Varazdin Development and Entrepreneurship Agency and **GOVCOPP - University of Aveiro, Portugal**
in cooperation with

Faculty of Management University of Warsaw, Poland
Faculty of Law, Economics and Social Sciences Sale - Mohammed V University in Rabat, Morocco
Ecole Nationale de Commerce et de Gestion de Tanger - Abdelmalek Essaadi University, Morocco
Medimurje University of Applied Sciences in Cakovec, Croatia
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Book of Proceedings – Selected Papers

121st esd Online 2025
122nd esd Aveiro 2025

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Editors:
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ISBN 978-953-6125-27-2

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Publishing Editor ■ Domagoj Cingula

Publisher ■ **Design** ■ **Print** ■ Varazdin Development and Entrepreneurship Agency, Varazdin, Croatia / GOVCOPP - University of Aveiro, Aveiro, Portugal / Faculty of Management University of Warsaw, Warsaw, Poland / Faculty of Law, Economics and Social Sciences Sale - Mohammed V University in Rabat, Morocco / ENCGT - Ecole Nationale de Commerce et de Gestion de Tanger - Abdelmalek Essaadi University, Tangier, Morocco / Medimurje University of Applied Sciences in Cakovec, Cakovec, Croatia / University North, Koprivnica, Croatia

Printing ■ Online Edition

ISBN 978-953-6125-27-2

The Book is open access and double-blind peer reviewed.
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EXPERIENCES AND TECHNOLOGIES OF SMART TOURISM: AN ANALYTICAL APPROACH TO LITERATURE REVIEW

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ABSTRACT

The paper focuses on examining relationships and communication in tourism based on the power of technology as a tool for reaching end users creating their personal experiences. This is evidenced by numerous literature and various aspects of individual tool evaluations. The dimension of added value contained in the positive effects of using ICT tooling, such as availability, concurrency of information, personalization based on tailored user requirements, real-time communication and marketing transparency that facilitates product management, have been specifically researched. Structural changes in the area of service marketing present the result of major changes that are reflected in other activities but also due to technological innovations. From demand perspectives, they are the result of tourist experiences and informatization. The formation of business models with a clearly defined development orientation, based on the values of knowledge, assumes a flexible business model that is based on goals that multiply the value of the company, the destination. Smart technologies and adequate ICT tooling enable more efficient evaluation of potential in space, providing a platform for emphasizing identity through a set of elements for product differentiation and space management. This is visible through positive customer experiences (CX). The results of numerous studies confirm the expansive dynamics of changes and differences in the level of acquired knowledge and digital competencies that depend on the geographical area and different levels of economic development are considered, as well as differences in the standard of living of the population, with which this could be associated. From the perspective of service providers, innovations are prerequisites for evolution. They are omnipresent in the transformation of organizational structures and cultures from production technologies to management perceptions with the aim of obtaining a productive process based on technological progress and a new management model in the area of labor-intensive activities.

Keywords*: Customer Experience (CX), Personal Experience, Value Proposition, ICT tooling, Time*

1. INTRODUCTION

Innovations in tourism are contained in new possibilities for creating and delivering value, with an emphasis on interactive dynamic systems of knowledge exchange. In this context, ICT is a catalyst for change in the environment, strengthening the effects of dimensions in the macro environment and accelerating qualitative market trends. The transfer of knowledge and acquisition of competencies in a competitive environment requires training, particularly in labor-intensive activities and beyond skill areas, including communication in the internal environment and adjustments to business models in line with market trends that test a company's competitiveness through innovation. With spatial and temporal convergence, ICT manages to create new needs through dynamic relationships of supply and demand, establishing new value metrics. The roles and impacts of ICT assess aspects of innovation through the spatial-market dimension and create a positive perception for users by adding value and managing time.

Innovations that have radically changed market relations and perceptions in tourism include the Internet, the development of mobile technology, interoperability, and multimedia. The views of theorists, supported by research results related to digital competencies and employee skills, investments in innovation, and innovative knowledge crucial for business operations, are additionally supported by secondary research. According to the European Commission, the basic components of the innovation impact indicators of EU member states through ICT contributions to Europe are:

1. **Inducator– Patents**: 26% in technological innovations.
2. **Indicator – Employment**: 19% of skill absorption, measured by employment in areas with a higher impact of ICT.
3. **Indicator – Export of Medium-High Technology Goods**: 25% in the competitiveness of knowledge-based goods.
4. **Indicator – Export of Knowledge-Intensive Services**: 20% in the competitiveness of knowledge-based services.
5. **Indicator – Innovation Dynamics of Companies**: 23% in the employment rate of innovative, fast-growing companies.

The results of numerous studies confirm the exponential growth dynamics of the demand for the application of primary and secondary digital technologies, with an uneven level of acquired knowledge and digital competencies in general. Different levels of economic development and living standards of the population could be linked to the results of the study, which indicate uneven levels of readiness for ICT and related to a specific geographical area. From the perspective of service providers, innovations are a prerequisite for evolution. They are omnipresent in the transformation of organizational structures and cultures from production technologies to management perceptions with the aim of obtaining a production process based on technological discoveries and a new management model in the field of labor-intensive activities. Innovations in the service segment are supported by digital transformation. In the service sector, an exceptional level of sensitivity is recorded with respect to the cost aspect, investment in human capital, the possibility of talent management, education necessary for the acquisition of digital competencies, and research studies indicate the volatility of SME behavior and the necessary support for investments in information and communication technology (ICT) for the integration of digital transformations into the overall company strategy. Competencies in the domain of digital literacy refer to the key qualities of measurable outcomes contained in the time dimension and are avoided by a more rational approach to time management, modality of accessibility, faster communication and delivery of products or information that create added value, marketing transparency, comparison possibilities, on which decision-making processes within the organization and strategic decisions in communicating with the business environment. It has been confirmed that the greatest usefulness in the use of information is assessed through features such as timely delivery of accurate information, possibility of comparison, coverage, accessibility, availability and usefulness in terms of time savings, as perceived. Tourist behavior and interests are very important when choosing a travel method. The development modalities, the level of use of digital tools have been pointed out in numerous studies. The perception of the experience prompted by this research could be conected to the time of travel, choice of travel motive that defines the activities, content and organization of the trip in accordance with the price.

