately increase profitability.

8. Improved Customer Relationships. Big Data provides a company with in-depth knowledge of the behavior and preference of customers. It thus allows the development of circular products in a manner adjusted to the needs and wants of individuals, hence improving customer loyalty.

Implementation of circular economy principles will ensure better and more transparent global supply chains by keeping track of materials and products throughout their life cycle, with minimal production of waste to reduce negative environmental impacts. Blockchain technology and the Internet of things will be of great importance considering encouraging transparency within supply chains. The focus of the circular economy is the renting of products rather than their buying, prolonging the life cycles of products, and encouraging recycling. Therefore, companies will be able to offer personalized services based on available information about customers' preferences. The sharing economy will hold an important place in the future, especially in the fashion, automotive, and electronics industries. Artificial intelligence contributes to the efficiency and prediction of resource usage, thus being great in shaping the future of synergy between the circular economy and big data by reducing negative impacts on the environment.

V. Conclusion

The implementation of circular economy principles is of exceptional importance at the global level, especially considering the large number of companies that recognize the importance of implementing sustainable business practices. Through the implementation of sustainable practices, companies can achieve greater resource efficiency, reduce the negative impact on the environment and respond to the growing demand for sustainable products. By embracing these changes, companies not only secure their competitive advantage, but also contribute to a more resilient and sustainable global economy. Striving to achieve the goals of sustainable development, among other things, requires synergy between the circular economy and big data, and it is important to focus on this topic in future research.

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Original Scientific Article

Artificial Intelligence and Financial System: Opportunities and Risks

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Abstract—**The financial system's functioning is influenced by technological, economic, and regulatory factors, which consequently dictate the operations of all its participants. A few of the numerous challenges confronting the financial system today include the battle against climate change, growing investments in digital infrastructure, considerable geopolitical uncertainty, and higher-than-target inflation rates. This is why the introduction of artificial intelligence, which fundamentally altered the way financial markets and all of the system's participants—banks, insurance companies, pension funds, and others—operate, was one of the revolutions that significantly transformed the way the financial system functions. The implementation of numerous actions in the financial system can be made more secure, precise, efficient, and effective through the application of artificial intelligence. It is important to keep in mind that while implementing artificial intelligence has many benefits, there are also certain risks involved. These include protecting data privacy and confidentiality, the difficulty of maintaining these systems, and current ethical dilemmas. The aforementioned risks highlight the necessity of enacting prompt and thorough laws that address the particulars of integrating artificial intelligence into the financial system and so eliminate any potential for misuse. To reduce risks, continuous monitoring, and use of artificial intelligence integration into financial system operations are necessary.**

Keywords - artificial intelligence, financial system, financial stability, regulation

I. INTRODUCTION

If artificial intelligence algorithms are used a large number of financial system activities could become more efficient. It is crucial that all actors participating in the financial system carefully assess the benefits and risks involved in the use of artificial intelligence [1]. Artificial intelligence is not a new concept, even though John McCarthy coined the phrase in 1955; its use dates back to 1642, when French mathematician Blaise Pascal created the first mechanical calculator [2]. Starting in the early 1960s, Bayesian theory gained popularity as a machine learning approach. Before then, decisions were made mostly on professional knowledge and experience, with a lot of unknown variables. For this reason, this theory was applied extensively in the auditing area. The rational probability and objectives of auditors were established with the aid of Bayesian theory, which enhanced the accuracy of the decisions made. Artificial intelligence and the financial system first collaborated on the principle of decreasing workload by using computers to complete the majority of the work. Up until the 1980s, market trends were predicted, and financial plans were adjusted using expert systems, also known as knowledge-based intelligence systems. Thanks to significant advances in computer power, financial fraud was identified through the use of artificial intelligence in the 1990s. The financial system currently uses artificial intelligence for market transactions, portfolio management, and

* The views expressed in this paper are those of the author and do not necessarily represent the official view of the Economists Association of Belgrade.

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user-oriented applications (front-end and back-end) [3].

The definition of artificial intelligence that is most frequently cited is the one provided by the Financial Stability Board in 2017. It states that artificial intelligence is a theory as well as the development of computer systems with the aim of performing tasks for which human intelligence is most often used [4]. Artificial intelligence brings with it social consequences, bearing in mind that it fundamentally changes the way of economic growth and the way of everyday life [5]. The correct use of artificial intelligence can lead to the improvement of the quality of services for their users, as well as to the reduction of business costs, which contributes to the transformation of the financial system at the global level [6]. Significant progress has been made in the domain of cognitive abilities and imitating human reasoning. This means that information may be communicated by artificial intelligence through the processing of enormous amounts of data, the speedy location of massive amounts of data, and the identification of patterns in the data that are already available [7]. Today, the use of artificial intelligence enables the integration of data on shifting market circumstances, the detection of fraudulent activity, the establishment of an early warning system if the security of financial transactions is breached, and the use of suitable algorithms and automatic reactions [8]. As a result, artificial intelligence is an extremely powerful worldwide economic force that supports the prosperity of the financial system [9].

The purpose of the research is to investigate the potential opportunities and risks that artificial intelligence could pose to the financial system. The main research questions (RQs) are:

RQ 1: What is the impact of artificial intelligence on the way the financial system functions?

RQ 2: What is the extend of artificial intelligence evolution in the field of regulations?

RQ 3: What are, from the side of the financial institutions, main opportunities and risks of artificial intelligence?

RQ 4: How does artificial intelligence affect financial stability?

This paper is structured as follows: The introductory presentation is followed by an analysis of the regulations that apply to artificial intelligence. The third part of the paper is devoted to an overview of opportunities and risks for financial institutions, while the fourth part shows the implications of applying artificial intelligence to financial stability. The main findings of the paper are summarized in the conclusion.

II. ARTIFICIAL INTELLIGENCE REGULATIONS

Artificial intelligence is the subject of interest of a large number of international organizations that are actively working on drafting regulations. From the point of view of countries that are members of the Organization for Economic Cooperation and Development (OECD), the goal of establishing regulations is the implementation of reliable use of artificial intelligence. On the other hand a non-profit organization dedicated to scientific progress - the Institute of Electrical and Electronics Engineers (IEEE) - seeks to establish ethical guidelines for the application of artificial intelligence. Establishing regulations for artificial intelligence is join aim of the countries in Europe and the United States. These strategies include requiring the algorithms that underpin artificial intelligence to be tested and holding artificial intelligence creators accountable for any unfavorable effects that may result from the application of artificial intelligence [10].

Digital transformation is one of the top priorities of the European Union, which will contribute to the development of digital technology, but at the same time will provide new business opportunities and thereby improve the quality of services in the public sector. The effort to establish regulations for artificial intelligence is one of the goals of the digital agenda promoted by the European Union. In this regard, the first steps were established by the European Commission, which proposed the first regulatory framework in April 2021, in order to categorize the risks associated with the use of artificial intelligence. This categorization led to the separation of unacceptable risk and high risk. Artificial intelligence carries an unacceptable risk, which suggests that some systems should be prohibited because they endanger human safety. This category of risk includes: (1) manipulating people's behavior or that of specific vulnerable groups (voice-activated toys, for instance, can lead to dangerous behavior in children); (2) social scoring (classifying people according to their behavior, personal traits, or socioeconomic status); (3) using biometrics to identify and categorize people; and (4) using real-time biometric identification systems (like facial recognition). In order to ensure the adequate application of the law, it is necessary to have exceptions in the application related to biometric identification, especially in the case when it is necessary to perform the identification of persons who are accused of a crime. With regard to systems that violate human rights or endanger people's safety, a division can be made into two categories: (1) systems used in products that are already covered by European Union legislation, the application of which aims to ensure the safety of use of those products such as are for example cars, toys, elevators, airplanes, automobiles and medical devices); and (2) systems related to the registration of databases in the European Union. The Law on Artificial Intelligence, at the level of the European Union, was approved by the European Parliament in March 2023, and then by the European Council in May 2024. This law enters into force in two years, with some provisions of the law being applied earlier. These include the system ban on artificial intelligence that pose unacceptable risks, which will take effect six months after the law is enacted, the codes of practice, which will go into effect nine months after the law is enacted, and the rules about the general application of artificial intelligence, which must be in line with transparency requirements and will go into effect twelve months after the law is enacted. The law will apply to artificial intelligence systems that pose a significant risk 36 months after it is enacted [11]. The Artificial Intelligence Act's implementation brings new regulations that forbid the use artificial intelligence applications that jeopardize human performance, such as biometric classification systems built on delicate characteristics [12].

In addition to the already adopted regulations at the level of the European Union, some countries are taking initiatives at the national level. Thus, Germany and France passed their national initiatives in 2018, and Spain and Italy did so in 2020. In March 2018, France adopted an artificial intelligence plan based on an artificial intelligence policy report with goals related to raising ethical standards and improving of artificial intelligence education. In November 2018, the German federal government published a national strategy for artificial intelligence, which it implemented in cooperation with the ministries of labor and social affairs, economic affairs and energy, and education and development. Increasing Germany's competitiveness in the field of artificial intelligence development, fulfilling the responsibility of developing artificial intelligence that will benefit society, and incorporating artificial intelligence into institutional, legal, and ethical norms are the objectives of the given strategy. A national strategy on artificial intelligence was issued by the Italian Ministry of Economic Development in October 2020. The strategy was developed to create a long-term vision for the sustainable development of artificial intelligence. To define the implementation of the various measures that the government administration will take to facilitate the development of artificial intelligence in society and the economy, the Spanish government adopted a national strategy on artificial intelligence in December 2020 [13].

The National Artificial Intelligence Initiative Act, which is the first national artificial intelligence law, was passed by the United States in 2020. This law thus represents the American initiative for the regulation of artificial intelligence, measures for the development of this field and assessment of the use of technology in federal agencies. Following that, in September 2020, the Artificial Intelligence in Government Act was approved by the United States Congress, allowing the General Affairs Administration to construct an artificial intelligence center of excellence. This center's objectives are to enhance competencies during the integration of artificial intelligence and to expedite its implementation within the federal government. he next step in the development of artificial intelligence regulation took place in December 2022 when Congress passed the American Artificial Intelligence Advancement Act with the aim of advancing the use of artificial intelligence while respecting the basic principles of American society (such as the defense of civil liberties, privacy and human rights). The National Institute of Standards and Technology in January 2023 published the AI Risk Management Framework, and the White House Office of Science and Technology released the AI Bill of Rights. Two important texts on artificial intelligence legislation were adopted during the summer of the 2023 - the SAFE Innovation Framework for Artificial Intelligence Policy and the Blumenthal and Hawley Comprehensive Artificial Intelligence Framework. The SAFE Innovation Framework for Artificial Intelligence Policy was enacted to strike a balance between the potential benefits and dangers of using artificial intelligence. The Blumenthal and Hawley Comprehensive Artificial Intelligence Framework was proposed by Senators Richard Blumenthal and Josh Hawley, who are members of the Senate Subcommittee on Privacy, Technology and Law Enforcement. This framework is built on the ideas of an independent regulatory body, transparency and user protection to ensure legal certainty against any potential harm that the application of artificial intelligence may bring [14].

III. Opportunities and Risks for Financial Institutions

Financial institutions need to strike a balance when implementing artificial intelligence in order to lower the level of risk, while at the same time using all the advantages that can offer. It is necessary to apply a high level of security protocols, respect ethical standards and ensure efficient administration of the artificial intelligence system. Artificial intelligence has the potential to improve the services of financial institutions in areas such as increasing customer satisfaction, cost savings, efficiency and service quality. Also, the use of artificial intelligence can lead to greater financial inclusion as it increases analytical capabilities and automates operational procedures. Increased automation of operational procedures means automating tasks that are mostly repetitive or have low value, such as responding to various customer inquiries. In this way there is posibility of reducing human error and increases performance when completing them. Financial institutions, as analytical capabilities grow, can use artificial intelligence to evaluate vast amounts of data more effectively and efficiently-both structured and unstructured-while cutting down on the time needed to complete these tasks. Additionally, a greater number of variables can be employed in the analysis, which immediately improves the analysis's quality by yielding more accurate results. The use of artificial intelligence can achieve improvements in the quality of services, including the potential for increased accuracy in the early detection of malicious activity and increasing access to financial services for customers that the bank has not previously provided (such as lending to customers who have never been a customer of a particular bank or the client previously lacked sufficient knowledge about the financial services offered by the bank). With this approach, significant savings in business costs can be achieved. Also, if financial institutions improve their analytical capabilities, they can use external and internal data to learn more about their current and potential customer preferences. Financial institutions can thus provide services that are tailored to the needs of their clients, helping to anticipate their future requirements (such as, for example, residential property insurance for clients who want to take out a mortgage loan). In the following activities, financial institutions can use artificial intelligence:

(1) *Credit scoring*: financial institutions can improve analytical skills by speeding the loan approval procedure;

(2) *Compliance*: artificial intelligence can help financial institutions operate in a manner that complies with legal requirements (such as reporting requirements) and at the same time adapt more quickly to changes in regulation;

(3) P*revention of fraud and money laundering*: abnormalities that could otherwise remain undetected can be easily identified if data from new sources are used and there is a possibility for financial institutions to analyze a larger volume of data;

(4) C*ustomer-specific products and services*: in order to increase the satisfaction of their customers, financial institutions can provide services that are adapted to the needs of a specific customer;

(5) *Chat bots and virtual assistants*: using these tools, clients have the opportunity to ask questions and thus get more information about financial services. These kinds of communications enable automated client connection and are accessible twenty-four hours a day, seven days a week [15].

Artificial intelligence has several intrinsic risks that can arise from its deployment in the financial system. These risks include a lack of privacy, robustness problems and cybersecurity [16]. *Protecting data privacy* is a risk associated with the use of artificial intelligence. Artificial intelligence has the potential to recall personal information about users or to directly or very inadvertently cause the disclosure of private information. Therefore, while concurrently working to improve the legislative framework that will enable the development of privacy standards, it is vital to develop tools whose objective is to strengthen the robustness of the use of artificial intelligence and the protection of sensitive data. The development of trust in the financial system based on artificial intelligence and the maintenance of its stability will be made possible by *the robust* application of artificial intelligence. This is particularly important as artificial intelligence is used by many financial institutions around the world and several national jurisdictions lack sufficient regulation. When used in a data environment that is largely stable and yields dependable results, artificial intelligence systems can be quite useful, but this can quickly alter if a particular structural upheaval takes place. Consequently, to prevent unintended outcomes, prudential monitoring must be strengthened. Since the development of artificial intelligence follows the software development process, it is necessary to recognize and implement the agility of the system in time. In the case of applying an artificial intelligence algorithm, this implies stages such as development, testing and establishment of a risk monitoring system. The use of artificial intelligence has made *cyber security* threats more prevalent. At some point during the creation of artificial intelligence to get beyond the constraints of artificial intelligence algorithms, artificial intelligence creates a new sort of risk linked to data manipulation in addition to the conventional cyber risks resulting from human mistakes or software defects. When it comes to cyber risk when applying artificial intelligence, it is necessary to distinguish between three sources of potential attacks: (1) data "poisoning" attacks, which implies that the artificial intelligence system performs incorrect identification and categorization of data; (2) ingress attacks, which involve artificial intelligence systems being misguided due to the occurrence of a specific disturbance; and (3) model extraction attacks, whose goal is to completely make it impossible to restore the input data or even the entire model. The risk of cyber security is a significant problem for the regulatory financial system because it directly affects the trust and integrity of the operations of all participants of the financial system. If cyber risk is not adequately managed, it can lead to the development of systemic risk. As a result of the above, it is necessary to establish an adequate reporting system that will ensure data security [17].

IV. Implication of Using Artificial Intellugence for Financial Stability

Financial systems have a long history and have been heavily influenced by analytical advances such as artificial intelligence. The origins of these innovations can be traced back to Leonardo Pisano Bigollo, an Italian mathematician from Pisa, who established formulas for calculating present value. More recently, Fisher Black, Myron Scholes, and Robert Merton developed the Black-Scholes model in the 1960s for the valuation of complex financial instruments [18]. But it's crucial to keep in mind that almost every financial innovation and liberalization may cause the financial system to experience a time of increased stress. The Asian crisis in the late 1980s, the banking crises in Scandinavian countries, such as in Norway in 1988–1992, in Sweden in 1990–1994, and Finland in the 1990s, and the global economic crisis in 2007–2008, are just a few examples of such occurrences.

Without a thorough comprehension and evaluation of the risks associated with these novelties in business, financial innovations may open up new opportunities for the growth of credit activity and the development of new financial services. Therefore, an increase in credit fuels economic growth, which in turn raises debt levels. At the same time, insufficient historical data makes it difficult to make a firm judgment on whether or not to use new financial services, making it impossible to fully assess their risk. There are various reasons why financial stability may be in jeopardy, and the question of how the digital revolution of the financial system, including artificial intelligence, affects it, emerges. The corresponding phenomenon to financial liberalization is the introduction of new financial services, the majority of which are unregulated. This generates unknown risks that could have an impact on obtaining and maintaining financial stability. Artificial intelligence, for instance, can speed up the loan approval process but also raise the possibility of more non-performing loans, which pose a systemic risk to the integrity of the financial system [19]. Artificial intelligence can also lead to systemic risk when it is used in financial institutions' risk management processes, which need to be compliant with current regulations. When a shock materializes, the financial system may become more procyclical if artificial intelligence algorithms produce answers that are comparable across all financial institutions. This is because all institutions would respond in the same way [20].