2. SMART TOURISM TEHNOLOGY

The Internet as an infrastructural framework of sophisticated models and belongings has radically changed relations in tourism and tourist experiences. As companies begin to move out of limited business operations, they move faster in their transformations, while digital transformation only becomes more critical to the business success of organizations. Numerous theorists confirm the findings according to which the application of ICT as a tool in the transformation processes of special areas is the driver of changes in the form of intelligent solutions for time management, contributes to spatial and temporal convergence, where the most intensive changes are contained in the creation, distribution and information about products. According to services and the application of modern tools with real-time reaction, priorities are contained in more efficient decision-making based on time management, rationalization in the segment of time saving. ICT tools and their application are visible in the context of intelligent solutions supported by primary and secondary digital technology contained in the following form as table 1 shows.

PRIMARY DIGITAL TECHNOLOGIES	SECONDARY DIGITAL TECHNOLOGIES
Computer hardware	Artificial Intelligence (AI)
Software	Internet of Things (IoT)
Network infrastructure	Blockchain
Cloud computing	Big Data Analytics
Computer security	Virtual Reality (VR) and Augmented Reality (AR)
	5G Technology
	Sharing economy

Table 1: Solutions based on Primary and Secondary Digital Technologies

By creating added value that complements tourist user experiences which are measured by the performance of the quality of the information that is the input for making decisions that are the answer in the creation of smart destinations. Seversl suthors such as Hzang CD considered a multidimensional construct of STT, evaluating its performances. A smart destination urban planning approach that creates a smart space**.** A strategic framework that uses ICT tools makes information more accessible, directs the effects of the economy, social change policies on the welfare of the environment and social benefits by affirming the natural and cultural context of the specific product of the destination and in this context contribute to a low level of substitution of product for product. The social and natural environment recognizes the importance of external drivers and actions in shaping and emphasizing the authenticity of the local community, which, by improving the quality of life, education, action and information, contributes to strengthening horizontal and vertical connections. These activities stimulate awareness of cultural values and have a preventive effect on the preservation of heritage values. Collaborative relationships, influenced by innovation, enable communication whose effects are assessed through experiences. Technology that transmits knowledge and information connects, educates and influences the awareness of service providers, the mobility of users and the media.

Characteristics of information attractiveness and sought-after attributes:

- reach,
- simultaneity,
- final impact,
- connectivity

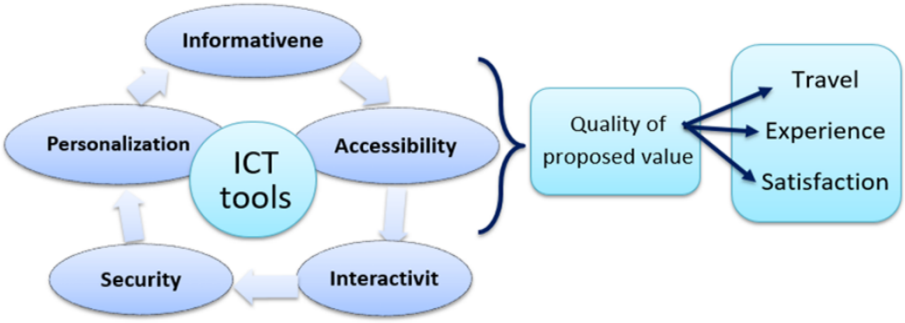
Outcomes of information reach:

- space management,
- consistency of attitudes,
- final creation and evaluation of a set of elements that create identity,
- raising awareness,
- management by time

Managing obstacles such as conflict and noise in communication with the optimal amount of information, the reality of which is to reduce the gap between the perceived value of the actual usefulness of the information being measured and the impact being assessed through:

- clarity,
- amplification,
- competitiveness,
- transparency

1. Figure: ICT Tooling as a Buisiness Driver



Source: Authors' analysis

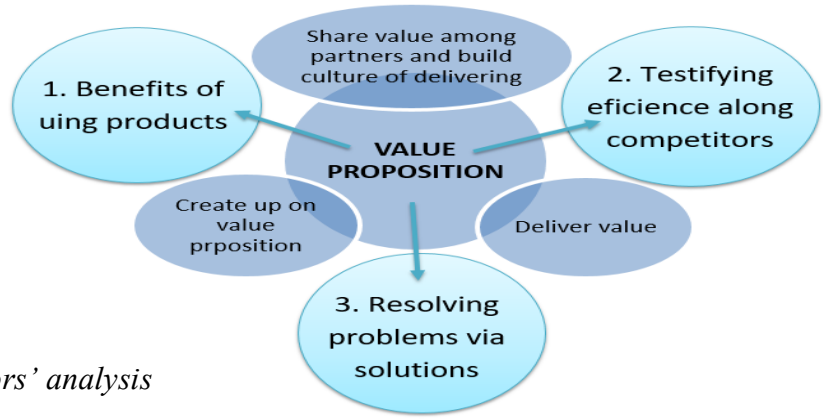
Technology that transfers knowledge, information, combines, educates and influences the awareness of providers, users and media by managing drivers:

- Drivers improve the tourist travel experience and the competitiveness of the destination, thus becoming smart tourist destinations. It is important to distinguish the concepts of experience and technology in the context of smart destinations.
- Customer experience is holistic in nature and include customer's cognitive, emotional, sensory, social, and spiritual responses to all interactions with a firm.
- While innovations in expectations understand: the quality of customer care, promotion, packaging, product and service features, ease of use, and reliability.

3. KEY DRIVERS OF CUSTOMER SATISFACTION

Smart destinations support the implementation of advanced technological tools, smart destinations facilitate the interaction and integration of tourists into the environment, improve the visitor experience with destinations, as well as the quality of life of residents. This allows both demand and supply to jointly create value and enrich the tourist experience. **Internal drivers** use tools, a set of services and HR, engaging them through investment in competencies in areas that will guarantee future value in the area of crystallizing identity, its irreplaceability in the world of the potential user and thus create an irreplaceable user experience. DMC and TZ must represent experience and technology in coalition. Information and technology are compatible in co-creating space. Supply through the identity and state of consciousness of the local community and demand through the transformation of information into an understandable image in the environment, through coalition create an image and a new view of reality and crystallize values in the destination space emphasizing the positive and sometimes negative.
External factors, through partnership cooperation, education, legal frameworks for cooperation and informal associations, promote awareness among the local population and key institutions about the importance of social, natural and cultural values as a space for development and spatial prosperity.