Artificial intelligence poses a threat to financial stability through a number of ways that it can upset the financial system. The first illustrates the *malicious application of artificial* *intelligence* that results from economic agents' aim to increase profits at the expense of its societal repercussions. Economic agents try to get around control structures and alter the system to suit their needs. Such agents are favored by technological advancement, particularly artificial intelligence, which opens up new options like the potential for attackers to access sensitive data. *Over-reliance on artificial intelligence and misinformed use* is the second channel. Misinformed use happens when artificial intelligence operators utilize the technology improperly because they don't completely understand how it operates. Artificial intelligence's algorithms must have undergone extensive testing and verification if it is to be accepted with confidence. However, if artificial intelligence makes judgments based on ambiguous objectives, as is frequently the case in the financial system, the accuracy of those judgments may be compromised because those judgments are based on intuition, hazy interpretations, and data extrapolation-all of which artificial intelligence still lacks. The third channel represents *the inability to modify artificial intelligence*, which occurs in the case when there is a mismatch of goals between the owner and the financial regulator. In this case, there is an ambiguity between the expectations of the financial regulator and the artificial intelligence that does not have enough input to comply with the regulation. For instance, one could argue that insider information should not be used while trading with the use on artificial intelligence; that is, one could argue that using insider information for trading purposes is prohibited even though it has been done frequently by human in the past. The fourth channel in which artificial intelligence can threaten financial stability is *the market structure*. This channel is manifested through the fact that financial institutions buy and sell different financial instruments, which can potentially can cause the creation of price bubbles and instability in the market. In this sence financial markets have always been unique, and the use of digital transformation emphasizes this even more. This channel will probably become even more a source of financial instability with the deployment of artificial intelligence [21].

With the simultaneous influence of social, economic, and political factors, the financial system is a dynamic and complex area in which numerous market participants engage with one another. Because artificially intelligence do not have the same level of worldly understanding as humans do, they will not always act with social context in mind, which poses a significant risk [22]. Adequate, prompt, and thorough regulation of this digital transition is required to avoid increasing systemic risk and jeopardizing the stability of the entire financial system, thereby mitigating the adverse impacts of artificial intelligence on financial stability. By employing this strategy, it is feasible to take advantage of every benefit that artificial intelligence offers while lowering the risks that it poses.

V. Conclusion

There are several issues affecting the global economy now that differ slightly from traditional risks. The prognosis for the global economy is being affected by the greatest inflation rates in decades that have just been recorded, tightening financial conditions, elevated geopolitical tensions, and extended uncertainty. The financial system is also exposed to a variety of new risks in such situations, many of which are structural in character. The basic character of financial sector activities is changing due to factors like rising interest rates and energy prices, escalating geopolitical tensions, the potential for quicker funding source switches and withdrawals, an increase in the risk of cyberattacks, and climate concerns. The very application of digitization in the operations of financial institutions can contribute to the emergence of cyber risks that can threaten the stability of operations. That is why it is necessary to apply the best practices in the application of regulations that will ensure the stability and continuity of the operations of financial institutions. The development of long-term procedures and the implementation of new risks in the risk management system is necessary to achieve the above.

In order to achieve the implementation of artificial intelligence, it is necessary to establish a digital transformation of almost all activities of financial institutions. When it comes to defining artificial intelligence, the definition published by the Financial Stability Board in 2017 is most often cited, stating that artificial intelligence represents the development of computer systems that are ready to perform tasks that are mostly performed by human intelligence. Artificial intelligence is applied to lower business costs, improve service quality and increase work efficiency, all of which affects the digital transformation of the global financial system.

Thus, the application of artificial intelligence directly affects the quality of providing services to existing clients, but also the possibility of acquiring potential ones. In addition to the mentioned advantages in the use of artificial intelligence, it is necessary to point out the potential risks. In order to properly manage those risks, it is necessary to establish an effective artificial intelligence regulation system. At the level of the European Union, great importance is attached to digital transformation and the establishment of regulations for the application of artificial intelligence systems. The first artificial intelligence law was passed in 2021 by the European Commission, which was later ratified first by the European Parliament in March 2024 and then by the European Council in May 2024. It is anticipated that this law will be fully implemented in two years. In addition to the already adopted regulations at the level of the European Union, some countries are taking initiatives at the national level. Thus, Germany and France passed their national initiatives in 2018, and Spain and Italy did so in 2020. In the United States of America great progress in the field of artificial intelligence regulation was achieved by adopting the National Artificial Intelligence Initiative Act in 2020.

When implementing artificial intelligence, it is necessary for financial institutions to thoroughly consider the advantages and disadvantages of its application. Today, artificial intelligence systems are used for various activities such as credit scoring, business compliance monitoring, as well as easier fraud detection and money laundering prevention. In addition to the mentioned advantages, it is also necessary to point out the potential risks of applying artificial intelligence, such as the protection of data privacy, cyber security and the issue of robustness. For the financial system as a whole to function smoothly, stability must be achieved and maintained. Therefore, it is imperative that the algorithms that support artificial intelligence are carefully researched and tested, that early warning systems are established for all potential threats, and that every possible advantage of this digital revolution is fully exploited. In order to support the continued expansion and sustainable development of the financial system, regulations must be adapted to the dynamic development of artificial intelligence systems.

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Original Scientific Article

Green Financing and Knowledge Management in Modern Organizations

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Abstract—**Today, financial education, also known as financial literacy, implies and encompasses not only behaviors and attitudes geared toward immediate financial gain but also positive effects on the environment and social development. This essentially entails having a thorough understanding of all the characteristics of both the modern consumer and the modern market. Over time, human activity has evolved, resulting in a scenario where irresponsible conduct toward the environment has a significant impact on the Earth's ecology. There is less will to limit future adverse effects through innovative policies at all decision-making levels, despite the diminishing opportunities for minimizing and remediating the consequential damage. Reaching sustainability goals and sustainable development go hand in hand with green financing. It is important to view knowledge management as a process that helps businesses create new value from their intellectual capital. Ensuring that sound responses at any given point in time translate into sound and long-lasting practices is the primary objective of knowledge management. The need to convert traditional business organizations into learning organizations with content from this area is obvious, given that current circumstances imply the need for ongoing learning and education of employees for environmental protection as a key dimension in the strategy of sustainable development. The authors of this paper's research observation concentrated on the theoretical consideration of the role and importance of applying the concept of knowledge management for teaching organizations about the significance of green financing for achieving the goals of sustainable development, but also for improvement of knowledge management, within the context and conditions of the "learning organization".**

Keywords - green financing, financial education, knowledge management

I. Introduction

When it comes to direct economic activity in the direction of sustainable and economic principles, the financial industry is a major player [1]. The phrase "green financing" is becoming increasingly popular these days, and it simply means that environmental preservation is considered when making choices about payments at all levels. It is impossible to claim that earlier generations put a lot of effort into putting forward the promoted and stated green goals because, at the time, awareness of the critical nature of environmental preservation and the dire consequences of climate change was not even elevated to the current level [2]. In actuality, it might be said that earlier generations were ignorant. An essential resource for the advancement of society and the entire human community. Similar to culture, which is passed down from generation to generation, knowledge is learned, shared, and expanded via sharing. The administration of human resources, which is the foundation of all activity, is known as knowledge management. Human resources must get an education that is relevant to their current circumstances and keep up with world events. Every human activity must prioritize protecting the environment, and every enterprise must adopt a "green" label [3]. Consequently, given that the current generation has already been alerted to the risks and hazards associated with climate change, it is evident that this is the moment for green action. To ensure that people's actions, choices, and behaviors have an impact on sustainable and economic financial growth, it is important to raise awareness of the need to respect environment and the finite resources [4].

A. *Transmission Channels of Green Politics and Green Choices*

The green funding strategy may be implemented with tangible outcomes through a variety of methods. To be more precise, the financial sector should play a role in both changing consumer behavior and providing funding for investments in production (goods and services) to preserve the nation's ecosystem [5]. A contribution to the preservation of the natural environment can be included in any category of loan that is approved by banks in numerous Western Balkan nations for a variety of objectives: cash for non-purpose loans; purchase of consumer goods; buying a car; purchase of apartments and adaptations; loans for agriculture; loans for education, etc. [6]. Banks and other institutions can persuade an individual or corporation to make greener decisions by setting circumstances, mostly related to interest rates and loan terms, such as the amount of collateral required. An individual or an organization has to be well informed to make decisions about certain offers and options. Investing in the expertise of each person inside the firm not only creates intellectual capital but also increases employees' awareness of the importance of making decisions and their resolve to make the right decision [7].

B. *"Green" Choices*

One commonly encounters the phrase "green choice" in contemporary business and company-to-business interactions [8]. Frequently, the decision to go "green" has to be well communicated and comprehended. Once more, understanding is essential to understanding this idea. Funding priorities should be established by lowering requirements, standards, and funding terms specifically for non-environmentally harmful industries. According to the systemic approach, banks and regulators collaborate to create credit policy, and the regulatory framework for credit burden includes standards that encourage lending [9]. In actuality, it's a project to fund environmentally friendly projects with lower restrictions and, hence, lower prices. International financial institutions should also be employed as creditors, or sources of funding for domestic banks, as they currently provide more advantageous ways to lend this kind of money. Funds allocated for final consumption to "greener" projects would be impacted in this way. In all phases of the production and consumption of commodities, awareness, knowledge, and the dissemination of "green" behavior (green culture) are therefore channeled and transferred [10].

I. FINANCING OF "GREEN" PROJECT

Environmental protection should be the primary consideration when funding "green" initiatives, from the start of the production chain to its conclusion. Initially, emphasis is placed on using materials that don't affect the environment (e.g., using renewable energy sources, recycling garbage that already exists, using more natural materials, using technology that doesn't release dangerous elements into the environment, etc.). It is essential to select packaging throughout the packing process that has the least negative environmental impact possible. Examples of such packaging include paper, glass, renewable, and biodegradable materials. During the marketing stage, it is important to show how one is personally responsible for protecting the environment through social campaigns, staff motivation, the portrayal of a green workplace, and encouraging people to commute by public transportation, bicycles, electric scooters, and similar vehicles. Last but not least, as it releases hazardous gases during the distribution phase, it is preferable to minimize transportation that relies on non-renewable energy (oil and oil derivatives) [1]. Raising consumer understanding of the value of savings and their role in supporting personal finances, while also highlighting the benefits of saving for the environment, is crucial for improving consumer behavior. In this instance, knowledge management offers a fundamental lesson in minimizing consumption: businesses and consumers alike should prioritize product quality above quantity. One of the responsibilities of knowledge management, while discussing customers and "green" behavior suggestions, is to emphasize the use of naturally occurring or organically grown items in addition to energy-efficient materials and products. And purchase goods from regional manufacturers [11]. Ultimately, individuals must enhance their quality of life, lower their stress levels, and spend as much of their leisure time as they can in a clean, healthy natural setting. Lastly, financial institutions should provide a clear example of environmental conservation; as a result, banks should adjust their operations to align with green ideals [12]. Since every change results in new information, a new way of thinking recommends changes, which are typical of knowledge management! While adopting this style of thinking may come at the expense of comfort in the short run, doing so will undoubtedly pay off in the long run by protecting the environment and improving human health, as well as benefiting the community at large and future generations.

II. Knowledge Management

What is more valuable than gold? - Diamond. From a diamond? - Knowledge. Of all the goods in the world, knowledge is the best: It can neither be taken, nor given, nor bought, nor sold; it remains yours forever, once you acquire it [13].

Knowledge constitutes contemporary society's worldwide economic resource. These days, productivity and innovation-both products of applying information to the workplace-are what produce value. “Knowledge workers”-executive management knowledge users who understand how to arrange information for beneficial outcomes, just as capitalists understand how to allocate wealth for beneficial outcomes-are the dominant social groups in the knowledge society. The “tools of production” belong to knowledge workers, who possess the ability to carry their knowledge with them wherever they go [14]. Technologists praise machinery; economists celebrate capital investment. It is only via the application of knowledge to knowledge-something that neither money nor robots can accomplish-that production is explained. In this sense, management stands for the collective knowledge society. For this reason, the manager is also in charge of applying information and making it practical. It is now acknowledged that knowledge is a valuable resource [15]. It is considerably simpler to get those additional resources-without which knowledge cannot “produce”-in environments where there is efficient administration and application of knowledge to knowledge. One factor in the development of a new social structure is the recognition of knowledge as a “real” resource. Human civilization has changed how knowledge is seen; knowledge in the plural is now prioritized rather than knowledge in the single. The shift from ignorance to understanding endowed knowledge with the capacity to forge new political, economic, and social structures [16]. Today's human civilization defines knowledge as information that is useful in practice and results-oriented. These outcomes are evident in the economy, in society, and in the growth of knowledge itself. As a result, it is becoming more and more obvious that traditional resources like land, labor, and money are producing less and less profit. This is currently the case as knowledge and information are now the primary “producers” of wealth [17].

A. Economy Based on Knowledge

The knowledge-based economy behaves differently from what current models predict. The first advantages obtained via the application and exploitation of information (learning curve) become permanent in the knowledge economy, making imperfect competition an inherent feature of the knowledge economy itself [17]. According to modern economics, the economy is driven by investments or consumption, which is untrue in the knowledge economy, which is extremely significant. It is not supported by any evidence that higher investment or higher consumption will result in higher knowledge creation in the knowledge economy. New knowledge appears in the following three forms [18]:

- as continuous improvement of production processes and services,
- as exploitation, that is, as continuous use of knowledge for the development of new products and services, and
- as an innovation, - a method of application of knowledge to produce changes in the economy.

These categories of knowledge have qualitatively diverse economic properties, such as how they are used and what impact they have. Except for estimating the “cost” of creating, dispersing, and allocating information, knowledge cannot be quantified. However, knowledge itself cannot be assessed. The fact that knowledge productivity is not directly correlated with knowledge quantity is fortunately for the knowledge possessor. Since knowledge must be acquired through costly means or pathways, it is not a cheap resource. Developed nations, for instance, invest over 5% of their GDP in the creation and dissemination of knowledge. Ten percent of the social product is taken up by young individuals receiving official education (formal schooling) before entering the workforce [19]. Businesses, or employers, contribute an extra 5% of the social product to their staff members' ongoing education. Modern nations set aside three to five percent of their national output for research and development (the creation of new knowledge) [19]. Thus, the greatest investment is in the development of knowledge. However, since the productivity of knowledge investments has not yet been proven by economic theory, companies are obliged to enlist the assistance of management, which is in charge of turning knowledge into a profitable asset. Laws and the state, or the market forces, cannot take on such responsibilities. Only management, which by definition entails the methodical, ordered, and responsible application of knowledge to knowledge, is capable of taking on responsibility [20]. Since knowledge productivity is the single element that determines a company's, branch's, region's, or economy's competitive position, it simply necessitates a rise in yield from what is known and what is known to be known. Businesses that can capitalize on information that is widely accessible have an advantage.

B. *Revolution Technology in Knowledge Management and Education*

Technology, particularly the current digital revolution, has altered the nature of education and its economics. All schools are now heavily capital-intensive, as opposed to entirely labor-intensive [21]. The school now serves as a social institution for IT education, catering to youth, those too young to be in the workforce or responsible for handling responsibilities. It is desirable to develop new learning technologies in the knowledge society to attain universal literacy. With computer programs as their instruments, pupils will be their teachers in the schools of the future. Instructors will only guide, inspire, and motivate [22]. The instructor would genuinely take on a leadership and resource role in that situation. Subject knowledge combined with process knowledge would be universal literacy. This implies that young people should learn and develop their learning skills in the knowledge society. Because information is not impersonal like money in the community of knowledge. Books, databases, or software programs do not contain knowledge. Only information makes up knowledge, and personality plays a major role in its implementation. Humans are knowledge bearers because they generate, expand, and enhance knowledge. The human personality uses, transfers, and applies knowledge. The mark and symbol of the knowledge society is an educated individual. The well-educated individual of the future is a professional ready for life in the global community. That individual is a global citizen prepared to operate in two cultural contexts: the “managerial” culture, which emphasizes people and labor, and the “intellectual” culture, which is focused on ideas and information. Intellectuals see the organization as a means of honing their methods and competencies into specialized knowledge [23]. Managers view knowledge as a tool that advances the objective of the organization's day-to-day operations. Just as a research manager requires a scientific researcher, so does a scientific researcher need a research manager. If the manager's cup isn't used as a weight to balance the intellectual world, then everyone “does their own thing” but nobody “achieves” anything. The world of managers devolves into a crippled bureaucracy of “organization man” if it is not counterbalanced by thought. However, creativity is possible when the two sides are in balance since it fulfills a meaningful task [23].

III. Transitions Economies and Knowledge

Knowledge is becoming a commodity in economies that are transitioning. Reading about the established market economies of the EU and the OECD, where there have been significant shifts in the information and intellectual services markets, has taught us this lesson [24]. New information is sought after by modern economies, particularly in the areas of management, marketing, entrepreneurship, banking, financial markets, stock exchanges, and entrepreneurial finance. Knowledge in the areas of budget engineering, tax management, public sector management, business management in public administration, environmental management, and education management is in high demand. The number of newly established businesses and privatized companies, as well as the emergence of new market economy institutions like institutional investors, financial markets, stock exchanges, brokerage and dealer houses, audit houses, rating agencies, consulting centers, tax consulting, quality control and standardization organizations, information centers, and personnel training centers, all influence the need for future economists with up-to-date knowledge. Young people's attitude toward business is almost exclusively replacing the earlier “struggle for employment” [24]. In addition to conventional and post-graduate degrees, innovative and specialized education is turning into a highly profitable career, and the business-entrepreneurship-management relationship is seeing daily growth in competitiveness [25]. Because of this, the educational motto—which states that anyone who studies economics without the intention of learning how to make money is wasting his time—is extremely significant. In the changing market environment, obtaining modern, high-quality information becomes a matter of prestige for attaining a commercial career, where money is indirectly obtained, as motivation. As a result, education plays an increasingly important role in business as knowledge is the "strongest" asset of an educated businessman, who is a trustworthy business partner. This also suggests job growth in business, which already suggests ongoing education and self-investment [26].