Figure 2. Proposition of Customer Satisfaction



Source: Authors' analysis

A layered approach to customer satisfaction IS BASED ON an analysis of key elements:

1. **Customer satisfaction is a strategic advantage**

The American Index of Customer Satisfaction considers satisfaction a key strategic asset that companies need to optimize. Optimization is key to managing satisfaction, taking into account customer expectations and company resources. Development and progress represent a trade-off between these expectations and resolving complaints. The challenges of optimizing satisfaction are caused by the high expectations of heterogeneous customers.

2. **Understanding what customers expect**

Researching the level of expectations – dizzying expectations in relation to experiences, we can conclude that informed, personalized value delivery creates tension and expectations significantly higher than possible, the moderator of the false trend must be quality and truthful available information that will facilitate the management of experiences by reducing the gap between perceived and actual value. These trends primarily relate to experiences in the use of luxury brands and higher-priced product categories.

3. **Quality of execution matters**

The quality of the composition of the attributes of reliability, flexibility and adaptability as drivers of satisfaction is key to improving satisfaction through content knowledge, and information is key. Although the phrase that quality is better than price is universal, the broader context of understanding the relationship between these two quantities implies that quality goes beyond value and is the driver of customer satisfaction. Therefore, "mass customization", "long tail" seems to be the only possible option, and satisfaction is sometimes more sensitive to personalization than to the reliability of products and services.

4. **Value is more-less price**

Customer perceptions of value are extremely dynamic, influenced by information that broadens the perspective compared to product quality assessments and customer expectations. Measures of perceived value are growing nationally, and according to the ACSI (American Customer Satisfaction Index), the essential focus on value as the primary driver of satisfaction opens up opportunities for further improvements.

5. **Satisfaction is never guaranteed**

The ACSI result is a scientific assessment of customer satisfaction based on a cause-and-effect system that aims to understand the customer experience, the customer journey.

6. **Value customers who complain**

Quality complaint resolution creates greater customer loyalty and positively affects the development of a more competitive brand, products and services, but prevention and detection of possible noise is a much stronger argument for encouraging the reliability of customer services and is the path to loyalty.

7. **Managing customer complaints builds loyalty**

Research confirms that managing customer complaints builds loyalty even more than the experiences of customers who did not have problems with the service. Customer experience management is aimed at increasing satisfaction and loyalty, while there is a tendency to overestimate customer expectations, perceived value, satisfaction and loyalty, while underestimating customer complaints.

Customer satisfaction and retention are key to the long-term success of any organization. Companies that prioritize these factors often report higher profitability, improved brand loyalty and better promotion among customers. However, measuring and improving customer satisfaction and retention rates can be a challenging task.

To help companies in this area, members of the Forbes Business Council recommend several effective steps:

1. **Collect customer feedback regularly**: Leverage surveys, reviews, and direct feedback to gather valuable insights.
2. **Analyze customer data:** Use analytics to understand customer behavior and preferences.
3. **Personalize interactions:** Tailor customer interactions to meet their individual needs.
4. **Implement loyalty programs:** Reward loyal customers to encourage repeat purchases.

5. **Improve customer service:** Ensure your support team is well-trained and responsive.
6. **Engage on social media:** Actively monitor and address customer concerns on social platforms.

By adopting these strategies, organizations can gain valuable insights and significantly improve customer satisfaction and retention rates. Understanding and meeting customer expectations is key to remaining competitive in today's marketplace.

4. SMART TOURISM EXPERIENCE BASED ON ICT TOOLING AND CX

Smart Tourism Technologies (STT) have transformed the destination experience (Ayeh, 2018). Digital technologies have enabled businesses and consumers to connect, interact, create and share experiences such as personalisation of product. Digital tehnology has resulted in positiv effects but also negative ones like privacy issues, and the digital divide distraction and alienation and loss of authenticity. Furthermore, the smart tourism experience relies on a system of algorithms in the communication process as an incentive for personalizing the travel experience, with a flexible approach to tourist expectations and preferences. Creating unique and more tailored experiences for tourists is enabled by ICT tools and the application of modern connected tools in value delivery. In essence, the use of technology seeks to create more engaging, efficient and customized experiences for tourists. Therefore, the main attributes of a smart tourism experience differ from those of a traditional experience in the sense that the gap in the literature focuses on ignoring negative experiences and uncritically taking over the tourist experience with ICT tools. The excessive use of technology can reduce the quality of the travel experience, creating obstacles to escape from reality and "momentary mental absence" by communicating in an online environment. Visitors' intention to preserve memories via mobile devices can prevent them from recalling the experience itself. Furthermore, hyper-connectedness and sharing of experiences can be detrimental to tourist enjoyment point out several negative emotions, such as potential cognitive overload, and new concepts such as technostress or technology stress and the need for digital detoxification, and disengagement also emerged. The issue of creating a concept of STT relationship based on the application of intelligent solutions that influence the tourist experience is considered crucial. It represents a set of sensations, experiences and emotions subjectively perceived by tourists and the time frame of experiences with respect to travel is reserved for the period before, during and after the trip. The beginning of personal experiences selectively create which are positively remembered after the event occurred. The operationalization of experiences considers the dimensions of passive engagement in the content offer, from entertainment to aesthetics and to education, escapism of active engagement. Moreover, the experience is not limited to staying at the destination. Experiences influence tourist behavior, such as revisit intention, and shape destination marketing. The smart tourism experience refers to the use of advanced digital technologies to improve the quality and personalization of the travel experience. These include tailoring tourism services based on the individual needs and preferences of tourists, using real-time information to improve decision-making, and enabling interaction with the tourism environment through mobile devices and other digitalmeans. Essentially, the use of technology seeks to create more engaging, efficient, and personalized experiences for tourists.

5. KEY METRICS IN ASSESSING CX IN TRAVEL

According to Forbes Business Council , creating unique and more personalized experiences for tourists is enabled by ICT tooling and the application of modern related tools in value delivery relies on the following:

Scores Satisfaction Levels: User satisfaction measured through post-trip surveys or feedback forms provides insight into the overall experience. By assessing satisfaction levels across different user touchpoints, researchers can identify areas for improvement and prioritize improvements to improve the overall user experience.

Task Completion Rate: Improve the efficiency and effectiveness of different travel platforms by assessing the success rate of user tasks, such as booking flights, accommodations, or activities. Analyzing task completion rates and identifying bottlenecks would help researchers streamline processes and optimize user journeys.

Task Completion Time: Track the time it takes users to complete tasks to gain insight into the efficiency of travel platforms. Use intuitive design and processes to ensure that task completion times are reduced.

Customer Loyalty: Customer retention rates and loyalty metrics such as repeat bookings indicate the long-term impact of customer experience on customer engagement and brand loyalty. It is important to foster positive experiences and emotional connections with customers so that companies can build a loyal customer base in a competitive travel market.

The most important step is to have well-disciplined operational processes to determine whether you are delivering value to your customers. The main issues related to value delivery are based on the internal readiness to understand the organizational culture that enables to use the full potential as accepted proposed solutions in the form of: a) joint measurement and review of business results, b) open proposals of conceptual solutions. Companies that prioritize measuring and improving satisfaction, in addition to profitability, promote trust and reliability, and improved loyalty to the product and organization. Organizations can gain valuable insight into the needs and preferences of their customers and take proactive measures to improve their overall experience.

Accordingly, next table shows key priorities and following activities:

Key priorities	Activities
1. Collecting customer feedback	1. Collecting customer feedback is an effective step in measuring and improving customer satisfaction and retention rates
2. Meet potential clients 3. Know your customers	Through user interviews that are an opportunity to uncover nuanced insights that quantitative data can overlook for understanding the user experience
4. Use the Pareto principle	Optimization of activities by applying the use of qualitative and quantitative methods.
5. Provide customers with unique, timely service and understand the right metrics	When it comes to increasing new sales, improving customer retention or reducing costs, Usability testing is essential to improve, and ultimately improve, the overall user experience.

Communicate with your clients and initiate recommendations, leverage insights from surveys	To measure and improve customer satisfaction and retention rates is to maintain open communication with your customer base. Incentives in building a stronger relationship with them to measure customer retention
Conduct strategic planning and development	To gain insight into feedback, retrieve more relevant data that can be examined - Ryan Godinho, Specialty Batch Coffee.
8. Word of mouth is one of the most cost-effective forms of advertising and a valuable tool.	Sharing personal experiences with friends and family members not only goes beyond a simple recommendation, but creates a strong, personal connection that has a major impact on the decisions of others. Kimberly Branham-Nelson, Nelson and Associates Insurance
9. Analyze drivers of dissatisfaction	Analyze results to identify areas for improvement and take action to resolve issues. This helps improve customer experience and increase loyalty and retention. Mark Snell, Polestar Plumbing, Heating & Air Conditioning
10. Conduct regular customer surveys	The aim is to achieve an effective step in measuring and improving customer satisfaction and retention rates based on clear questions easy to complete, usage of representative sample

Source: Forbes Business Council. Brabham Nielson K. Expert Panel: 15 Effective Ways to Improve Customer Satisfaction and Retention Available at: Kimberly Branham-Nelson | Chief Executive Officer - Nelson and Associates Insurance | Forbes Business Council. Retrieved December 20 2024

6. CONCLUSION

Customer experiences simplify the complexity involved in gaining and understanding insights into the travel market. Primary research methods are essential for brands to gain valuable insights into the needs, preferences, and behaviors of their target audiences. These insights, in turn, drive innovation, differentiation, and customer satisfaction in an already saturated travel space, built on expectations that are constantly evolving along with the research industry. CX research serves as one of the most advanced ways to understand travel and build a successful business system. Cultural acceptance of digital transformation is the biggest challenge most organizations face, and competencies and demand intelligence raise the bar. Successful digital transformation fosters transparency and supports open communication, a level of job accountability, and investment in employee skills needed to professionally communicate with consumers in response to sophisticated and specific consumer demands and expectations. High expectations put pressure on the offer in creating and delivering value. Ubiquitous tools as technological solutions in organizational communication increase market competitiveness.

The emphasis is on greater clarity, privacy and security, and the complementarity of digital technologies in communication is primarily reflected in the creation of additional space for assessing the performance of information quality, transparency, comparison possibilities and, accordingly, the delivery of expected service values, as numerous studies show.

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COMPARATIVE ANALYSIS OF PROS AND CONS OF MARKET-BASED AND BANK-BASED FINANCIAL SYSTEM IN THE LIGHTS OF THE FUTURE OF EUROPEAN COMPETITIVENESS

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ABSTRACT

This paper analyses the comparative advantages and disadvantages of market-based and bank-based financial systems, emphasising their implications for the future competitiveness of the European Union. Market-based financial systems, characterised by a reliance on capital markets for funding, offer benefits such as enhanced liquidity, better access to diverse financing options, and increased transparency. These features can enhance the EU single market by effectively directing substantial household savings into cross-border investments, lowering financing costs for businesses, and boosting the wealth of EU households. However, they also present challenges, including volatility and vulnerability to market fluctuations, which can weaken financial stability. Conversely, bank-based financial systems emphasise the role of banks as intermediaries in channelling funds from savers to borrowers. This model provides stability and a more predictable funding environment, enabling long-term investments in critical sectors. Nonetheless, it may restrain competition and limit access to finance for smaller enterprises, potentially hampering innovation and economic diversification. As the European Union struggles with economic uncertainties and seeks to enhance its global competitiveness, contemplating these contrasting financial systems is beneficial. The ongoing integration of European markets and the push for digital finance further complicate this landscape. Policymakers must weigh the benefits of fostering a robust capital market against the need for a stable banking sector that supports sustainable growth and financial stability. This analysis highlights the necessity for a balanced approach, integrating the strengths of both systems to build a resilient financial framework that can adapt to future challenges. Ultimately, the effectiveness of EU's financial structure will significantly influence its ability to compete in an interconnected global economy encumbered by geopolitical uncertainties.