A. *Educated Modern Businessman*

The businessman or entrepreneurial manager has acquired the abilities of negotiation, business communication, business correspondence, and business etiquette, making education and business the new "partners" in advancement. Business ethics, business logistics, personal marketing, personal finance, and "business" management of "oneself" are among the sources of information that today's businessmen possess [27]. Additionally, he became aware of the potential for translating macroeconomic models at the managerial information, entrepreneurial concept management, and business plan levels. Here, the outcome of the "work" is determined by the money generated from effectively finished tasks. Because nothing succeeds better than success, only success is valued for this reason. Modern, educated businesspeople, entrepreneurs, and managers typically respect megatrends in development, which denote a shift in the company's focus from the short to the long term and highlight the significance of a strategic development vision. The modern businessperson acknowledges the shift from the industrial to the information age, as well as the shift from the national to the global economy (business integration, globalization of markets and production, and collaboration in R&D).

He comprehends the shift from imposed and "decorative" technology to ubiquitous and acceptable technology (in company, profession, labor, and life), as well as the shift from centralization to decentralization (synergistic impact of the initiative of parts) [28]. The contemporary businessman also appreciates the decentralization of education and the knowledge economy, as well as the shift from hierarchy to networks (efficient information flow, quick communication, and the growth of equality and collaboration instead of subordination and competitiveness). The idea that "Economy cannot be explained by economics" states that knowledge and skill mastery are necessary for understanding the economy. These days, sustainable ideas are used to explain economics. The theory of acquired knowledge is the best practice, thus the concept of practicality includes knowledge that enhances the capacity to identify issues quickly and solve practical difficulties.

The individuality concept stands for the growth of the student's capacity to exercise self-control over their freedom and accept personal responsibility. The practice of giving students and learners more options in terms of subjects, instructors, scientific domains, and professional activities is known as the "marketability" principle. The concept of implementation encompasses the learning process through experience with real-world situations. Operating guidelines and sister values, such as creativity and entrepreneurship, morality, professionalism, winning attitude, and family orientation, are included in these educational concepts.

A concentration on innovation and novel solutions, overthrowing the status quo, inventiveness and curiosity, creating a prosperous corporate career, dissonance with the routine and daily, and the refers to business perfectionism, respecting partners and eliminating egoism. Professionalism emphasizes expertise, competitiveness, knowledge and legality of the profession. A winning mentality reflects belief in success, belief in oneself, belief in perseverance, belief in competitiveness - belief in family orientation is a reflection of modern business - understanding that family is a fundamental element of success in the desire to live better. Morality, on the other hand, refers to business perfectionism, respecting partners, and eliminating egoism. Professionalism emphasizes expertise, competitiveness, knowledge and legality of the profession.

A winning mentality reflects belief in success, belief in oneself, belief in perseverance, belief in competitiveness, belief in perseverance. Finally, family orientation is a reflection of modern business - understanding that family is a fundamental element of success in life and career [29].

B. Education for Sustainable Development – Green Activities and Green Financing

People redistribute their time in favor of educational services that they conditionally say “buy”, that is, in which they invest both funds and time, reacting to changes in expected incomes and pleasures (expect) from future activities related to education. People direct their time in favor of future abilities that have value [30].

The ability supply curve rises in parallel with the rise in value and the way resources are redistributed. This redistribution applies to all resources, economic, natural, and social. Thus, Fig. 1 shows the general support for modern management, as a profession of the future, which includes: directions of development, advantages, information, help in the form of assistance, versatility, and competencies [30]. Competencies are precisely related to knowledge management because only educated managers are competent to be transformational leaders of the future in modern society.

Transformational leaders educate themselves about sustainable development but also share their knowledge about the importance of sustainability with others. Knowledge for sustainable development represents the most important resource - a way to raise the awareness of the population and people on a global level, for the importance of preserving a healthy environment - indirectly for the preservation of the Planet [31]. In the process of modernization, the demand curve for the economic values of abilities grows, which is affected by the increase of general production, but with sustainable additions. Production, as a social good, should be harmonized with the capacity of the environment, and therefore with the improvement of resources for a better life, as a private good - which is redistributed and allocated using additional human capital and the growing quality of the population.

That is why schooling, i.e. education for sustainable development, is considered not only as a consumable activity in the sense of exclusively achieving satisfaction and usefulness but also a way to consciously bear the costs of education, to acquire productive capital embodied in people, which provides the future for generations that have just are coming.

Figure 1. Support of Modern Management

Education for sustainable development and green activities means investing in future services, which consist of future earnings, future occupations, and future pleasures, as well as future investments in human capital. Green financing is related to projects that are financed to achieve the goals of sustainable development - they support all three components of sustainability - economic, environmental and social [31].

The definition of green financing is related to finance that is provided or attracted for sustainable development projects. Sustainable development projects contain all three components of sustainability, apart from the economic, they contain both the social and the most important - environmental dimension. Knowledge management helps in raising awareness when creating projects - to be as sustainable as possible, without harming the environment. Knowledge management acts on organizations to strengthen their employees' awareness of sustainable consumption and the consumption of sustainable products, i.e. services. As a result, the emphasis on the market is also placed on sustainable organizations, that is, on organizations that operate in a socially responsible manner. In order to strengthen and attract green finance in Serbia, the assistance of the state, the change of certain legal norms and the introduction of various reliefs for organizations that deal with green financing, but also for organizations that operate in a socially responsible manner, are necessary. However, due to the ubiquitous crisis that is evident in “smaller” economies, such as Serbia, it is more difficult to move on the path of sustainability - because economically stronger countries have greater opportunities to invest both in innovations and in the knowledge management that supports these innovations, and ultimately in sustainable development.

IV. Conclusion

Millions of people were effectively pulled out of poverty by industrialism in the 19th century. Nevertheless, resource and environmental damage has resulted from this economic prosperity. This begs the question is harm to the environment a prerequisite for stable economies? Even if there are plenty of natural resources, emerging nations' potential to grow economically is threatened by their susceptibility to climate change. Governments have been keen to establish policies and guidelines to guarantee the production of products and services in an ecologically sustainable manner for many years. The Sustainable Development Goals (SDGs) were set by the United Nations (UN) to safeguard and enhance social and environmental circumstances. As a result, businesses started to understand the value of protecting the environment and were motivated to update their management systems and operational procedures.

This is how new green disciplines have developed, which are related to the sustainable management of organizations and the preservation of natural capacities, respecting the social dimension. Green finance is part of the sustainable goals, which are aimed at sustainable development projects - globally. Since knowledge is the most important resource for all endeavors, understanding sustainable development also entails understanding green funding. Since the globe and mankind cannot know or anticipate what will happen in the future without knowledge of what is occurring now, education is essential for effective management and current activities. Given the challenges of ecological disaster and survival facing the whole human race, the community's consciousness of sustainable development must be raised. And it connects everything from the beginning - knowledge is the only way to elevate awareness.

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Original Scientific Article

Benefits and Challenges of Implementing the Internet of Things in the Field of Accounting

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Abstract—**The Internet of Things (IoT) is a state-of-the-art technology that provides great potential for modernizing any business model. This technology represents a network of physical objects with a specific purpose, which have built-in technologies for interaction with the external environment or with their internal state. IoT ensures that billions of physical devices globally, which are connected to the Internet, collect and share data, as well as coordinate decisions. The aim of the paper is to explore the advantages and challenges of IoT implementation, with special reference to the field of accounting. Through a case study, the effects of IoT innovations in the sphere of finance, banking and accounting will be examined. IoT means a revolution in the field of accounting and auditing profession, which indicates the need for professionals to follow its development and master the skills in applying IoT.**

Keywords - Internet of Things, accounting, advantages, limitations

I. Introduction

IoT represents a paradigm where objects are capable of identifying, detecting, networking and processing, in order to achieve their mutual communication or communication with other devices and services via the Internet, with the purpose of realizing set of goals [1]. The three characteristics that are unique to IoT are [2]: extreme heterogeneity, large number of devices and unpredictable dynamics partly due to human interaction. Based on statistical data, by the end of 2018, there were 22 billion connected devices worldwide, and according to the forecast, by 2030, there will be around 50 billion [3].

IoT technology is inextricably linked with the concept of Industry 4.0, which is called the Second Machine Age. Industry 4.0 is based on vertical and horizontal integration of various IT systems [4], where horizontal integration includes various stages of production and business planning processes, which are related to the exchange of information, energy and materials in the organization or among different companies. Vertical integration, on the other hand, takes place at different levels of the hierarchy [4]. It is inevitable that the Internet of Things represents the technology of the future. As technologies with the greatest impact on the industry on the example of companies in Poland based on EY research, the respondents mention: artificial intelligence (66%), robotic process automation (RPA) (54%), cloud computing (45%), big data (33%), Internet of Things (31%), 3D printing (25%), blockchain (24%) and 5G (18%) [5]. Given that technologies are interdependent, IoT must be analyzed within other technologies, not independently of them. In addition, companies generally introduce complex solutions based on a large number of technologies [6].

The paper will first talk about the definition, advantages and limitations of the use of IoT, as well as about the technologies involved in IoT, models and application of technology. The focus will then be on the benefits and challenges of IoT adoption and implementation, particularly in the accounting field. Through a case study on the example of the American Bank, the impact of this technology on the transformation of the banking industry and the field of accounting will be shown.

II. DEFINITION AND CHARACTERISTICS OF IOT

The first use of the term “Internet of Things” is generally associated with the pioneer in the field of British technology, Kevin Ashton. He used it in a presentation for Procter and Gamble in 1999, and sought to provide a way to collect data in the world, but without the need for people to enter it (eg. by typing). The term IoT is relatively new, but the technologies covered under it date back much longer. The growth of IoT applications comes only with the widespread use of the Internet and mobile connectivity, the improvement of sensors, and the reduced costs of computer processing and storage [7].

The term IoT refers to a network of physical objects with an IP address for Internet connection, as well as communication between these objects and other systems and devices based on the Internet [8]. Via IoT, it is possible to access remote sensor data, and monitor and control the physical world from a distance. Thanks to communication between devices, quality data is provided to e-commerce, with the aim of generating information that is necessary for timely decision-making and making accurate decisions. In addition, IoT can enhance the e-commerce process by technologically mediating stakeholder relationships. E-commerce includes the trading of information, products and services through computer networks, as well as the use of Internet technologies to exchange and share information within an organization or with external parties. With that in mind, IoT can have a significant impact on e-commerce in terms of improving the customer experience and ensuring reliable product delivery, by combining data in new, creative ways.

IoT is based on the combined integration of multiple technologies and communication solutions, which include: tracking and identification technologies, advanced communication protocols, wired and wireless sensor networks, distributed intelligence for smart objects, radio frequency identification technology, electronic product code technology and ZigBee technology. If applications are installed on mobile devices or tablets, the device can become a sensor in a large network. For

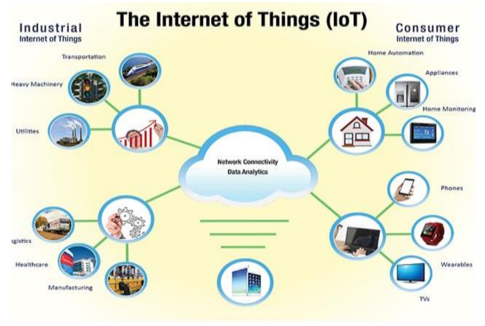

Figure 1. Internet of things [9]

example microphones and cameras can be used to collect evidence from riots or robberies, with the devices allowing the measurement of fine particle concentrations. By using sensors to achieve public safety and regulatory compliance, it is possible to achieve a more effective control mechanism.

IoT refers to a network of devices such as home appliances and vehicles that contain sensors, software, electronics, actuators and connectivity that enables these things to communicate, connect and exchange data. IoT encompasses the expansion of Internet connectivity beyond smartphones to other physical technologies and everyday objects. With built-in technology, the devices communicate via the Internet, and their remote monitoring and control is enabled (Fig. 1).

III. ADVANTAGES AND BARRIERS OF USING IOT

On the basis of IoT, it is possible to realize numerous advantages that include real-time measurement, analysis of the efficiency of service sensor data, improved efficiency and flexibility of services in the domain of historical data trend analysis over time. The advantages of IoT can be seen from the perspective of strategic/political, tactical and operational divisions. Strategic/policy benefits of IoT include improved forecasting and trend analysis, promotion of government transparency, improved citizen empowerment. Tactical benefits relate to improved management and maintenance planning, improvement of safety and health measures, cost reduction, more efficient enforcement of regulations and new revenue streams. In the field of operational benefits, improved efficiency, effectiveness and flexibility of services can be included.

The IoT faces a variety of obstacles when it comes to the adequate use and management of data collected by a large number of interconnected things. In this regard, strategic/political, tactical and operational obstacles are distinguished. Strategic barriers include data privacy and security issues, weak or uncoordinated policies and data governance, and conflicting market forces. Tactical constraints include cost, integration and interoperability issues, trust and IoT adoption. Operational barriers include limitations in the domain of IT infrastructure, insufficient knowledge of IoT as well as data management issues.

IV. Technologies Involved in IoT

The following technologies can be integrated into objects such as consumer products and industrial machines [7]:

- sensors - they are used to generate and measure data on numerous variables (vibrations, temperatures, location) as well as variables related to the chemical composition of substances,
- video cameras,
- actuators - used to control and move the mechanism that ensures the automation of tasks (turning off machines, opening valves, based on sensor data),
- transmitters and receivers - for transmitting and receiving data and messages that include radio frequency identification tags, which can be read automatically, without line of sight. Tags can be active with periodic signal emission, passive or only activating when within range of the reader,
- computer chips - serve for data processing in the device (so-called edge computing).

In order to form the IoT, it is necessary that previous technologies are supported by means of interconnection and connection to private servers or in the cloud. The connection is made using Wi-Fi, wired connections or through mobile technologies (2G, 3G, 4G and 5G). Certain technologies have been adapted to specific IoT requirements such as wide area networks. Part of the IoT technical infrastructure is also software (in the cloud or at the edge) whose purpose is to analyze and act on IoT data. For example if sensors are placed on a factory machine to monitor variables (eg. temperature or vibration) it is possible to achieve certain results. If the vibrations exceed the tolerance threshold, there is a possibility of automatic shutdown based on the actuator, in order to avoid possible damage. In addition, it is possible to achieve communication and connection of the machine with a spare machine that can turn it on if necessary and alarm the engineer via mobile phone. Based on the data from the sensors, it is possible for the operators in the control room to evaluate the performance of the machine, based on which they can further adjust the settings remotely. Through the current flow of vibration data, it is possible to set up predictive models in order to plan preventive maintenance. Technologies included in the definition of the IoT include mobile telephones, robots, driverless cars, i.e. any connected object that is able to generate data without conscious human input via keyboard or voice can be considered an IoT device.

V. Model and Implementation of IoT

The basic model of IoT implies a three-layer architecture consisting of application, network, and perception [10]. The perception layer consists of:

- identifiers used to identify data sources (eg sensors, devices),
- sensors to measure, collect and generate data such as temperature, location, weight, vibration, movement,
- actuators that use sensor data to start or control the task automation mechanism (e.g. valve opening),
- video cameras [11,12].

At the level of perception, data is collected and transferred to the network layer where routers, receivers and transmitters, gateways and switches are used to transmit and receive messages. Certain technologies are used for data transmission.The perception layer collects and transmits data to the network layer where transmitters and receivers, gateways, routers, switches are used to broadcast and receive messages. Data is transmitted using the following technologies: RFID (radio frequency identification), WiFi, Bluetooth low energy, infrared, mobile (3G, 4G, 5G). At the application level, the key functions of the management software are included for the complete management of IoT devices [11].

Various sectors of industry have adopted the concept of Industry 4.0. For example, IoT technology is used in urban architecture, such as the smart city of Songdo in South Korea. This area is fully wired and equipped, and functions like a living organism. As part of its infrastructure, sensors are included to monitor and regulate numerous things, such as building temperatures, energy consumption, and even traffic flow and street lighting. Residents' communication takes place through the city monitoring system using digital devices [13].

When it comes to promoting the spread of IoT in industry sectors, as many as 90% of companies in the world advocate this concept to achieve future goals [14]. The Internet of Things also drives Logistics 4.0, bearing in mind that it affects all its tasks, which include incoming, outgoing, internal and material flows.

The application of IoT in fiscal policy is particularly significant, considering that it affects the stability and size of tax inflows. For example online checkouts introduced in Poland [15]. Through online cash registers, details of all recorded transactions are sent directly to the central IT system, i.e. the Central Repository Cash Register, with details important for their identification (tax rate, amount of the taxable base and VAT, type of goods or services, time when the sale was recorded).

Finally, IoT is also applied in Accounting 4.0. It is a conceptual framework for modernly designed accounting processes in the context of new technologies. Given that the accounting information system (AIS) accepts transactions as input and then converts them through various processes into financial information, thanks to IoT, most transactions are automatically processed without human intervention. The use of IoT achieves positive effects on the satisfaction of qualitative characteristics of financial information such as verifiability, comprehensibility, timeliness and comparability, which are required by international and local accounting standards.