Keywords: *market-based financial systems; bank-based financial systems; innovation, competitiveness, EU*

1. INTRODUCTION

The existence of financial systems enables the functioning of trade in any modern form. Through their development, more of the gains from regional and international trade can be captured, including the benefits from risk-sharing, diversification, insurance, intertemporal smoothing, efficient investment allocation and larger investment opportunities (Allen & Gale, 2001); as they can efficiently select the most productive recipients for available resources and

ensure their allocation for use in high return activities while monitoring the process to confirm that the capital is being used in an efficient manner. Four approaches have been developed for analysing financial systems: institutional, intermediation, functional, and systematic (Schmidt & Tyrell, 2003). The first three provide useful insights for comparative analysis, while the systematic approach focuses on the relationships among the components of a financial system, employing the concepts of complementarity and consistency. Complementarity indicates how well the elements of a financial system fit together optimally, while consistency describes the extent to which the system approaches its potential. This approach enhances understanding of financial system functions and mechanisms, highlighting key differences between systems and their potential fundamental changes (Schmidt & Hryckiewicz, 2006). Demirgüç-Kunt and Levine (1999) studied financial systems in approximately 150 countries from the early 1960s to the late 1990s to identify trends and correlations between financial system development and economic growth. They categorised financial systems as underdeveloped, bank-based, and market-based. It is noted that many underdeveloped countries tend to have bank-based systems, as the developed non-banking financial sector is typically a characteristic of wealthier nations. Several common features and trends were identified in financial systems: firstly, financial systems are more developed in wealthier countries, where higher per capita income correlates with larger, more active, and efficient financial systems. Secondly, as economic prosperity increases, capital market activity becomes more pronounced, although the share of banks does not necessarily increase or may even decrease, depending on the size of the domestic capital market. In wealthier nations, the non-banking financial intermediation sector, which includes insurance companies, pension funds, and investment funds, is more prominent. According to Allen and Gale (2001), the US serves as a key example of a market-based financial system, where financial markets and the banking system developed simultaneously, while Germany exemplifies a bank-based system, where banks are the primary source of external financing for companies. The UK and Japan are also notable examples. Although some argue that financial crisis management had an impact, it is widely agreed that the timing of industrialisation significantly shaped modern financial systems. Countries like the UK, which industrialised early, enjoyed abundant capital and developed financial markets, making market financing viable. This facilitated the financial growth of companies, technological innovation, and economic expansion. In contrast, 'moderately backward' economies in north-western Europe, where industrialisation occurred later, relied primarily on bank financing to compete with the UK's advanced progress. In Germany, for instance, where financial capital was limited, bank financing became the only realistic option for businesses striving to catch up. Levine (2002, 1997) downplays the debate over which financial system is superior and focuses instead on the quality of financial services within the broader financial framework. He asserts that a conducive business environment, characterised by effective financial intermediaries and markets, is crucial for optimising financial services. Research indicates that industries reliant on external financing tend to grow faster in countries with advanced financial systems and efficient legal frameworks. Thus, the key to effective capital allocation and industrial development lies not in the type of financial system but in the overall level of financial development and the legal environment that supports it. This paper aims to examine the relative strengths and weaknesses of market-based versus bank-based financial systems, highlighting their potential impact on the future competitiveness of the European Union. Ultimately, it supports a balanced strategy that combines the advantages of both systems to create a robust financial framework capable of adapting to upcoming economic and geopolitical challenges. The foundation of this paper's research was based on a qualitative analysis that involved in-depth examination of secondary sources. The paper is organised as follows: the introduction provides a comprehensive overview

of the various analyses conducted on financial systems, establishing a foundational context for the discussions that will follow. In section two, there is an in-depth exploration of the comparative aspects of market-based and bank-based systems, examining their respective characteristics and implications in detail. Section three outlines the strategic policy of the European Union concerning the EU single market and the Capital Markets Union, highlighting its importance in fostering economic growth. Moving on to section four, the discussion focuses on the new initiatives and strategies that are being implemented with the aim of enhancing the competitiveness of the European Union in a rapidly evolving global environment. Finally, section five delivers the conclusion, which summarises the key findings.

2. COMPARATIVE OVERVIEW OF FINANCIAL SYSTEMS

Market-based financial systems

In this type of system, the main source of external financing for companies is acquired through capital markets via stock and bond issues and it is also where households also place a large part of their savings through non-bank financial intermediaries. Banks are functionally specialised in either investment or commercial banking activities and institution-client relationships are best described as arm-length and short-term. As a result, banks do not acquire large amounts of information about companies and selected information is rather made public and collected through the market which results in a prevalent free-rider problem. Consequently, there is no need for banks to engage in an active way in corporate governance making market-based financial systems shareholder-oriented; and therefore, don't intervene in case of serious financial difficulties for the additional reason that their countries courts have generally penalised banks which have engaged in that practice. In Anglo-American countries it is by law forbidden for banks to intervene in an insider role during times of turmoil for companies and the US goes a step further by penalising informal workout agreements (Frankel et al., 1991). This system type also allows for funds to be more quickly channelled towards companies since they don't have to go through the rigorous process of getting bank funding. Naturally the goal is to eliminate capital market imperfections and perfect the allocation system, consequently developing strict accounting regulations and prohibitions on insider trading, market manipulations, anti-competitive behaviour, and on true universal banking. Additionally, whilst having better cross-sectional risk sharing which enables higher returns because it allows for riskier investments, which can adversely make it more vulnerable to shocks and financial crisis in number and severity (Katušić, 2024).

The United Kingdom

Financial markets and instruments were more refined in the UK than in other countries in the 19th century and their quality and success achieved was attributed to allowing non-wealthy talented individuals to become entrepreneurs. (Schmidt & Hryckiewicz, 2006) Most chose to attain financing by self-funding or from securities issued in financial markets. An additional reason was that smaller companies at the time couldn't afford the capital needed for commercial banks which in turn established short-term lending as the preferred type of relationship between banks and companies and was solidified by the tries of banks during the 19th century to finance industry which led to failure of such companies during liquidity crisis.