VI. Benefits and Challenges of Implementing IOT

On the one hand, the application of IoT contributes to the provision of advantages for organizations, but on the other hand, it can affect the occurrence of unforeseen risks as well as the implementation of significant transformations in organizations. In most research, the emphasis is on analyzing the advantages and challenges of applying IoT in business in general, while the literature on the advantages of applying IoT specifically in the field of accounting is limited. Haddud et. al [16], in a survey of participants on six continents, analyzed the advantages and challenges of IoT in organizations. Based on the results, the authors note the following possible benefits that organizations get from the implementation of IoT: better visibility and transparency of the flow of information and materials, better product monitoring, improved inventory management and control, better integration of internal business processes, improved operational efficiency. By realizing potential advantages, benefits are realized in organizations, which include: provision of timely information for business decision-making, automation of decision-making, improved planning, reduction of operating costs, creation of new income streams and improved communication with clients. When it comes to possible challenges, the authors highlight the following: device and network security risks, risks of introducing a new business model, the need to hire staff with appropriate skills and knowledge. Insufficient understanding of IoT benefits, issues of technical-technological integration. Similar results were obtained by Van Niekerk and Rudman [17], who conclude that the implementation of IoT contributes to the generation of value through integration and better quality of information based on obtaining data in real time. They observe that the application of IoT preserves the characteristics of timeliness, accuracy, completeness and validity of financial information. When it comes to risks, they identify issues related to verifiability, authenticity, data integrity and network availability, as well as technological issues. In the research of Corte-Real et al. [6] analyzed the application of IoT and Big Data Analytics (BDA) applications. Based on the obtained results, they identified that IoT and BDA influence the creation of significant value in business processes by providing quality data. Based on research by Wu et al. [18] indicates the impact of IoT on modifying the existing AIS in terms of improving the quality of accounting information due to new transaction data sources. On the basis of devices with sensors, obtaining and processing of accounting information that is visible in real time is ensured, without the participation and interaction of people. By applying IoT, a financial report is created that would provide a significantly larger amount of information, given

TABLE I. BENEFITS AND RISKS OF IOT ADOPTION [1].

Benefits	Risks
Improving employee productivity	Insufficient legal provisions regarding the implementation and use of IoT
Automating the entry and processing of transactions	Provision of technical-technological integration
Creation of new business models	Resistance to change and innovation by employees
Better asset management	Lack of employees in terms of the necessary knowledge and skills in the field of IoT
Optimization of costs and provision of management support through accounting tools	Achieving compatibility between networks, sensors, and applications from multiple vendors and vendors
Improving the quality of financial information based on accessing data in real time	Lack of knowledge about the benefits of IoT adoption
By obtaining a large amount of data, the performance of multidimensional data analysis is realized	The processing and access of personal data reduces their transparency and confidentiality
A richer financial report by including non-financial information obtained through sensors	Distrust in modern technology
Access to data through cloud computing without time and place restrictions	Cyber security
By automating the process, a simpler audit of financial reports is achieved in real time	Building the necessary infrastructure for the introduction of IoT
Reduction of employees	Distrust in the precision of the sensor
Better use of resources and automation of inventory, orders and warehouse documentation generation	Limited freedom of employees due to increased control of their work by micro-level management
Modifying the architecture of AIS	Limitations in the development of companies in the field of the IoT sector
Modifications of the accounting profession in terms of knowledge and skills in the field of computing	Insufficient support from public institutions for the development of the IoT market
Advanced forecasting, budgeting and product pricing	Issues of ethical application of IoT systems and technologies
Improved risk management by eliminating production downtime	Device and IoT Network Threats and Vulnerabilities
Better decision-making and efficiency by accessing large amounts of data in real time	Possible job loss due to automation
Supply chain optimization	Difficult access to financial resources for the maintenance and introduction of IoT
Introducing new products and services to clients	Insufficiently strong encryption and authentication system to protect data transmitted to IoT devices
Better user experience	The location of an Internet connection in a public area where a large number of users have access to the network

that IoT collects a variety of data concerning sound, location, and physical measures. According to the authors, the effects of applying IoT refer to improving the characteristics of accounting information in terms of completeness, relevance, timeliness and neutrality, as well as achieving a balance of benefits and costs of information. Based on the research of Roszkovska [19], the use of sensors enables the automation of the accounting system with the realization of numerous advantages such as: providing data in real time, reducing labor costs, reducing errors and the ability to manipulate records.

A report by the Institute of Chartered Accountants of England and Wales (ICAEV) in collaboration with the Shanghai National Institute of Accountancy and Inspur presents the impact of IoT on accounting. The results indicate the positive effects of IoT on management, performance and organizational culture. The advantages are reflected in the following: better automation and precision in transaction processing, asset monitoring, better asset utilization, realization of cost optimization, improved prices, improved forecasting and budgeting processes, as well as realization of employee quantification due to better safety and health conditions. Based on these advantages, it contributes to the improvement of accounting processes and business differentiation. When it comes to risks, the following are mentioned: provision of adequate infrastructure, issues of cyber privacy and security, accuracy of sensors, possession of necessary skills. A significant legal challenge in this area relates to the protection of personal data and issues of privacy violations.

Altuk and Kablan [20] indicate that IoT means a revolution in the field of accounting and auditing profession, which indicates the need for professionals to monitor its development and master the skills in applying IoT. According to Kruskoff et al. [21], future requirements for accountants will make mastering demanding technical skills such as data visualization, basic coding, data warehouse management and understanding of software capabilities.

In the research [1], the results of the analysis show that the most significant benefits realized from the implementation of IoT in the field of accounting in organizations are the improvement of the accounting process and reporting, in terms of data quality, automation of transaction processing and asset management. The use of IoT provides accounting information that meets quality standards such as timeliness, reliability, and verifiability. On the other hand, when it comes to barriers, the results show that the main concern of the respondents is regarding the construction and financing of the infrastructure for the adoption of IoT.

Mitigating the data security and privacy challenges posed by the introduction of IoT in accounting requires a multifaceted approach. This approach includes robust encryption, i.e. strong encryption protocols, strict financial data access control policies, regular updates of IoT devices and their software, regular audits and security assessments, alignment of IoT accounting services with relevant privacy policies, as well as work on training and raising awareness of employees and users on implementing IoT security best practices.

Ethical implications of IoT adoption and automation of accounting processes include issues of accountability, establishing appropriate guidelines and regulations to strike a balance between process automation and human involvement in performance. IoT in accounting is resulting in workforce retraining, i.e. new skills in areas such as data analysis, cyber security and maintenance and troubleshooting of connected devices. This means that companies invest in training programs to equip their workforce for these new demands. The appearance of the workplace in the future will involve the joint work of people and intelligent machines, i.e. work with IoT. The IoT represents an opportunity to reshape the future of work in accounting, not to replace human jobs. By embracing this technology and prioritizing employee training and data security, businesses can create a more efficient, innovative and collaborative work environment for everyone.

The long-term impact of IoT on the accounting profession is reflected in better decision-making, rationalization of accounting operations, minimization of audit efforts, effective workforce management. With advances in technology, particularly automation and data analytics, the modern accountant is becoming a strategic business partner, equipped with the skills to leverage data and drive informed decision-making. The role of the accountant is expanding beyond traditional financial reporting. With a deep understanding of business, data-driven accountants contribute to strategic decision-making, risk management and performance improvement. They help identify opportunities for growth, optimize operations and mitigate financial risks.

In context of smaller organizations with limited resources, by applying IoT technology to accounting, they can automate many manual tasks, freeing up valuable time and resources. One of the key benefits of IoT for small businesses is the ability to collect and analyze data. This data can then be analyzed to gain insight into business performance, enabling businesses to make informed decisions and improve their operations. Another benefit of IoT for small businesses is increased efficiency. IoT devices can be used to automate invoicing and billing processes, reducing the time and resources required to manage these tasks. IoT also offers benefits to customers by improving the customer experience. IoT also offers benefits to small businesses in terms of cost savings. By using IoT devices, customers can track their spending and manage their finances more efficiently. IoT devices can be used to automate bill payments and remind customers of upcoming bills, reducing the risk of missed payments and late fees. IoT therefore offers numerous benefits for small businesses in the accounting field such as improved operational efficiency, cost savings and improved user experience. Embracing the IoT can give small businesses a competitive advantage. IoT has the potential to revolutionize small business operations by enabling better control, optimization and automation of accounting processes. With proper planning, robust security measures, and strategic partnerships with IoT service providers, small businesses can overcome the potential challenges and barriers associated with IoT implementation and take full advantage of the IoT.

VII. Case Study - Transformation of the Banking Industry and Accounting on the Example of the American Bank

The financial industry is a leader in the implementation of new technologies, which are in the function of more practical and safer banking [22]. The American Bank is among the leaders in testing contactless payment technologies and introducing photo banking services (mobile check deposits, mobile photo bill payments, mobile credit card balance transfers). In line with public perception of the generally positive effects of IoT innovation on banking, the American Bank is seeking ways to provide financial security, convenience and value within the broader IoT industry through innovative research and development. In that process, it is necessary to discover the financial potential of innovative products and services, as well as to make efforts to realize that potential, in accordance with the needs of consumers in terms of convenience, privacy and security, while complying with the regulatory environment that is continuously developing. Within the American Bank, there is an innovation laboratory, whose prototypes include a large number of devices that would not traditionally fit into the financial services portfolio, but now do, thanks to the IoT that reduces the limitations between industries and creates wider collaboration. American Bank's innovation team looks at the "what ifs" of IoT when implementing IoT. One example is what if a device could provide real-time visual bank notifications of accounts payable and credit? Accordingly, if you imagine a traffic light with lights - red, yellow and green, if we are at or close to a low balance, the light is yellow, if we are in the red, the light is red.

The innovation team is interested in an idea at the heart of the automotive industry, such as the "Automatic" car device. This device tracks mileage and safety data. Through it, it is possible to automatically arrange an oil change service, if there is a connection with the driver's financial account. With the development of driverless cars, embedded financial services are becoming increasingly important. For example, the operation of a driverless car that would be driven to a service for maintenance or refueling, where the driver does not need to be present to pay with a credit card. It is the American bank that is among the leaders in the scope of understanding and possible development of technologies and security standards that would make this possible. The goal of the bank's innovation team is to improve the user experience, and through devices that can drastically improve it. The bank's role, given the importance of connected devices in all aspects of people's lives, is to ensure efficient automation, as well as safe, secure and private connectivity between financial accounts and IoT devices.

VIII. Conclusion

IoT contributes to the realization of numerous benefits such as real-time measurement, efficiency analysis of service sensor data, improved efficiency and flexibility of services in the domain of historical data trend analysis over time. The IoT faces various barriers when it comes to the adequate use and management of data collected by a large number of interconnected things. Strategic barriers relate to data privacy and security issues, weak or uncoordinated policies and data governance, and conflicting market forces. Tactical constraints include cost, integration and interoperability issues, trust and IoT adoption. Operational barriers are limitations in the field of IT infrastructure, insufficient knowledge of IoT as well as data management issues. IoT represents a conceptual framework for modernly designed accounting processes in the context of new technologies. The accounting information system accepts transactions as input, and then converts them through various processes into financial information. Thanks to IoT, most transactions are processed automatically without human intervention. The application of IoT in accounting enables the achievement of positive effects such as verifiability, comprehensibility, timeliness and comparability of financial information, which is one of the basic requirements prescribed by international and local accounting standards. The research results indicate that the most significant benefits realized from the implementation of IoT in the field of accounting in organizations are the improvement of the accounting process and reporting, in terms of data quality, automation of transaction processing and asset management.

Therefore, using IoT provides accounting information that meets quality standards such as timeliness, reliability, verifiability. On the other hand, when it comes to barriers, the main problem facing organizations is the issues of building and financing the infrastructure for IoT adoption.

IoT means a revolution in the field of accounting and auditing profession, which indicates the need for professionals to follow its development and master the skills in applying IoT. The demands of the future for accountants will make mastering demanding technical skills such as data visualization, basic coding, data warehouse management and understanding software capabilities.

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Original Scientific Article

Managing Changes and Innovations in Companies - Aspects of Green Finance

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Abstract—**Constantly changing environments and innovation processes influence companies to adapt and change their business activities, operations, development strategy, and organizational structure and accordingly advance the skills and knowledge of their managers and employees to survive in the market. The success of companies and their managers is largely determined by the ability to respond to environmental changes. Quick response to changes and implementing innovations are the core factors that establish long-term business. This requires flexibility, information and knowledge, analysis, quality, continuous development, and sustainable finance. Today, green finance has become a crucial aspect of this process to ensure better environmental protection activities and overall outcomes. This paper aims to analyze and point out the importance and role of managing changes and innovations in companies with an emphasis on green finance since it represents the basis of the success of modern organizations contributing to the environmental protection and well-being of the community.**

Keywords - changes, innovations, management, companies, green finance

I. Introduction

Rapid development, innovations, globalization, technological progress, wide availability, and the use of information technologies have become a part of our lives in all spheres. Changes in the environment especially affect companies impacting and shaping their business activities, operations, competitiveness in the market, and as well performance [1]. Quick adaptation to changes in the environment and implementation of innovations are mandatory requirements for all companies because that is the only way they can ensure their continued existence in the market and long-term development. Therefore every company has to effectively manage changes and innovations in their business practice [2]. This process is very complex and should be conducted through holistic, multidisciplinary, and interdisciplinary approaches as it includes many different disciplines, functional areas, and aspects of management such as strategy development, IT, information systems and knowledge, organizational structure, continuous development, research and analyses, quality management, marketing, HR, sustainable finance, etc. [3]. In this way, it is possible to successfully manage changes and implement innovations in day-to-day operations, i.e. to create an efficient, flexible, and agile organization and management able to respond quickly to the complex problems of a fast-paced changing environment [4].

The importance of the financial sector and sustainable finance is huge in this process. Moreover, due to the high level of environmental pollution and climate change issues with the element of ecological crises [5], the focus of the entire global society has shifted to green finance. This emphasizes the importance of engaging the financial sector and financing mobility in this area which raises awareness of risks related to pollution and climate change and promotes strategies to mitigate these risks through the

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implementation of green projects [6]. Modernization of industry production and manufacturing from the aspect of environmental protection and in parallel with activities aimed at remediation of pollution and improving the management of the environmental protection system is necessary in all companies and countries [7]. It also includes the redesign of industry production and manufacturing processes and the application of new technologies with less pollution and threats to the balance of the environment and optimal use of natural resources [5]. In managing changes and innovations, thus green finance, the first initial step of great importance for all companies and their managers who run the business, is to understand well contemporary environment and global processes well, possess advanced knowledge and relevant analyses to succeed in making correct, efficient and effective decisions, managing people and achieve set goals [8]. Accordingly, every company has to pay special attention to the advanced competencies, skills, and specialized knowledge of their managers and employees [9]. Green finance implies various green projects where the participation of all employees in the company is necessary because they cannot be realized without it [10].

Today, organizing and running the business of the company implies an organization that is constantly learning and building teamwork and players at all levels. Management teams are expected to be flexible to the changes, creative in thinking, solving problems, working on diverse innovative projects, and developing and improving business [11]. The roles of managers have to be focused on team leadership, training, and motivating employees, meeting the needs and desires of the market, sustainability with implementation of green projects, and thus long-term efficient, highly productive, and successful work. Therefore, today's managers must accept change as a challenge, be flexible in making decisions, innovation, and other plans, and be aware of the importance of green finance projects for all members of society including themselves [12]. Environmental protection and the contribution of every company and its employees to the safety of the planet is necessary since without a well-preserved environment and natural resources it will not be possible to run businesses with a resilient future [7].

II. Literature Review

Today the world is changing faster than ever. The new millennium has brought numerous changes to the world market and local, international, and global business organizations. Globalization, internalization, rapid technological/ICT progress, market and management trends, competition, and other changes followed by economic, political, and climate change issues produce an unpredictable volatile business environment full of risks. It can be claimed that many factors generate constant business changes. However, the most powerful ones are [2,3]:

- Technological development and advancement – ICT, AI, robotics, and other technologies;
- Global economic fluctuations such as competition, market trends, international relations, economic/legal systems, fiscal and monetary policy, inflation, etc.;
- Global political instability and broad societal changes including international conflicts;
- Environmental afflictions and natural disasters.

Every company, regardless of size or type of business, is deeply influenced by this which directly affects their business activities and decisions in everyday business and imposes rapid changes in entire company operations and development. Changes bring uncertainty to any organization and can become a threat or an opportunity. That is why in today's world, the ability to accept, continuously adapt, monitor, and manage changes is the most important driver of the success of the company. To survive in the market and develop, companies are forced to implement changes and innovations in their business [9]. It should be underlined that changes and innovations are deeply interconnected, interdependent, and complementary fields and cannot be observed as isolated processes. Application of new ideas and innovations requires the implementation of changes in the organization, more precisely their realization is carried out through the changes. On the other hand, the application of any change in the company usually requires some innovations in a certain field or organization unit, to improve its realization in the operations and functioning of a whole company [13]. Accordingly, for any company, the most important aspect is managing efficiently and effectively changes and innovations, i.e. agile management [4]. This is an extremely complex process that requires all resources, and forces of the company, and a holistic multidisciplinary systematic approach includes technological, product, production, organizational, management, personnel, financial, communication, and many other changes in day-to-day business. That means that this is the structured and intentional process of making significant changes to various aspects and functions of a company which also needs the transformation in business and development, marketing, strategy, production technology, organizational design and structure, culture, and management affairs. Their execution in practice requires deep analysis, efficient planning with actions, decision making, information systems and knowledge, control, involvement of all departments, employees and building a learning organization with capable leaders since without continuous learning, training, and the application of new knowledge it is not possible to realize these processes [8].

All of that triggers high pressure on managers and employees to achieve the desired results and can cause many conflicts and in most cases resistance of employees to changes. Company managers have a key role in these processes and therefore they must have the ability to anticipate, adapt, and react quickly and promptly to the changes. They have to be charismatic committed leaders in building teamwork and motivating employees and their participation to establish control over that process and overcome the challenges and employees resistance [10]. Such changes also require a lot of time, money, and energy, advanced technologies, and different thinking, but bring many benefits to the company, improving its performance and ensuring long-term positive and quality business progress [12]. One of the crucial aspects of this process is implementing sustainable business practices and green finance in response to the environmental and changing climate issues. High environmental pollution and ecological crisis at the global level have questioned the future existence of life on the planet and, thus economic activities and businesses [1].

Green finance refers to any financial activity created to establish a higher level of environmental protection and outcomes and enhance a more resilient future. Environmental protection from the economic point of view pertains to the efficiency in the use of resources which requires a new form of financing - green financing. As a concept, it combines interconnections between the financial sector and businesses with environmental behavior and economic development of creating green products and services in business operations [6]. In other words, unlike traditional financial activities, green finance emphasizes the benefits of environmental protection and pays more attention to environmental protection in industry. The trend towards green finance has emerged from the need to preserve the environment and accordingly harmonize economic activities. In recent decades there has been widespread public recognition in the world that the global financial system should actively contribute to sustainable development. However, the concept of green finance has become increasingly prominent around the world in the last few years due to the urgency of finance sustainable development [14].

Figure 1. Sustainable finance

The growth of interest in green finance also represents a significant wave for the scientific community, whose task is to identify, systematize, and present the current conditions in practice. Hence, the participation of companies is also necessary in that process, which implies the implementation of green projects in practice [15,7]. The structure of green financial products and services can be divided into the primary areas: businesses and investment banking, asset management, insurance, and retail business. Investment banking deals with lending business green projects to business entities in their practice. Also, banks act with the provision of services in corporate mergers and acquisitions, as well as the process of securitization of loans and other forms of assets. In addition to these activities, financial institutions also deal with capital management, leasing, insurance services, etc. [6]. In general, those investments and funds can be directed towards [5]:

- Renewable energy and energy efficiency (including efficient buildings);
- Sustainable waste management;
- Sustainable water management (including drinking and wastewater);
- Sustainable land use (including agriculture and sustainable forestry);
- Biodiversity conservation;
- Eco transport, and
- Adapting to climate change issues.

Broadly, these processes include businesses, investors financial institutions, and business consumers (individuals). However, it should be underlined that the main participants in the current work on green financing are [14]:

- Governments -public sector on creating a green environment;
- Businesses - green investment and financing mechanisms including green bonds;
- Citizens - capacity building of community green environment.

Partnerships in this process are very important and should include entire financial markets, banks, investors, insurance companies, and other relevant entities together with the public sector.

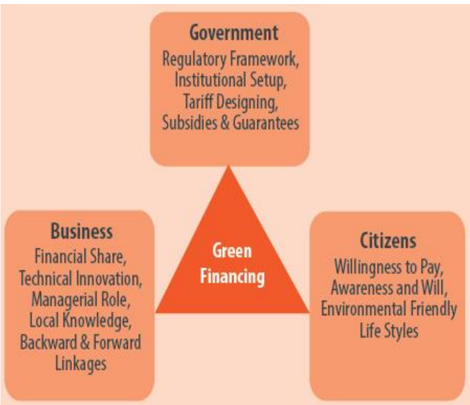

Figure 2. The main participants in green financing

Managing environmental risks and building partnerships is a key part of the green finance process that brings together better opportunities for a decent rate of return on investment and greater accountability in achieving benefits to the environment [14].

Green finance is future-oriented finance. At the same time, this type of financing strives for the development of industry and society by improving the conservation of the environment and sustainable economic development and social well-being with the desire to save the planet [15].

III. The Role and Importance of Management, Managers and Employees in Change, Innovation and Green Processes in Companies

The role of management managers today plays a pivotal role in monitoring and managing changes, innovations, global trends, business development, and improvement of the company in an increasingly complex and dynamic environment [13]. Managers should readily welcome and accept changes, and perform them well. In other words, managers are the ones who lead companies and must have the ability to quickly notice changes in the environment, to analyze, interpret, and implement them in their company. Those abilities of managers are very important especially in the light of their inertia and resistance to changes, which exist in every company, as well as in creating a positive atmosphere for changes, so that employees see changes as their opportunities, and not as threats [3].

For a company, the manager's attitude towards changes can determine its further growth and even decline of the business. This implies a change in their behaviors and attitudes constant professional development and learning to react and lead properly changes and innovations [8].

On the other side, today, managers face an increasingly demanding business environment with numerous risks, threats, and challenges wherein the quick actions on reversal of strategy, policy, decisions, and tactics are crucial in the struggle to achieve goals and successful business [13]. Everyday business takeovers, new operation processes, products, sustainable development, IT, green, and other projects, company mergers can lead to the creation of better business opportunities, while on the other hand, if not managed well can lead companies to laying off a large number of employees or even shutting down business [4].

The key characteristic of the implementation of changes and innovations in business practice is that they directly affect the work and behavior of employees. For employees, changes represent a path to uncertainty and can exert either resistance to changes, or an inert attitude. Resistance arises for several reasons, among which the most important are the fear of losing a job, position, and status, the impossibility of career advancement, etc. These are the biggest problems for the companies and their managers. Certainly, without employees, it is not possible to successfully apply and manage changes and innovations, which particularly refers to green finance projects [15]. In every organization, human resources are the most important for the implementation of changes and innovations which means that the participation of all employees in this process is necessary [7].

In most cases, this implies overcoming resistance to change and changing the organizational culture and structure of the company. Since the change in business systems is achieved by changing the behavior of their employees, this entails further employee transformation through the process of additional training, learning, motivations, and ways of organizing efficient operations. Also, managers should clearly explain and instruct all employees about change processes, advantages, and benefits as well as engage them, and ask for their opinions, solutions, etc. [11]. All this requires effective planning and building a learning organization that fosters continuous learning and knowledge creation at all levels [9] as represented in Fig. 3. Since managers today are faced with a large number of problems in day-to-day operations that need to be solved within a limited time frame, they have to be efficient, inspirational, and charismatic leaders. Such leaders should have characteristics such as: being goal-oriented, making prompt decisions on time, determining the right direction of the organization, having effective communication-listening and communicating, creating teamwork-encourage and facilitating work, bringing out the best in people, acting as a change agent and lead by example [10].

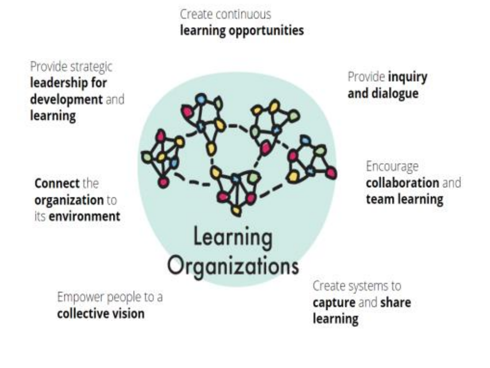

Figure 3. Learning organization

It should be emphasized that successful decisions of managers are the result of experience and knowledge, management practice, good information, monitoring of the environment, and two-way communication with employees [2]. Upper-level managers, department heads, and team leaders play an essential role in implementing innovations and changes in practice and presenting them to their employees. The innovations should be seen as combinations of ideas and information that bring positive changes [11]. Without good and agile management and managers, companies become chaotic and often have to close business. Therefore change in the company means adapting quickly to the new conditions of the environment to succeed in the market. The management is there to ensure stability in the company, including the quality and profitability of the products and services, and environmental protection, i.e. to turn the change into profit and contribute to the safety of the planet [1,12].

IV. Managing Green Finance and Projects in Business – is It Possible?

Due to the increasing commitment of governments and governmental organizations at the global level, as actors who play the role of regulators when it comes to climate change and global warming, there is an urgent need to examine the factors that allow companies to engage in green financing. Environment, the priority of numerous actors of public management shows the need for green innovations. Green financing enables finance for research and development of both clean energy and environmentally friendly goods and processes. Research and development are complemented by green innovations - when it comes to environmental protection. Adequate political action within the framework of green financing (financial restrictions) mitigates the impacts on organizations and industrial branches, which have the designation of geographical damage - in terms of new products, processes, as well as services, on the global market. Various financial restrictions and privileges affect the improvement of the business and production performance of organizations, to innovate their technologies and products. To better understand how green finance and green innovation act in terms of catalysts for green economy practice, it is necessary to review and research many scientific articles in which the authors tried to present historical and contemporary overviews of these concepts [16-18]. Research by Agrawal et al. (2024) included a systematic literature review over 7 years (2016-2023). Agrawal et al. (2024) presented four main research topics related to the implementation of green finance and green technologies in organizations. By reviewing the literature, it was determined that several organizational theories are related to the field of green finance and management research. In a research paper by Ilic et al. (2024), presented a model illustrating how green finance and green innovation can be combined to achieve a circular supply chain in organizations. According to Ilic et al., the great importance of new technologies for supply chain management and human resources education in the framework of sustainable development and green activities was established [19].

The results of the aforementioned research provide a new concept related to green finance in the context of green innovation - significant for environmentalists, global policymakers, green investors, and researchers. Conceptual frameworks are presented that promote sustainable strategies for effectively balancing financial green investments and environmental innovations. Examining the importance of green activities and the practice that implements these activities, helps both organizations and society as a whole. The results could draw the attention of policymakers and stakeholders to a greater combination of the two concepts in a practical sense, with the ultimate goal of establishing long-term sustainability.

V. Conclusion

Constant and rapid changes are the main characteristics of the times we live in. Globalization, internationalization of business, emerging technologies and trends, the economic, political, high environmental pollution, climate change issues, competition, and other elements, create a business environment full of insecurity, complexity, conflicts, and contradictions wherein changes are the only sure constant. All of that hugely affects companies and their managers in directing everyday business.

To survive in an ever-changing environment every company must adapt and manage changes and innovations effectively and efficiently. The connection and interdependence of change and innovation processes in the company is very deep and represents an extremely complex process that requires the involvement of all company forces, resources, management tools, and affairs, i.e. agile management to keep the capability of always adapting to the changing environment in time and implementing them in practice. In that way, companies can achieve competitiveness and the best possible position in the market, positive effect on its development, constant progress, and profitability. One of the essential areas in this process is green finance and accordingly application of green finance projects.

The high level of environmental pollution, climate change issues, and ecological crises today bring more uncertainty to businesses questioning the future and existence of the life of our planet. That is why every company must be dedicated to environmental protection by implementing green projects in practice. In this process, the managers of the companies, as main drivers of the business, need to adapt quickly to changes and to be charismatic leaders to their employees facilitating their participation in these processes and teamwork. Changes in the company must be a well-thought-out plan presented clearly to all employees because only in this way will ensure an effective change management application system in practice which is of particular importance for green finance projects.

There are no simple recipes for successful business in today's turbulent environment, but great flexibility in all fields of action, constant adaptability to contemporary business conditions with effective and efficient management, monitoring and initiating innovations, especially in green finance and projects, protecting the environment are the direction to run a successful business, contribute to the well-being of entire community and safety to the planet.

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Original Scientific Article

Towards a Circular Economy: Innovative Strategies and Youth Perspectives on Slow Fashion

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Abstract—**The fashion industry faces significant environmental and social challenges, with fast-fashion brands contributing to excessive consumption and waste generation. The paper reveals that the transition from fast fashion to slow fashion is of crucial importance and should be enabled by introducing the circular economy principles focused on product life cycle extension, eco-design, and waste reduction. The study shall highlight barriers and opportunities regarding the implementation of the circular economy in the fashion industry by analyzing the role of key stakeholders: consumers, designers, and policy makers. The paper presents the results of research on the attitudes of young people regarding sustainability and the circular economy in fashion both in Serbia and across Romania and Slovenia. Results of research show a very high level of awareness about sustainability among young people, while knowledge on the principles of the circular economy is different, having Slovenia as the forerunner, and Serbia needing further efforts to raise awareness on the benefits of implementation of the circular economy principles. The study highlights the importance of including the circular economy as a globally significant topic in formal and informal curricula to accelerate the transition from a linear to a circular model. The paper concludes that adopting sustainable fashion practices can lead to environmental, social and economic benefits, encouraging the fashion industry to balance creative design with sustainability for a greener future.**

Keywords - circular economy, sustainable development, youth perspectives, slow fashion, fast fashion.

I. INTRODUCTION

The fashion industry faces numerous environmental and social challenges, bearing in mind that consumer demand for cheap clothes from fast fashion brands continues to grow, and the amount of textile waste is increasing significantly. Fast fashion is characterized by short product life cycles and low prices, excessive consumption and waste, resulting in negative effects on the environment and workers in the global supply chain. In order to face these challenges, an urgent transition to slow fashion, which is based on the principles of the circular economy, is needed. Slow fashion brands focus on extending the life of clothes, promoting eco-design and minimizing waste through innovative solutions that prioritize sustainability at every stage of the production and consumption process.

This paper points out the obstacles and opportunities for the application of circular economy principles in the fashion industry, focusing on the roles of key stakeholders - consumers, designers and policy makers in creating innovative solutions to the challenges facing fashion. The aim of the paper is to point out the importance of applying the principles of the circular economy in the fashion industry and to analyze the attitudes of young people in

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Serbia, Romania and Slovenia about slow fashion.

II. Circular Economy as a Solution for Sustainable Fashion

Sustainable development is a concept recognized by the United Nations back in 1972 and defined as meeting the needs of the present without compromising the ability of future generations to meet their own needs [1]. The circular economy is closely related to the principles of sustainability and emphasizes the importance of keeping the value of resources, materials and products in the economy as long as possible, with minimal waste generation [2]. To achieve sustainable development, the transition from linear to circular economy, that is, from the take/make-use-dispose model to the reduce-reuse-recycle model, is extremely important. The circular economy focuses on reducing waste, reusing resources and minimizing the impact on the environment [3].

The concept of circular economy in the fashion industry means designing clothes that can be used for as long as possible and can be recycled at the end of their life [4]. However, the fashion industry today is unfortunately characterized by mass production and consumerism, which clearly affects the degradation of the environment. Therefore, there is an urgent need to implement circular economy principles in the fashion industry [5,6]. The fashion industry has undergone significant transformations over the past century. Namely, thanks to mass production and standardization, fashion has become available to the broad masses of society [7]. The concept of fast fashion emerged in the early 2000s with the aim of delivering cheap clothing with a short life cycle to consumers as quickly as possible. This has contributed to the doubling of the number of fashion collections every year, to the fact that clothes are discarded after only a few wears, and to a significant increase in textile waste. An additional problem is the fact that most of the textile waste is burned, disposed of in a landfill or exported to developing countries, further damaging ecosystems and depleting natural resources [8].

Global fashion trends dictate a shorter lifespan of clothing and excessive production and consumption, leading to excessive waste and environmental pollution. The fashion industry, along with the automotive and high-tech sectors, has experienced significant growth over the past decades. However, due to inefficient disposal and recycling, the fashion industry faces significant losses amounting to around $500 million each year [9]. The fashion industry is one of the biggest polluters globally, just behind the oil industry [10-12]. The negative consequences of fast fashion are extremely large. For example, when washing clothes, plastic microfibers are released, which contributes to ocean pollution. The fashion industry is responsible for 8-10% of global greenhouse gas emissions and 20% of world's industrial wastewater pollution [9].

Whereas fast fashion embraces rapid style changes, slow fashion concerns the development of commercially viable solutions for socially and environmentally conscious consumers [13]. The environmental, economic, and social impacts viewed from the perspective of the fashion industry are taken into consideration in the slow fashion. This concept encompasses the importance of using environmentally friendly materials, reducing resource consumption, and giving employees fair compensation. By sustainable fashion, we mean clothes, shoes, and accessories that are made in a way that least affects the environment and secures workers' rights within the fashion industry. Slow fashion puts quality in place of quantity, allowing consumers to buy less but higher quality products that will last longer [14].

III. Innovative Strategies for Sustainable Fashion Design

Fast fashion is unsustainable in the long term, and there is a strong need to apply the principles of the circular economy and innovative solutions that minimize the negative impact on the environment. The focus should be on increased lifespan of clothing products, eco-design, greater recycling and waste minimization [15,16]. The United Nations and the European Union have emphasized the importance of sustainable consumption and production in the fashion industry, especially through SDG 12, which promotes responsible production and consumption. Organizations such as the United Nations Alliance for Sustainable Fashion and the European Commission's Strategy for Sustainable Textiles are leading the charge in promoting circularity within the industry. The future of fashion depends on consumers, fashion designers, and policy makers, so long-term sustainability of the fashion industry depends on their willingness to accept sustainable solutions. Policy makers should foster sustainable solutions in the fashion industry, while fashion designers need to think of innovative ways to create fashionable and quality garments in accordance with the principles of circular economy [17].

Policymakers have an extremely important role in fast fashion, because they create a regulatory framework and can demand high transparency in the business of fashion brands that will contribute to informed consumer choices. Decision makers can introduce tax incentives for companies that implement environmental practices. Policymakers are supposed to support awareness of the importance of the circular economy and slow fashion. Policymakers can encourage public-private partnerships that stimulate cooperation between governments, businesses, and educational institutions with the aim of cooperating in developing sustainable textiles and circular innovation.

Consumers play an important role in shaping the fashion industry. Unfortunately, the excessive purchase of clothes, shoes and accessories, as well as the attachment to fast fashion brands that offer low prices, results in a huge amount of waste and the fact that many purchased items of clothing are worn once or not at all [18]. The short shelf life and low price of clothing items encourage consumers to keep buying new products. Unfortunately, consumers are not sufficiently aware of the unethical business practices behind cheap clothes, especially when it comes to labor exploitation [19]. However, the major barrier to the adoption of sustainable fashion is still consumer behavior. Indeed, even among those consumers who are aware of various environmental and social issues related to the fashion industry, price remains the primary factor influencing purchase decisions. To encourage consumers to make more sustainable choices, targeted awareness campaigns should be created to emphasize the importance of sustainable fashion and environmental protection. Consumer education and raising awareness of the negative impact of fast fashion on the environment, both in the process of manufacturing garments and due to inadequate disposal, should result in the desire of consumers to buy more slow fashion products with a longer production cycle. It is extremely important to actively involve consumers in the process of creating fashion design, so that they understand the threat to the environment if they continue with their consumer habits and to engage them in the promotion of sustainable practices [20].