The United States

Originally the American banking system was organised similarly to the UKs which quickly proved itself to be inoperative due to the strong mistrust towards powerful institutions with large concentrations of power, ascribable to their shared history. Attempts at recharting proved

unsuccessful as inclination towards the decentralisation of the banking system grew. Even with multiple attempts at restructuring banking panics ensued and the US banking system was considered a malfunction and its economy known for disruptions and depressions. To better illustrate the severity of the situation in the US, during the pre-recession period and during the first four year of the Great approximately more than 17,000 banks closed. (Encyclopedia Britannica, 2024) Such a devastating situation led to the creation of two important reforms which finally remedied this situation - the Banking Acts of 1933 and 1935. The Glass-Steagall Act of 1933 introduced alongside deposit insurance, the legal separation of commercial and investment banking, with the argument based on the belief that lending and equity investing leads to conflict of interest as a bank with equity in another company cannot decide about its creditworthiness in an objective manor. (Frankel et al., 1991) The second Banking Act augmented the operating system of the US central bank - the Federal Reserve and expanded its powers, and with this reconstruction stabilisation was starting to show.

The Anglo-American model of corporate governance

The US model and the UK model for corporate governance follow the "Anglo-American" model and its shareholder theory - that the role of public companies is to maximise the profit of those who hold parts of it in the form of shares of stock. This is a result of their financial systems being market-based. "Capital will be allocated in the financial market when optimal decision rules are hard to formulate, and there is little consensus on how the firm should be run; for example, when information decays rapidly and "new information arrives almost constantly. In contrast, banks are desirable institutions for allocating resources in situations in which there is consensus on decision making, and the main problem is monitoring firms." Simply, whilst banks provide a 'single check' the financial market provides 'multiple checks' through a variety of mechanisms - market prices, trading volume, takeover attempts, etc (Thakor, 1996). The feedback role of the financial market is invaluable because it can present information which can't be find on summary reports and may present one of the reasons it led to the adoption of market-based systems. A company's stock prices movement can also signal the effectiveness of managerial performance which in turn affects decision making and holds its managers accountable.

Bank-based financial systems

This type of system is described an intermediary based financial system in which liquidity creation is mainly directed through universally structured banks which play the dominant role in external financing for companies with which they form close long-lasting relationships. Most have their "house bank" so they play an active role in the governance of a pluralistic and stakeholder-oriented system of corporate governance even in non-financial companies. This enables them to accumulate large amounts of information about their current and potential clients and gives them the ability to serve as an effective monitor of corporate activities. The former allows them to intervene and help their client companies recover from financial difficulties they encounter to further elevate their own reputation as being capable in devising successful (mostly informal) arrangements for leading companies and attract promising new clients that way. In Germany and Japan not only have the courts protected banks in such endeavours, but have done so at the expense of other creditors. These arrangements are invaluable for companies based in these systems as, for example, if a company in Germany manages to go bankrupt the owners will be stigmatised by and meet significant resistance going forward in attaining new bank loans for business ventures. The objective of the bank-based systems is perfecting corporate governance, reduction of occurrences of financial crises and the

costs of financial distress in general and also aiming to improve coordinative efficiency. On the grounds of focusing more on the banking system instead of markets the outcome is vague laws on accounting, market manipulations, and the extent of banking functions. The result is a system with a better resistance to systematic financial shocks due to its better intertemporal risk sharing abilities and an emphasis on acquiring profit through long-term investments. It is of note that the mere fact of having developed and efficient markets doesn't negate the systems bank-based status. (Schmidt & Hryckiewicz, 2006)

Germany

The use of German financial markets was limited to forms of governmental debt and loans to other states and even with the attempts of utilising markets in financing the industry, nothing significant changed after managing to partly finance the railway system. (Allen & Gale, 2001) Financial markets remained unimportant and few companies were publicly listed which didn't drastically change till today. One of the reasons for that is the belief that with the underdevelopment of markets it is not significantly beneficial to try when enough finances can be procured otherwise. This became a cycle that proved itself hard to break. Thusly banks became the main revenue for external financing and universal banks developed. The variety of services provided by such banks can be assigned as the reason for their formation of long-lasting relationships with their clients which in turn assisted with efficient resource allocation. To continuously facilitate this arrangement, through their collection of large amounts of information about their clients, banks intervened and helped their client-companies out of financially troubling times. Even though some companies in areas such as steel and coal turned away from close relationships with banks, most industry companies collaborated to such a degree that banks and companies were represented on each other's boards. This kind of close relationships led to the formation of the "Hausbank" system – forming of a close long-lasting relationship between a company and one or two banks as sources of external financing.

Japan

The development of Japan's financial systems was in large part intentional as with the efforts during several wars and the rebuilding after, the government played a direct part in shaping the entire financial system. After the Meiji Restoration the decision was made to integrate western types of financial institutions as a way to modernize the country after more than two hundred years of isolation. The implemented liberal approach proved unsuccessful as repetitional banking crises which intensity progressively increased and after three major panics in the 1920s the prototype of a main bank system was introduced. As the excessive number of banks was seen as the main contributor to the crises banks were given monopoly in a particular area to effectively reduce the number of banks through mergers (Allen & Gale, 2001). There was an attempt at a significant financial reconstruction right after World War II. The General Headquarters of the Allied Powers tried to introduce a United States style of securities markets that would serve as the source of long-term financing and banks would be mainly providing short-term loans. This proved not to be a real possibility as the banking system in place attested itself to be too deeply rooted, as strong long-term client-bank relationships have been established during wartime and with additional post-war regulations, a main bank system was firmly in place.