A fundamental principle in the relationship with consumers is transparency. Nowadays, more and more consumers are asking for detailed information on the origin, methods of production, quality, and composition of clothes. In such a way, trust between producers and consumers would be created to assist informed decision-making, promoting loyalty toward sustainable brands. Moreover, sharing the story of each fashion piece creates an emotional bond between the brand and consumer, as it enables the consumers to look at their purchases as personal achievements-a reflection of values and ideals [20]. The use of social networks like Instagram, TikTok, and Facebook has become salient in the promotional of sustainable fashion, since through it, a means of communication between the fashion designers and consumers is readily available. Social networks allow fashion brands to instantly obtain consumer feedback, which can attain rapid adaptation of strategies for their activities to meet the changed needs of the consumers [19].

Fashion designers play an important role in the transition towards the implementation of circular principles in the fashion industry. The designer must come out with creative and innovative solutions which could balance the aesthetic and utility value of the produced clothes with the principles of sustainable development. The United Nations and the European Union clearly express the position that the role of fashion designers should be redefined, whose focus in the coming period should be dealing with the problems caused by the fashion industry and creating innovative solutions for new challenges. However, restructuring the fashion industry is a complex process that requires collaboration across the entire supply chain. Fashion designers have a major role in the development of innovative solutions that will meet the needs of environmentally conscious consumers, thus ensuring a sustainable future for the fashion industry [19].

Sustainable fashion design strategies aim to reduce the negative impact of clothing production and consumption on the environment. One of the basic strategies is the selection of appropriate materials and the minimization of waste, thus promoting the principles of sustainability in the fashion industry. The focus is on the use of environmentally friendly textiles, recycled materials or materials that can be easily recycled. However, there are limitations related to the scarcity of sustainable textile options, thus limiting the ability of fashion designers to meet high aesthetic standards while respecting the principles of sustainability [21]. The fashion industry produces two basic types of waste: waste generated during production and waste generated when consumers discard garments. To minimize waste, fashion designers should focus on creating products with a longer lifespan. Therefore, the focus is on high-quality clothing and creating a "timeless" design that further extends the active life of the clothing [22].

One of the effective strategies to extend the life of garments is to implement handmade elements in the design, thus creating personalized and innovative products. In this way, the emotional value of the product increases, and consumers are ready to store and use such products for a longer time. However, this approach is largely limited to small and medium-sized enterprises, because large fashion companies are focused on mass production and rarely apply manual production techniques. In addition to the above, fashion designers can promote sustainability by offering repair services for damaged garments, thereby contributing to resource conservation. In this case, it is necessary for designers and manufacturers to plan for this possibility of repair, to provide spare parts and materials in time, which is not widely accepted in the mass fashion industry [23].

Other strategies for extending garment life involve designing multifunctional clothes. Multifunctional garments can be changed in appearance or function rather easily by the consumer or specialized services. The approach does indeed encourage consumers to adapt their clothes to changing needs, thereby reducing the need for frequent purchases and indirectly contributing toward sustainability. Zero-waste design is an innovative design strategy in the context of waste reduction before the products reach the consumer, especially in the reduction of waste during the making of clothes. This will involve the use of material with maximum efficiency during production to limit the amount of waste from material residues [24,25].

Despite the numerous advantages realized in the fashion industry by applying the principles of the circular economy, even in countries where this concept is widely accepted, its implementation in this sector is slow. Obstacles are primarily related to difficulties in radically changing the production processes of companies with the aim of extending the life cycle of products [4]. On the other hand, consumers are still inclined to buy large quantities of clothing from fast fashion brands that offer lower prices. Therefore, it is important to motivate companies from the fashion industry to raise the awareness of their consumers about the importance of environmental protection and to build long-term relationships with them, which will result in loyalty to slow fashion brands. It can be said that consumers play a key role in driving the transition to a circular economy because increasing consumer demand for sustainable fashion will result in companies' willingness to implement circular principles in their business. [26]. Therefore, innovative solutions and sustainable investments could significantly contribute to overcoming these barriers for implementing the principles of circular economy in the fashion industry. It is extremely important to focus on raising the community's awareness of the importance of environmental protection, which could indirectly influence changes in consumer habits and the growth of demand for sustainable fashion.

IV. Youth Perspectives on Slow Fashion

During July 2024, authors conducted research on the attitudes of young people in Serbia, Slovenia and Romania on the importance of sustainable practices in the fashion industry. 139 respondents participated in the research, with more than half of respondents under 25 years. The survey included closed-ended questions, and the attitude of sustainability and slow fashion was measured using the Likert scale. The online survey was distributed using social media. This questionnaire had three major areas: awareness level of the importance of sustainable development and the implementation of sustainable principles into the fashion industry, knowledge about the concept of the circular economy, and willingness to adopt sustainable fashion practices. Descriptive statistics were used to analyze the data, as well as a comparative analysis of the results in the three analyzed countries.

Out of the total number of respondents, almost 85% of young people pointed out that sustainability is important or very important to them. In the Republic of Serbia, as many as 76.9% of young people pointed out that sustainability is very important or important to them. In Romania, young people attach even more importance to sustainability, with as many as 91.4% of young people emphasizing that sustainability is very important or important to them. In Slovenia, this percentage is 80% of young people who say that sustainability is very important or important to them. The above indicates that in all three countries, young people's awareness of sustainable development and the importance of applying the principles of sustainability is at a very high level.

When it comes to the concept of circular economy, slightly more than 53% of young people in all three countries are familiar with this concept. In Serbia, 40% of young people are familiar with this concept, in Romania 52.8% and in Slovenia even 70%. The results indicate that young people in Slovenia are much more familiar with this concept and that there is an urgent need to raise the awareness of young people in Romania, and especially in Serbia, about the importance of circular economy. The above can be achieved through the introduction of this topic in formal education curricula, the introduction of new study programs and subjects dealing with the circular economy, as well as additional informal forms of education on this very important topic.

This is supported by the fact that Slovenia is one of the first EU countries to actively integrate the concept of circular economy into its educational programs and implement a zero waste policy. Also, Slovenia is actively involved in a large number of projects funded by the EU on the topic of sustainable development and green entrepreneurship. Romania is taking steps towards raising awareness of the circular economy, particularly through national policies aligned with EU targets. However, the integration of this concept into formal education is still not at a satisfactory level. In Romania, the number of ecological startups and green initiatives is growing, but they are often limited to urban areas. In Serbia, the process of adopting circular practices has been slowed down by environmental challenges. Nevertheless, there is an increasing number of informal educational programs focused on sustainable development and the circular economy, but it is very important to implement these topics in the curricula of formal education.

When asked how important it is to implement the principles of sustainability and circular economy in the fashion industry, slightly more than 78% of young people from all three countries answered that these principles are important or very important in the fashion industry. In Serbia, this percentage is 56.4%, in Romania even 88.5%, while in Slovenia this percentage is 83.3%.

We asked young people how willing they are to adopt sustainable practices in their fashion choices (Figs. 1-3). Almost 77% of respondents point out that they are ready to be guided by sustainable principles when choosing clothing items. That percentage in Serbia is 51.3%, in Romania even 87.2%, in Slovenia 86.7%. More than 74% of respondents in all three countries point out that they would like to learn more about the circular economy and sustainable development. In Serbia, that percentage is 74.4%, in Romania 72.9% and in Slovenia 76.7%.

When asked what would motivate them to participate in activities related to slow fashion and workshops for upcycling fashion items, young people in Serbia emphasize concern for

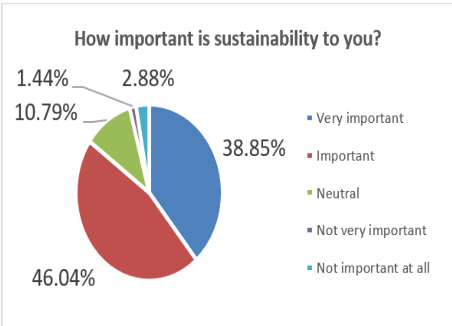

Figure 1. Youth attitudes about the importance of sustainability.

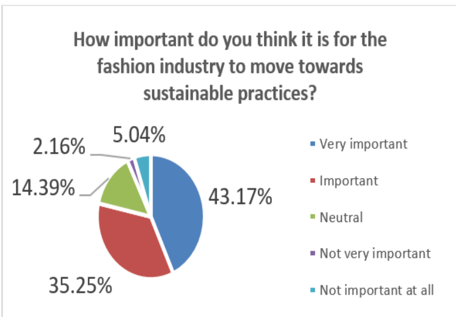

Figure 2. Youth attitudes about the sustainable practices in the fashion industry.

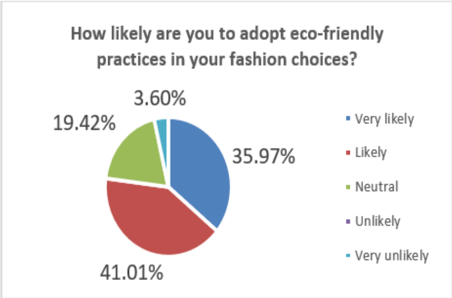

Figure 3. Youth attitudes about the adoption of eco-friendly fashion practices.

the environment (48.7%) and acquiring new skills (43.6%). In Romania, young people highlight concern for the environment (57.1%), acquiring new skills (52.9%), but also the desire to reduce the waste they produce (51.4%) as key motives. In Slovenia, the most important motives are concern for the environment (60%) and acquiring new skills (53.3%), but also financial savings that can be achieved if they create their own clothing items (53.3%).

V. Conclusion

The transition from a linear to a circular economy will bring about several environmental, as well as social and economic benefits. The circular economy contributes to sustainable development through the conservation of resources, reuse and recycling, but also through the promotion of social equality, the creation of new jobs and ethical business practices. While the whole world is shifting towards a sustainable future, the fashion industry is also bound to adapt itself to the circular economy, thereby creating more long-term value with less carbon footprint. One of the most significant economic benefits of the circular economy is related to the reduction of resource consumption, through recycling, reuse and designing products with a longer life cycle. The shift from fast fashion to slow fashion has the potential to create jobs in sectors such as textile recycling, clothing repair and sustainable design.

The fashion industry is one of the most polluting industries in the world. Fast fashion and hyperproduction of clothes have caused serious environmental degradation. To reduce the pressure on the environment, the fashion industry should make a greener shift in design, production, consumer engagement, and disposal methods at the end of a garment's life. A successful transition to implementation of circular economy principles in the fashion industry requires balance between creative design, sustainable materials and product quality. Despite global efforts, the transition to sustainable fashion is still slow. Since manufacturers and designers in the fashion world become more aware of their contribution toward environmental concern, they might attain an important role in ensuring a transition toward sustainable fashion. Customers can drive a more sustainable fashion future through more sustainable consumer habits enabling circularity in fashion.

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Extended Abstract

Financial Support of Agricultural Enterprises in Ukraine

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KEYWORDS

Financial support, financial resources, financial management, efficiency

SUMMARY

Ukraine is currently in a full-scale war. This creates numerous destructive factors for the development of enterprises. Domestic agricultural enterprises face a serious problem of insufficient financial resources. The modern agricultural sector is characterized by inefficient formation and use of financial resources by business entities. We consider that the formation and use of financial resources for any business entity is an extremely important component of the overall system of financial management at enterprises. The main indicators for assessing the efficiency of the use of financial resources of an enterprise are outlined, including analysis of the dynamics and structure of funds, financial stability, liquidity, business activity and profitability of an enterprise.

The authors identify a number of problems that hinder the smooth conduct of economic activity. Recommendations for improving the quality of formation and use of financial resources of an agricultural enterprise are developed. It is proved that ensuring careful control over the formation and use of financial resources of an enterprise is a prerequisite for its effective functioning

The agricultural sector of Ukraine faces serious challenges caused by the full-scale war. The destruction of infrastructure, land mining, reduction of production volumes, as well as difficult access to financial resources and sales markets create significant difficulties for the functioning of agricultural enterprises.

The main problems that slow down the development of the agricultural sector are the temporary occupation of territories, the destruction of agricultural infrastructure and agricultural machinery, the deterioration of the ecological situation as a result of hostilities, as well as difficulties with the sale of products caused by the lack of free access to markets and the blocking of sea ports. Additional challenges include the impact on the labor market, which makes it difficult to retain or attract qualified personnel, insufficient financial and credit resources, unpredictable growth in inflation, low financial stability of agricultural enterprises that threaten bankruptcy, dependence on limited energy resources necessary for growing and processing agricultural products. In particular, the destruction of the Kremenchug oil refinery in 2022 led to a shortage of diesel fuel, which is critically important for the operation of agricultural machinery.

Despite the difficulties and challenges, the agricultural sector managed to adapt and adapt to work under martial law. It has remained almost the main industry with the potential for further development and can play an important role in the recovery of the entire national economy of the country. However, achieving this goal is possible under the condition of state agrarian policy and appropriate financial support.

Financial support, as an economic category, can be defined as a set of methods, sources and objects in the form of financial instruments. From the point of view of researchers, the main methods of financial support for agricultural enterprises are self-financing, which is the most common among domestic enterprises; budget financing, which includes the use of various tools; and market financing, which includes bank lending, financial leasing, and raising capital through the issuance of securities.

Financial support of agricultural enterprises has its own specific features, due to the length of the production cycle, lack of own financial resources, high costs of attracting loan funds and shortcomings in the system of state financial support. Formation of a sufficient level of financial support for agricultural enterprises is complicated by significant risks that accompany production processes [1-7].

Under the conditions of martial law in Ukraine, a situation has developed in which agricultural enterprises do not receive sufficient support from the state. This especially applies to the livestock industry. Although in recent years the state has increased the amount of allocations for this area, the size of dairy farming, in particular among private farms, continues to decrease. This is primarily due to the high capital intensity of the industry, the reduction of the rural population and low prices for products.

During the war, the state implemented a number of measures to support agricultural enterprises. Among them: exemption from payment for land in the event of force majeure, provision of non-refundable grants for the development of processing enterprises, as well as restrictions on the export of certain types of agricultural products to meet domestic needs.

In the modern conditions of martial law in Ukraine, a situation has arisen in which agricultural enterprises face an insufficient level of state support. This is especially true for the livestock industry, which requires significant resources and technological investments. Despite the fact that government spending on livestock support has been increased in recent years, this industry, particularly dairy farming, continues to experience a significant decline. This reduction is observed both in large agricultural enterprises and in private farms.

The main factors influencing the reduction of production volumes in dairy farming are the high capital intensity of this industry, which requires significant investments in modern equipment and technologies. In addition, the reduction of the rural population, which is the main producer of dairy products in the private sector, also negatively affects the development of the industry. An important aspect is the low level of prices for dairy products, which reduces the economic feasibility of its production, especially in the conditions of rising resource costs and financial risks.

During the war, the state introduced a number of measures to support agricultural enterprises, in particular: exemption from payment for land in case of force majeure; provision of non-refundable grants for the development of processing enterprises; limiting the export of certain types of agricultural products to ensure domestic needs.

To support agricultural enterprises, the government implemented a number of measures: minimizing bureaucratic procedures for agribusiness, allowing the use of agricultural machinery without registration, simplifying the import of seed materials, introducing a zero excise tax rate and reducing the VAT rate to 7% on fuel.

Credit support for agricultural enterprises is an important tool for the uninterrupted functioning and development of the agricultural sector. In order to support agricultural enterprises, changes were made to the terms of lending to farmers within the framework of the state program "Affordable loans 5-7-9%" during the period of martial law and within a month after its termination/cancellation. Thus, agricultural commodity producers can get a loan at 0% in the amount of up to UAH 60 million for a period of up to six months for carrying out agricultural activities (purchase of machinery, fuel, seeds, fertilizers, etc.). The government's introduction of preferential lending "Affordable loans 5-7-9" allowed agricultural enterprises to obtain the necessary financial resources for existence. However, the complicated procedure for obtaining a loan and the low creditworthiness of many enterprises in the industry hinder the development of credit relations. Solving the problem of crediting agricultural enterprises with the support of the government and the banking sector will be important for the financial support of the industrial and economic activities of enterprises and the further development of their innovative potential. The government also offers alternative logistics networks for export, due to the blockade of ports. Tax holidays have been introduced, which provide for changes in payment for land of state and communal forms of ownership during the period of martial law [8].

To develop the potential in the agricultural sector, with the help of the US, the Agricultural Sustainability Initiative (AGRI-Ukraine) was created for $100 million until 2023, the purpose of which is to ensure access to agricultural resources: seeds, fertilizers, equipment and pesticides, as well as to improve the infrastructure for efficient export and product processing [9].

In the conditions of martial law, the role of the state is increasing regarding the need to create an agro-food system taking into account the challenges and directing financial policy vectors to financial support of the industry through the improvement of existing financial instruments, giving them weight in terms of impact on the results of agricultural activities, which contributes to national and global food security.

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Extended Abstract

Real and Probable Threats in Ensuring the Financial Security of an Agricultural Enterprise

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KEYWORDS

Financial security, financial resources, risks, threats, factors, agricultural enterprise

SUMMARY

The purpose of the study is to assess the practice of ensuring the identification of probable threats to financial security at the micro level and the elimination of risks.

During the study, the level of financial security of an agricultural enterprise is analyzed. Groups of indicators of financial security of an agricultural enterprise have been allocated. As a basis for the formation of a system of integrated assessment of financial security of an agricultural enterprise, a system of threats and risks is applied in accordance with two levels: financial and economic.

We believe that in order to ensure the financial security of an agricultural enterprise, the main place is occupied by monitoring and constant analysis of deviations of financial condition indicators from planned or marginal values. The main focus should be on the development of prevention and response indicators in accordance with probable threats to the financial security of an agricultural enterprise. The key success of applying an integrated approach to assessing the financial security of an agricultural enterprise is the preparation and implementation of effective programs for eliminating threats and minimizing existing and probable risks. To this end, the enterprise should pay great attention to improving the professional level of financial management of an agricultural enterprise at all stages of the program.

In the agricultural sector, the risk of losing financial security is much higher than in other sectors of the Ukrainian economy. The financial security of agricultural enterprises is affected by external and internal factors.

Ensuring the functioning of any business entity, including agrarian, is possible mainly with the systematic, complete and timely identification of probable challenges and threats, elimination of risks, since their detailed analysis allows to form the conceptual foundations of the strategy for ensuring the financial security of enterprise [1-4].

The risk factors of the external environment that have a negative impact on the financial security of an agricultural enterprise do not depend on the activities of the enterprise itself, but are determined by the financial and economic situation of the country. External risk factors to financial security should be taken into account by an agricultural enterprise; they cannot be completely overcome, but they can be minimised. Internal risk factors are directly related to the activities of the agricultural enterprise, the efficiency of the use of production, labor and financial resources and the level of financial management.

Risks represent a potential threat to the activities of an agricultural enterprise, which can lead to negative consequences, including financial losses. This requires managers to take appropriate measures to ensure the financial security of the enterprise. Therefore, the main objective of financial risk management is to create conditions that guarantee the financial security of an agricultural enterprise throughout its operation and development, as well as to maximize its market value [1,2].

It should be noted that there is a significant correlation between risks, especially internal risks, and the level of financial security of an agricultural enterprise. The management of these risks should aim to identify them in good time and minimize their impact on the financial position of the farm [5].

In other words, in our opinion, financial risk management is an important and necessary element of ensuring overall financial security at the micro level. This management should include constant monitoring of risks, assessment of their impact on the company's operations, as well as development and implementation of measures aimed at minimizing the negative consequences of risk events.

In our opinion, the risks that pose the greatest threat to the financial security of agricultural enterprises include:

- risk of loss of financial stability;
- operational risk;
- liquidity risk;
- environmental risk;
- risk of inefficient capital structure;
- investment risk;
- other types of risk.

A full-scale war, the resulting economic instability in the country, rising fuel and energy prices and other negative factors pose a significant threat to the financial security of agricultural enterprises. Under such conditions, agricultural enterprises cannot achieve the planned financial results that would have been possible under stable operating conditions [6].

The main threats to the operation and financial security of agricultural enterprises during the war include the fact that it was and is impossible to carry out agricultural activities on a significant part of agricultural land (due to occupation, constant shelling, mining) and the impossibility of relocating agricultural enterprises (land) to safe regions of Ukraine. Before the outbreak of active hostilities, about 40% of domestic agricultural products were exported through the commercial port of Mykolaiv. At the same time, the destruction, blocking of sales and export of agricultural products (by sea and other means) has a negative impact on the profitability of Ukrainian agricultural enterprises and reduces their financial security. For the third year in a row, Ukraine has experienced significant destruction of its agricultural production, processing and storage infrastructure. This in turn makes it impossible to conduct efficient agricultural production, worsens the food supply and creates and spreads negative views about food shortages among the population [7,8].

In a highly competitive environment, there are certain risks, even if the profitability of the business is relatively high. For example, stronger competitors can easily take over a less defensible business. In addition, the rapid growth and development of a business is often accompanied by an increased dependence on external sources of finance. This can lead to a loss of financial stability, autonomy and control over the management of the business. During the full-scale Russian invasion, there was a decrease in the labour potential and material and technical support of agricultural enterprises, which led to a shortage of financial resources and, as a result, a decrease in the financial security of agricultural enterprises, the impossibility of long-term planning of activities, simplification of production processes (reduced use of fertilisers, pesticides, etc.), resulting in lower crop yields and deterioration of the quality of arable land, shortage of fuel and machinery (fixed assets).

The peculiarities of reproduction processes in the agricultural sector significantly limit the ability of enterprises to operate solely on the basis of their own financial resources. Therefore, it is particularly important for the effective functioning of enterprises to receive financial and credit support from the state, especially for seasonal field work throughout the production cycle. In addition, agricultural enterprises are required to meet their financial obligations to the budgetary system, ensure timely payment of salaries to employees and renew their agricultural machinery fleet, which has become particularly important due to significant losses and damage to machinery as a result of military operations.

An important issue at this stage is the development of bank lending to agricultural enterprises, which should be based on the interaction between the state and banking institutions. In this context, existing credit programmes for the agricultural sector should be expanded and new initiatives should be introduced. Among these, special attention should be paid to state support programmes for agricultural enterprises and lower interest rates on agricultural loans, increased state allocations for affordable loans, continuation of the 5-7-9% programme and increased lending to small and medium-sized agricultural enterprises. The implementation of these measures will contribute to the development of agricultural enterprises and ensure their financial stability. Such support is crucial for increasing their competitiveness, resilience to external risks and ability to ensure the country's food security.

In our view, it is therefore advisable to identify potential threats to a company's financial security in good time and to develop and implement strategies to neutralize them. Ensuring the long-term financial sustainability of a company should be one of the priority tasks of management. This requires not only controlling internal and external risks, but also actively working to strengthen the company's financial base, increase its competitiveness and ability to adapt to a changing economic environment.

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Extended Abstract

Small Studies of Competition in Organizations: What Really Moves Organizations Forward?

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KEYWORDS

Competition, organizations, leadership, leaders, organizational theory

SUMMARY

Darvin is attributed to emphasizing competition as a major driving principle in a species' survival [1]. Smith described competition as a major progress factor in the capitalist society of free markets [2]. It is generally believed that competition is a good and positive driver of behavior. It is most encouraged in today's capitalist market economy. Competition is also thought of as something positive and beneficial in many organizations.

The authors decided to study mini cases in various types of organizations and scenarios to understand the competitive behaviors better. These mini studies included a formal organization where people work, sports, family, and a small military unit.

This paper is a collection of mini-case studies of competition in various types of organizations and environments that each author has been involved in professionally. We explore dynamics of competition through small cases in an organization of work, sports, family, and a military unit. By examining real-life small cases from diverse contexts, we hope to gain insights into competitive behaviors. What we found, however, was that only replacing competitive behaviors with cooperation, as many scholars have found, [3-8] drives positive results. Competition in today's society leads to great danger [9,10], and must be overcome to build a better 21st century society [10-14].

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Extended Abstract

Selection of Normalization Methods for Multi-criteria Decision Making with Consistency in Criteria Weighting

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Keywords

Normalization, MCDM, AROMAN, RANCOM, hydrogen fuel

Summary

Selection of normalization technique plays a pivotal role in successful execution of multi-criteria decision-making (MCDM) to get a reliable result [1]. On the other hand, consistency in criteria weight determination is another crucial area for the decision-makers [2]. In this paper, we aim to figure out the effect of normalization on a recent decision-making model such as Alternative Ranking Order Method Accounting for Two-Step Normalization (AROMAN) [3]. To determine the criteria weights, we propose a novel extension of Ranking Comparison (RANCOM) method [4] with consistency checking [5]. To apply the proposed developments, we select a real-life case study on comparison of electrodes for H2 fuel cells. The usefulness of the methods is demonstrated through a detailed analysis, comparison with various other MCDM methods and investigation for sensitivity of the outcome. The approach and its application in sustainable transportation is of significant interest to the decision-makers in logistics and data analysts.

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Extended Abstract

Overcoming Adolescent Risks via Theater: How and Why Does It Actually Work?

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KEYWORDS

Adolescence, theater, drama, experimenting, zone of proximal development

SUMMARY

Adolescence is probably the most controversial age period in human development. Though it regularly becomes the focus of research, there is still no consent even on such fundamentals as its duration, its main psychological content and the leading activity. A possible explanation for this paradox might be the complexity of the age, which lies on the boundary of childhood and adulthood [1-3].

Obviously enough, adolescents face an objective challenge of entering the system of social roles and relations the society has to offer, and they eagerly get involved in different forms of social experiments. On the one hand, experimenting allows adolescents to resolve the task of “trying on” various patterns of role interactions, which is necessary for finding their place in the system of social relationships. On the other hand, experimenting exposes adolescents to innumerable psychological and physical risks, which they are often not mature enough to deal with. Thus, there is a growing necessity of constructing culturally-organized “training platforms”, where adolescents could experiment-particularly with social roles and images-in a relatively safe way [1,4]. In L. S. Vygotsky’s terms, creation of such spaces relates to constructing the zone of proximal development for individuals in their teens [5].

In 2019 a multidisciplinary research project “Digital Storytelling Theater” was launched in Moscow State University of Psychology and Education. The project aims at elaborating, evaluating, and introducing drama technologies into secondary school settings with the goal of applying them as a powerful tool for learning and development [1,4].

The paper focuses on the ways, in which drama can be used for constructing the zone of proximal development in adolescence. It is argued that not any kind of drama-based activities is consistent with the principles of a developing environment in the framework of the Cultural-Historical Concept. Creating such a setting is a challenging research task, which requires organization of such types of activity and interaction as role exchanges and reflexive communication. On the example of creating a play with a class of adolescents, it is demonstrated how drama, based on role experimenting, can contribute to turning adolescent “risky behavior” into a resource for development.

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Extended Abstract

The Role of Knowledge Management and Innovative Processes in Agricultural Business

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KEYWORDS

Agricultural business, knowledge management, innovative processes.

SUMMARY

The challenges of today's world bring many pressures on agriculture. On the one hand, the growing population, must be fed while adapting to a context of increasing devastation: climate change, downfall of biodiversity, reduction of resources (soil, fresh water, phosphorus). On the other hand, agriculture must accelerate changes to implement production systems that are more respectful of welfare and reduce its impact on the environment and the preservation of biodiversity. This leads to great complexity that amplifies instability, multiplies the risks of failure and is ultimately a major hindrance to change.

Contemporary agriculture is becoming more knowledge-intensive, changing rapidly, and making agriculture management more complex. Skills and knowledge are critical for a agriculture success. It is therefore crucial to very quickly implement strategies to improve production techniques and ways of organizing the agrifood system to increase their efficiency. As one of the modern strategic responses to emerging problems is the application of knowledge management and innovative processes and technologies.

Knowledge management implies the transfer of personalized and codified knowledge between employees in the organization, which lead to the creation of new organizational knowledge.

Agricultural knowledge base as an asset of knowledge management is composed of scientific or specific knowledge linked to agricultural production and to innovations in that production [1]. Knowledge is a critical enabling factor for healthy agri-food systems and is required to generate contextual information and processes to improve productivity, increase profitability, reliability, and resilience. Deficient knowledge may result in poor production, decreased stability and flexibility, and harm to natural resources as well as producing agricultural products that do not meet planned demands [2,3].

The use of innovative technologies for the agricultural sector is necessary to increase the efficiency of the functioning of agricultural production entities and contributes to a radical change in the quality of manufactured products. Therefore, the intensification of innovative processes in agriculture is very topical, as it contributes to the growth of labor productivity, savings in material, labor and financial resources and an increase in the volume of production [4].

New knowledge enables better and more practical solutions, which are closely related to innovations process. The success of the implementation of these two strategic tools largely depends on the application of information and communication technologies in the sphere of the agricultural sector. New technologies in agriculture are based on computer technology and integrated systems and represent great support in the exchange of knowledge and innovative processes. They provide numerous opportunities for the realization of new

knowledge and the application of innovations, such as the use of satellite navigation and satellite guidance of self-propelled agricultural machines, automatic control during agricultural operations and other forms of development of precision agriculture [5].

This article aims to highlight the role and importance of knowledge management and innovative processes, which in synergy with modern information technologies have in the development of agriculture. Through a literary review of eminent experts and authors, the characteristics and importance of knowledge management and innovative processes, as a tool and an integral part of strategic methods used in modern agribusiness, are shown.

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Extended Abstract

Determinants of Organizational Agility and Sustainable Competitive Advantage

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KEYWORDS

Knowledge sharing, IT competence, environmental scanning, organizational agility sustainable competitive advantage

SUMMARY

Organizations are facing intense competition in today's highly dynamic and uncertain business environment. [1,2] It is essential for firms to continuously evolve and adapt to the changing environment and customer needs. They need to be flexible, customer-responsive and technologically competent in order to survive in the industry [3,4]. The banking sector of Pakistan is highly competitive [5]. This is mainly because of the entrance of foreign banks into the domestic market. In developing countries, foreign banks show superior performance than the local banks because of their advanced technology and efficient strategies [6].

Studies have confirmed that agile firms show superior performance in the market [7,8]. However, it is quite challenging for firms to endure customer responsiveness and ultimate sustainable competitive advantage in a fast-paced environment [9]. Previous studies have recognized the importance of knowledge management on organizational agility and competitive advantage [10,11]. However, the effect of various important internal and external factors through a mediation mechanism has largely been ignored. Therefore, the purpose of this study is to investigate the effect of explicit knowledge sharing (EKS), tacit knowledge sharing (TKS), IT competence (ITC) and environmental scanning (ES) on sustainable competitive advantage (ECA) via mediating role of operational agility (OA) and market capitalizing agility (MCA) of the banking sector of Pakistan.

The study used a quantitative approach with a cross-sectional study design. To collect survey data, 32 banks regulated by the State Bank of Pakistan (SBP) were selected. Data was collected from 320 bank managers using a convenience sampling technique. A structured questionnaire was designed by adopting items from already developed scales to measure the constructs of the study. The study employed Structural Equation Modeling Technique (SEM) to analyze the relationship between among the variables.

The study found that EKS and TKS significantly affect OA and MCA. The results have shown that ITC and ES positively affect bank's OA and MCA. The research has also found that OA significantly mediates the relationship between all explanatory variables and SCA. MCA significantly mediates the relationship between EKS, TKS, ES and SCA. Whereas, MCA does not significantly mediate the association between ITC and SCA.

The study provides a basis for a vigorous framework for future studies in the organizational field by emphasizing both internal and external factors. The study will help strategists and managers in attaining sustainable competitive advantage by having a clear understanding of its determinants. It will also aid

them in creating a favorable environment of knowledge exchange in the organization.

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Extended Abstract

How Reading AR Books Helps Keep Kids Engaged

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KEYWORDS

Children’s reading, children’s books, augmented reality, AR books

SUMMARY

The development of modern technologies and the digitalization of various fields have led to a transformation in reading practices. Different formats of books, such as printed, digital, and those with interactive features, have emerged.

Books with illustrations in augmented reality format appeared. Books that use this technology allow you to combine printed text with digital content. Augmented reality books (AR books) are becoming popular today. Unlike e-books, augmented reality books (AR books) are printed books that connect with additional digital content using augmented reality technologies. This technology allows you to combine the physical world with the virtual using a technological device. For example, when a person points the camera of their smartphone at a page of a printed book for which additional content has been created, the installed application displays this additional content on the device screen.

The wide availability of digital reading devices and the rich tradition of children's paper books raise the question of what opportunities for the development of a child are provided by different reading formats? What do we lose and what do we gain by choosing one or another book format?

At the moment psychological science is at the stage of accumulating an array of empirical data on the impact of augmented reality technology in children's books on children's understanding of the contents of the book and children's attitude to the reading process.

Cheng et al. conducted a comparative study of the effectiveness of teaching children by parents using traditional books and self-education of children using books with augmented reality. The children of the experimental group independently engaged in reading using the augmented reality function. The results showed that the effectiveness of training in the experimental group was significantly higher than in the control group [1].

A number of studies have shown that augmented reality in a book allows you to better maintain the logic of the narrative, helps to overcome difficulties in understanding the text due to complex words and complex grammar, rarely found in daily life conversations. But this is only if the augmented reality effect is synchronized with the logic of the presentation [2,3].

At the same time, it was recorded that when reading books with augmented reality, the level of concentration decreases [4].

Center for Interdisciplinary Research on Contemporary Childhood of Moscow State University of Psychology and Education conducted an empirical research aimed of perception of a literary text by children of senior preschool age, depending on the format of illustrations. The peculiarities of children's perception of the content of books in three formats were studied: books without illustrations, with printed illustrations and with illustrations in augmented reality format. The study involved 120 children (M = 75 months). The results obtained made it possible to identify the specifics of the perception by older preschoolers of the content of the text of the book, depending on the format of the illustrations. Illustrations in any format become a means of organizing children's attention and set the logic of content perception. The demonstration of illustrations in augmented reality format distracts children from the content of the text, but creates conditions for the manifestation of activity regarding the read text, expressed in the number of questions and comments asked [5].

Augmented reality can increase children's motivation and interest in both the reading process and the content of what they read, which should certainly have a positive impact on the learning process. When developing such a book format, it is necessary to carefully approach the development of the augmented reality effect, taking into account research data.

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Extended Abstract

National Data Collection Contribution to Higher Education Students Inclusion and Equity within the European Education Area

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KEYWORDS

Higher education, European Union, social dimension, data

SUMMARY

Inclusion and equity certainly stand out among the key values of the European Union. These are also the values that represent the essence of the social dimension within the actual European Strategy for Universities. The most important authors who dealt with inclusion and equity are [1,2], while equality studied by [3-5]. Reliable and high-quality data are a prerequisite for improving the social dimension of national higher education strategies and they are an excellent basis for the creation of adequate support programs for students from vulnerable groups.