The German and Japan models of corporate governance

The German corporate governance model contrasts the Anglo-American on multiple fronts. Firstly, a free-rider problem is not as prevalent as information doesn't need to be publicised to the same degree due to two reasons. The companies don't have to work as hard to attract new

investors since they typically have a bank as a long-term investor which can intervene in case of financial difficulties. The stakeholder model helps to bridge the divergent interests of shareholders and others affected by the company's performance. It can be said that a shareholder's interest is short term and of the other stakeholders is long term, so to bridge that gap, stakeholders' interest are translated to mean the company's interest as a legal person – what is best for the company is at the same time best for its stakeholders. Japan's corporate governance model is very similar to the German model with the most significant distinction being that Japanese companies form "keiretsu" alliances or enterprise groups composed of companies in various industries where all have partial ownership in each other and all rely on the financing of a large main bank (Douthett et al., 2004). The idea behind these cross-shareholding arrangements is that in theory it provides additional support and monitoring, helping them maintain stable profit and with that interest of all their stakeholders.

3. THE EUROPEAN SINGLE MARKET

The European Union even though an example of a strong bank-based system developed its single market to the degree that it serves as the world's biggest barrier-free, economic area that includes almost 450 million people with a gross domestic product of about €14.5 trillion (in 2021) and it is estimated that it has created 2.8 million jobs. The EU became a leading trading partner for 80 countries and its now one of the largest players in international trade due to its numerous trade agreements. It is the world's second largest exporter of goods after China and the third largest importer after the US and China. In addition, the EU is the number one trader of services (European Parliament, 2023). However, the EU experiences a significant problem, lower economic growth than theoretically possible attributable partly to the bank-market ratio being significantly tilted towards the banking system. It can be argued that this is to be expected when compared a market-based country but that stays the case even when compared other examples of bank-based countries, like Japan. The question is how has this happened? Banks are historically conservative in choosing which projects and companies to fund and that is why they ex ante acquire large amounts of information of about their possible clients. Granting, information collecting activities of banks eliminate some problems of market-based systems, namely information asymmetry and free-riding; however, this creates a problem of its own – this kind of advantage allows banks to lay claims to a substantial part of their client-company's profits which in turn hinders their motivation to perform. Rajan (1992) has addressed this and explained that if the client can partly fund themselves through the market, that creates external competition and mitigates the banks bargaining power. This would not present such a substantial problem if other avenues of financing would be more accessible, but the problem is, capital markets in the EU are underdeveloped, making market funding unattainable for most companies especially small and medium (Langfield & Pagano, 2015); which brings the EU to a position similar to Germany in the 19th century – since capital markets are underdeveloped and there is a need to keep up with other developed economies, external financing must be done through the banking system. Brexit was certainly a consequential issue for the continued development of EUs capital markets since the financial centres in London played a significant role within the EU financial system as the London-based capital markets and financial institutions account also for a notable part in the global finances. Financial centres, like the London one, are a result of its historical development which helped it gain its todays comparative advantage and economic clusters (International Monetary Fund, 2023). Whilst this is naturally harder to replicate, factors like the taxing system and regulatory requirements are incredibly important and offer insight to the changes needed to be implemented to develop the weaker financial markets.

The Capital Markets Union

After the Banking Union became operational in 2014 the Five Presidents' Report of 22 June 2015 presented the plan for the deeper integration of the Economic and Monetary Union (EMU). Four goals were highlighted: a genuine Economic Union, a Financial Union, a Fiscal Union and a Political Union. As means to achieve the Financial Union, the completion of the Banking Union and the Capital Markets Union (CMU) were named as a priority as both banks and capital markets are complementing vital parts of the financial system. The CMU is envisioned in a three-pillar form: first, EU Single Market, second, clear and simple rules and third, effective supervision (European Commission, 2019). Strong capital markets would act as a complementary to the already strong banking system of the EU and would thus diversify the available sources of external funding. This would act as a turning point and allow small and medium enterprises (SMEs) to get easier access to financing and mitigate the aforementioned problem of the bargaining power of banks. Consequently, it would help SMEs to expand and to create new job opportunities whilst providing households with better opportunities regarding their saving and investments allowing their decisions to the result of a competitive choice (European Commission, 2020). By integrating into a single capital market across the EU and removing all implicit and explicit borders and developing equity markets, risk sharing will improve allowing Member States to share the impacts of financial shocks (European Commission, 2015). With these conditions' competitiveness will increase and with it financial innovations which lead to the emergence of new markets (Thakor, 1996) further diversifying sources of funding, which in turn deepens the financial integration, lowers costs and elevates the position of the EU on the global market.

Action plans – 2015 & 2020

After the Five Presidents' Report the European Commission published the five-year 2015 CMU action plan and followed it with a progress report March 15 2019 in preparation for the new action plan. In that time, two important plans have been made as part of building the CMU - the action plan on sustainable finance and the FinTech action plan; regulations have been adopted on the topics of securitisation, the prospectus and European venture capital funds; the European Parliament and the Council of the EU have reached political agreements on several subjects. While market capitalisation of listed companies showed to be above pre-crisis level (2008), initial public offerings have not significantly changed, listed equity of non-financial companies has from 2014 to 2018 increased by 5%, debt securities by 2% and the cross-border distribution of investment funds has shown steady growth. Member States and stakeholders could be involved to a higher degree and national measures need to be refined. To continue the work on building the CMU with the additional task of supporting market recovery after the COVID-19 crisis, the European Commission adopted on 24 September 2020 a new action plan, based on three main objectives and their 16 legislative and non-legislative actions: (1) making financing more accessible for EU-based companies and with that support a green, digital, inclusive and resilient economic recovery (making companies more visible to cross-border investors, supporting access to public markets and vehicles for long-term investment, encouraging more long-term and equity financing from institutional investors, directing SMEs to alternative providers of funding, helping banks to lend more to the real economy), (2) working on ensuring that the EU stays a safe place for savings and long-term investments of individuals (empowering citizens through improving their financial literacy, building retail investors' trust in capital markets, supporting people in their retirement) and (3) integrating national capital markets and thus establishing the EU single market (alleviation of the tax associated burden in cross-border investment, securing the predictability of cross-border

investment as regards insolvency proceedings, facilitating shareholder engagement, developing cross-border settlement services, consolidated tape, investment protection and facilitation and supervision). The reports in anticipation of the 2020 action plan as well as European Court of Auditors and the Council of the EU have noted that a need exists to establish clearly defined and propriate indicators to monitor the progress of accomplishing the objectives of the CMU. In line with that, the European Commission has on 9 June 2021 (corrected version of 14 July 2021 currently published) drafted up a Commission Staff Working Document which introduced and explained the indicators it has adopted. The effects of individual measures are now also tracked and considered under the overall CMU plans. The indicators serve three purposes: 1) monitoring the progress made towards the CMU objectives, 2) providing a framework and an empirical basis for the analysis of capital market development and of the overall impact of past CMU measures and 3) pointing out areas that need to be newly regulated or existing policies need to be adjusted.