The research problem of this paperwork refers to the analysis of the system and capacity for data collection in terms of the contribution to the implementation of the social dimension in the national strategies of higher education of EU member states and candidate countries. These issues were researched by [6,7]. The subject of the research refers to administrative data on student characteristics, data on degree completion rates at the end of the first cycle, data linked to specific student characteristics and data on completion rates at the end of the first year of the first cycle.

The aim of the paper is to compare the efficiency of national data collection systems, to determine the degree of system adaptation of candidate countries to EU standards in a given context, to propose guidelines for future system improvements and develop mechanism for identifying members of vulnerable, disadvantaged and underrepresented groups based on the collected data.

In order to develop effective higher education strategies, it is very important to continuously collect the mentioned data at national levels and adapt them to national legal frameworks, while ensuring international comparability.

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Extended Abstract

Production of Digital Stories as a Means of Moral Development in Adolescence

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KEYWORDS

Adolescents, digital storytelling, moral values

SUMMARY

In the era of high technologies with its instant connection, information insecurity and violation of information ethics the issues of moral education and implementing of moral values at schools and colleges are becoming increasingly important [1,2]. Not only are young people intense modern technology users, but also researchers, active learners and creative thinkers due to the stage of development. Being an active learning method and organized as a project activity, digital storytelling responds to the age needs of adolescents [3,4]. However, teachers still prefer to create or select digital stories themselves rather than use the production of digital stories as a collective students' activity [5].

In order to foster values and study the influence of digital storytelling on adolescents' understanding and interpretation of moral problems the research was conducted on the basis of the Center for Interdisciplinary Research on Contemporary Childhood in March, 2024. 48 students aged 13-14 years old from school № 4 (town Kashira in Moscow region) took part in 8 lessons in Fine Arts. The students worked in the groups of 2 or 3 people. Lessons were split into 3 sessions. The research was supported by the government assignment "Development of technology for overcoming adolescent risks: school theater based on role-playing experimentation". The adolescents created 12 cartoons. The products, created by adolescents during the research, were included into the final theatre performance to enhance its moral aspects.

At the first session (2 lessons) the teacher explained the techniques of stop-motion animation and principles of digital stories construction, then acquainted the students with the software for digital stories creation. The students made up plots, designed storyboards and wrote the scripts with the focus on characters' moral development through the choices they made. The adolescents figured out the ideas for their stories from the book "Letters about the good and beautiful" by Russian literary scholar and philologist Dmitriy Likhachev.

The second session (4 lessons) included activities on drawing backgrounds for digital stories (landscapes, interiors of the rooms, etc.) as well as drawing, cutting out and construction of the characters. Then students set the scenes due to the storyboards and shot the material in the stop-motion technique (took photos via smartphones while moving the characters across the backgrounds).

The third session (2 lessons) was aimed at editing the project products (cartoons), reshooting the material if necessary and discussion of the cartoon. The discussion covered such aspects as the main idea of the cartoon, which similar situations students had already faced in their lives, what moral decisions and choices should be taken to resolve the moral dilemmas shown in the cartoons, etc.

Due to the students' reflective journals and interviews after the sessions it was found out that the adolescents experienced mostly pleasure and fun while working on the cartoons because of the opportunities to communicate with friends and experience new activities. Also, they were interested in acquiring new digital skills and boosting creative thinking. Adolescents mentioned that it was not easy to convert their ideas into the short moral stories as they had to imagine themselves in their characters' places and reflect on their motives, emotions and actions. The plots of the stories touched upon such values as friendship, support, justice, beauty of nature, peace of mind and others. The adolescent as authors denounced and condemned bullying, inactivity, despondency, slandering and injustice.

Therefore, digital storytelling activity might teach adolescents moral values to response to the challenges of the times. It might make them more conscious and resistant to the threats. It also worth including into curriculum and becoming a pedagogical tool as the production of digital stories helps students reconsider their values and attitudes, it gives the opportunity to think over and moralize on different topics.

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Extended Abstract

Social Media Analytics using Machine Learning in Product Development and Customer Management

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KEYWORDS

Social media analytics, machine learning, product development, customer management, sentiment analysis

SUMMARY

Social media is becoming an inevitable platform for the businesses to acquire more insights on customer preferences, customer behavior and the dynamic trends of the market. The feedback and the experiences shared as posts and comments in different platforms of social media is offering a wide range of opportunities for the businesses to draw data-driven decisions on enhancing the product features and managing the customers. The traditional methods of sentiment analysis facilitate in making inferences from the customer reviews only if the data is in organized form. However, if the data is not rightly organized then traditional methods fail in making decisions and this is the entry point of machine learning. Researchers have leveraged the algorithms of machine learning in making inferences on customer review on product. Rekha and Gowda [1] formulated a framework of integrating machine learning in sentiment analysis. Imtiaz and Ben [2] determined the product features using diverse machine learning approaches. Gurumoorthy and Suresh, Keerthy et al [3,4] applied supervised machine learning in making sentiment analysis. Deborah et al [5] employed ML algorithm in analyzing Flipkart reviews. Kanakamedala et al [6] utilized ML approaches in drawing inferences on online reviews. Panduro [7] applied ML approaches in making inferences on E-commerce. However, these research works focus only on product reviews but not much on product development and customer management. Hence, this research work proposes a decision model which applies machine learning algorithms in leveraging the analytics of social media to make predictions on customer sentiment in designing optimal decisions on product development and customer management.

Problem Statement: Social media platforms are the carriers of huge volumes of data especially subjected to product features and feedback. However, the businesses are unable to extract insights from the unstructured nature of the data. This hurdles in drawing inferences and devising action plans for further progress. This study strongly emphasizes the need of machine learning techniques to social media analytics to obtain optimal data-driven inferences to align product development based on the customer sentiment, market trends to improve customer satisfaction and engagement. The primary objective of this study is to develop a robust machine learning model to handle the large volumes of social media data to make predictions on the sentiments of the customers by drawing inferences from their feedback and to devise suitable strategies to promote product development and customer engagement.

Methodology: The proposed decision-making model encompasses sequential steps

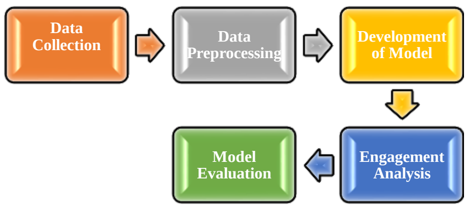

Figure 1. Framework of the proposed model

beginning with collection of data from the feedback posted by the customers in the social media, engagement metrics such as likes shares and comments, preprocessing of data using tokenization and vectorization, development of model with logistic regression to train the labelled data set, analysis of the engagement and evaluation using performance metrics.

The developed machine learning model in this research work facilitates in classifying the social media posts. The performance score values indicate the efficacy of the model in classifying the social media posts. The results obtained facilitate the businesses in devising suitable strategies in product development and customer management. The comparison of the results of the proposed model with conventional methods favour machine learning based decision model. The proposed work exhibits the efficacy of the proposed machine learning based model in handling unstructured social media data. The sentiment analysis integrated with machine learning assist the organization in devising dynamic strategies to make the business stay agile and responsive to the changing trends of the market. This research work shall be extended with the applications of other machine learning algorithms.

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Extended Abstract

Rethinking Leadership: 50 Years of Wrong Direction

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KEYWORDS

Leaders, leadership, followers, followership, organizations, management, systems structures, social systems

SUMMARY

Maccoby [1], and other scholars [2-5], writes books on the topic "why people follow leaders." The central topic of most of these studies is the assumption – I consider a fallacy – that people follow leaders, and not always good ones.

There are no such notions altogether as leaders or followers. Discussing them is misleading, confusing understanding of the major questions of the structure of the human relationships in the organization and society.

Milgram [6] offers a different paradigm to understand a hierarchical society, and the laws governing its social structures. Other scholars also attempt to understand the social organization differently [7-20], attempting to develop a new theory of leadership and organizations.

The best way to settle an argument is to test empirically, via various case studies. Let's examine the concepts of leaders and followers in real-life scenarios in families, corporations, government organizations, universities, and other societal structures. The paper proceeds to analyze the concepts of leaders and followers in different societal structures.

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Extended Abstract

Key Challenges of Smart Village

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Keywords

Smart village, urbanization, circular economy, Georgia, Kazakhstan

Summary

Adapting to depopulation and shifts in demographics - although depopulation is viewed as an aspect of rural decline versus a cause, it represents one of the primary drivers of the smart village program. According to the World Bank's [1] compilation of development indicators, the rural population as a percentage of the total population in 2023 was 39% in Georgia and 42% in Kazakhstan. Based on the UN World Urbanization Outlook, this will decrease to 30% by 2050.

Finding local remedies to reductions and the centralization of public services: Even when rural populations are steady or expanding, decreased population density combined with challenging logistics raise the unit costs of delivering fundamental services such as health care, educational opportunities, sales, and public transportation [2,3].

Exploiting connections with tiny municipalities and towns - Rural regions share a symbiotic connection with urban areas. Historically, the relationship has been seen in solely competitive terms, as a game in which there is no winner. What the city obtained rural communities were expected to lose. However, the Organization for Economic Cooperation and Development (OECD) [4-6] and others [7-9] have examined the intricate web of links between cities and rural regions and demonstrated that, if well handled, there is a lot of room for win-win partnerships between both of them. Smart villages [10-14] are about more than just bridging the urban-rural divide; they are about using each other's unique strengths for mutual gain.

Maximizing rural regions' role in the transition to an environmentally friendly, circular economy - according to the OECD, rural areas are at the forefront of the low-carbon economy. These natural advantages frequently serve as the foundation for their edge in the marketplace, identity, and appeal as locations to live [15-18]. As a result, they are both particularly vulnerable to the hazards of global warming and environmental deterioration, as well as in a unique position to influence change.

Supporting the digital transformation of rural regions - electronic devices have the potential to significantly reduce the disadvantages that rural areas suffer in terms of distance and low number of people by allowing for quick virtual contact and access to e-services. Rural communities are sometimes described as impacted by a triple digital split: internet connection, skills, and adoption.

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Extended Abstract

Application of Digital and Board Games for Cognitive Development of Preschoolers

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KEYWORDS

Digital game, preschoolers, executive functions, working memory

SUMMARY

Numerous studies worldwide indicate a change in the role of adults in constructing a child's zone of proximal development, as well as a multifaceted transformation of the ways they interact. In this context, there is an increasing discussion about the emergence of the phenomenon of "digital childhood" [1,2]. From the perspective of cultural-historical psychology, this phenomenon is driven by the appearance of a new mediating tool, which, in turn, always brings about changes in the structure of higher psychological functions and processes [3,4].

In this context, the emergence of a new type of child's activity, namely digital play, has attracted the attention of researchers. Along with digital games, a special type of rule-based games-board games-has gained great popularity among Russian preschoolers. This is evidenced, in particular, by the results of a survey of parents conducted in 2023, which showed that 70% of preschool-aged children play digital games, and more than 90% play board games [5].

In 2024, an empirical study was conducted at the Center for Interdisciplinary Research of Contemporary Childhood at MSUPE to compare the effects of digital and board games on the development of regulatory functions and intelligence in preschool children. A total of 88 preschool children participated in the study (M = 6.64 years, SD = 0.46, 55.7% boys). The children were divided into two experimental and one control group. In the experiment, children from Experimental Group 1 (EG1) played board versions of "Dobble" and "Tangram," while children from Experimental Group 2 (EG2) played digital versions of these games. Children in the experimental groups played each game once a week for 10-15 minutes over the course of 8 weeks. The control group (CG) children did not participate in the experimental part. Diagnostics were conducted before and after the experimental study.

The results of the study showed:

1. All children who participated in the study are at a stage of active cognitive development, as evidenced by significant differences between the measurements across all studied parameters.
2. A significant moderate direct correlation was found between abstract intelligence scores (Raven's Colored Progressive Matrices) and cognitive flexibility scores (Dimensional Change Card Sort, P.D. Zelazo), during both pre- and post-diagnostics ($\alpha < 0.001$; Spearman's coefficient $r = 0.4$ at the start and $r = 0.5$ at the end).
3. It was proven that the digital versions of the games "Dobble" and "Tangram" have a more positive effect on the development of auditory short-term and long-term memory in children (Memorizing of 10 words, A.R. Luria) than the traditional board game versions.

According to the data obtained, the average scores for reproduction were significantly higher in experimental group 2 (EG2) compared to both the control group (CG) and experimental group 1 (EG1), based on the Mann-Whitney test ($\alpha < 0.001$). The difference was also significant when comparing EG2 to EG1 on two indicators: "average over 5 trials" ($\alpha = 0.009 < 0.01$) and "average over 5 trials + delayed reproduction" ($\alpha = 0.018 < 0.05$). Therefore, it can be concluded that the type of game or its absence plays a significant role in the development of auditory memory (*Femp* = 13.586, $\alpha = 0.001$).

These findings partially confirm our hypothesis about the positive relationship between the type of game (board or digital) and cognitive function indicators in preschoolers and are consistent with the results of the pilot study [6]. However, the research question we posed remains open. Further research may focus on exploring what qualitative transformations occur in children's memory processes and what mediation tools are embedded in digital games that allow for the transformation of memorization techniques. This research direction seems particularly promising to us.

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Extended Abstract

Knowledge Representation in Internet-memes

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KEYWORDS

Meme, Internet lore, knowledge transfer, knowledge perception

SUMMARY

Progress has enabled Internet users to approach the process of transmitting information in more creative ways, which has resulted in the new units of Internet lore – "memes".

Memes and perception. R. Dawkins correlates culture and genetic evolution and defines "meme" as a unit of transmitting cultural heritage. If genes are based on a physical process: reproduction and replication (multiplication), then memes are based on mental processes: observation, imitation, learning, etc. [1]. In order to transmit knowledge meme creators use various visual and textual elements, which may include bright colors, contrasting images, and non-standard fonts, to help them be perceived more effectively by the target audience. These strategies are aimed at forming the first visual impression, which plays an important role in understanding the target knowledge.

Memes and memory. Memes often contain short and catchy texts, which help them stick in people's memory. Research shows that people remember information presented in the form of memes more easily than traditional texts. It has been proven that images accompanied by text messages are easier to remember than text-only information. This is due to such mnemonic strategies as rhyming phrases, wordplay, precedent names, etc.

Memes and emotions. Memes are usually aimed at causing emotional reactions in readers: laughter, indignation, admiration, etc., which can influence how users perceive and interpret the knowledge. Also, emotional reactions allow us to more firmly consolidate the information obtained from memes in our memory.

Memes and social impact. Memes are often commentaries on current events and socio-cultural phenomena. In terms of social impact, memes can reflect and shape public opinion or mood, certain stereotypes, cultural ideas and norms of social behavior. They can become a subject of discussion, exchange of opinions and communication between users. The analysis of the memes selected from the Internet in 2020-2021 showed that the most relevant social phenomena for America at that time were coronavirus infection, BLM (Black Lives Matter) rallies, quarantine, presidential elections, an attempt to seize the Capitol; for Russia - coronavirus, self-isolation, constitutional amendments, zeroing out presidential terms, events in Belarus, rallies. It is important to note that ambiguous perception and interpretation of memes can even lead to conflict situations.

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Extended Abstract

AI versus Human Judges: A Comparative Analysis of Fairness in Judicial Decision-making

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KEYWORDS

Judicial decision-making, substantive fairness, human judges, artificial intelligence

SUMMARY

Today, the judiciary faces a major challenge of integrating artificial intelligence. This paper presents an analysis of the substantively fair judicial decision-making process and its key criteria judges must meet, reached by examining the philosophical-legal thought on justice and fairness throughout history. Traditionally, these criteria have been fulfilled by human judges, but recent technological advancement and the use of artificial intelligence (AI) demands an examination of AI's potential to replace them in this role.

The criteria for making substantially fair judicial decisions that we have come to are: ethical behavior, independent and impartial decision-making, judges' freedom in law application and interpretation, consistency, transparency, and responsibility in decision-making.

Comparative analysis of human judges' and AI's ability to fulfill the decision-making fairness criteria reveals that humans have a significant advantage in several key areas: ethical behavior, independence, impartiality, fair interpretation and application of law, filling legal gaps, transparency, and responsibility for fair judicial decision-making. Humans can apply ethical principles, forming a hierarchy of values, as well as understand the spirit of the law, the legal system, and the ruling spiritual and moral values in society, taking into account the general interest and socio-economic circumstances [1]. Human judges possess a profound understanding of the legal system's context and complexities, enabling them to articulate clear and persuasive explanations of their decisions [2].

While AI is far more advanced in analyzing large amounts of data and is extremely capable of recognizing patterns and providing predictions, it often lacks transparency, making it difficult for the parties and public to understand the precise decision-making process and conclusions [3]. This "black box" phenomenon raises concerns about predictability and accountability [4]. Moreover, AI cannot be independent from the people who create it, nor from the database sources, which limits its independence and impartiality [5,6]. AI's ethical decision-making capabilities are also questionable since it cannot ethically reflect on all the details of the context of a case [6]. These shortcomings constitute a significant threat to human rights and fair trials.

On the other hand, the deterministic nature of AI systems is an advantage, regarding consistency in decision-making [6].

Given the legal consequences of court decisions, and the direct and profound impact on lives, rights, and freedoms, we propose that AI

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remains a tool for human judges, rather than replacing them. Its primary role should be to assist human judges in making efficient, and fair decisions. Ultimately, absolute respect for human autonomy is crucial for achieving democracy, the rule of law, and fundamental human rights. By providing human judges with the necessary knowledge and means to understand and interact with AI, we can harness the potential of AI while preserving the essential role of human judgment in the judicial process.

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