4. CAPITAL MARKETS UNION – MOVING FOWARD

The European Commission has made significant strides towards establishing a Capital Markets Union (CMU) through the release of two comprehensive packages in 2021 and 2022. The first package introduced pivotal legislative initiatives, including the European Single Access Point (ESAP), reviews of the European Long-Term Investment Funds (ELTIFs), and updates to the Alternative Investment Fund Managers Directive (AIFMD), alongside revisions to the Markets in Financial Instruments Regulation (MiFIR) and Directive (MiFID II). These measures were designed to stimulate a sustainable economic recovery, foster long-term savings and investments, and create a cohesive European capital market. The subsequent package prioritised enhancements to EU clearing services, harmonisation of insolvency laws for cross-border investments, and the establishment of listing rules for small and medium-sized enterprises (SMEs), further reflecting the Commission's commitment to a unified financial landscape (European Commission, 2021a & 2022). Moving into 2023 and early 2024, the Eurogroup initiated a strategic effort to align EU finance ministers on essential priorities for advancing capital markets. An integrated European capital market presents numerous advantages: it could bolster funding for innovation and growth, facilitate green and digital transitions, enhance resilience and risk-sharing across Member States, reduce financing costs for businesses, and expand investment options and returns for savers (Eurogroup, 2024). Despite these promising initiatives, the current state of EU capital markets remains suboptimal. The Eurofi Report (Truchet, 2023, p. 35-39) highlights several challenges, including fragmentation, reduced liquidity, and limited investor participation which impede growth and development. As of the end of 2021, EU capital markets were only about half the size of their US counterparts in relation to GDP, with total EU27 debt securities and public equity markets representing 233% of GDP, compared to 449% for the US. The relative immaturity of EU capital markets can be attributed to lower liquidity, competitiveness, and a scarcity of venture capital and private equity funding. Furthermore, regional disparities are pronounced; while the Nordic countries boast relatively developed capital markets (approximately 360% of GDP), Southern European countries and Central and Eastern Europe (CEE) exhibit markedly lower levels of market capitalisation, with equity markets in CEE being nearly non-existent and Southern Europe facing similar limitations. The decline in securitisation issuance and the low participation of households and non-financial companies in capital markets—where only 32% of EU households' financial assets are held in securities compared to 51% in the US—exacerbate these issues (Mack & Lindner, 2024).

The urgency of addressing these challenges is underscored in a recent report by former ECB President Mario Draghi (2024), which emphasises the critical need for advancing the Capital Markets Union. The report indicates that Europe has not fully harnessed its potential to create a robust financing ecosystem for high-growth companies, particularly start-ups and scale-ups. The inadequacy of a cohesive capital market structure has driven many innovative firms to seek funding outside the EU, primarily from US venture capitalists, which undermines local growth and dynamism within the EU market. Currently, the EU captures only about 5% of global venture capital funds raised, in stark contrast to the US's 52% (ibid., p. 29). This disparity accentuates the need for a concerted strategy to develop a more integrated and efficient capital market framework. To tackle these issues, the report suggests establishing a unified capital markets framework that channels high household savings into productive investments. Recommendations include enhancing the CMU to create a more streamlined and accessible funding environment for innovative businesses, transforming the European Securities and Markets Authority (ESMA) into a common regulator for all EU securities markets, similar to the US Securities and Exchange Commission (ibid., p. 65). Additionally, harmonising insolvency frameworks and mitigating taxation obstacles to cross-border investing are essential steps towards centralising clearing and settlement processes. These measures would simplify access to finance and contribute to a deeper, more liquid market for EU bonds, which is crucial for financing joint investment initiatives aimed at promoting innovation. Furthermore, a more developed capital market can play a pivotal role in closing the innovation gap by providing necessary financial resources for disruptive technologies and high-risk projects. Given that the EU's public spending on research and innovation significantly lags behind that of the US, strengthening capital markets to encourage private investment is imperative. The report advocates for issuing common safe assets to fund critical public goods, such as research initiatives and defence procurement, which typically suffer from underfunding without coordinated action. By establishing a common financial instrument that serves as a reliable benchmark, the EU can enhance the allure of its markets for both domestic and international investors, thereby stimulating further innovation and growth. In summary, the advancement of European capital markets is both a financial necessity and a strategic imperative for fostering innovation and maintaining competitiveness in an increasingly global economy. By developing a unified and efficient capital market structure, the EU can better leverage its collective resources, attract investment, and empower its innovative companies to scale effectively within the region. This strategy will enable Europe to keep pace with global innovation trends, ensuring economic resilience and leadership in key sectors.

5. CONCLUSION

In examining the comparative advantages and disadvantages of market-based and bank-based financial systems, this paper clarifies their implications for the future competitiveness of the European Union. The analysis revealed that market-based financial systems, e.g. the United States or the United Kingdom, can bring benefits of the economy, like enhanced innovation and more financing options. They also carry the risks of volatility and market fluctuations. On the other hand, bank-based systems, such as those prevalent in Germany and Japan, offer stability and predictable funding environments, which are essential for long-term investments. Nevertheless, these systems can supress competition and limit access to finance for smaller enterprises, thereby hindering innovation and economic diversification. As the European Union navigates economic uncertainties, it is evident that a balanced approach, leveraging the strengths of both financial systems, is crucial for creating an adaptable and resilient financial framework that can thrive amidst global challenges.

The EU's financial system is inclined towards bank-based system. Even though the EU has significant economic potential, it has been struggling with slow growth, primarily due to the underdevelopment of capital markets. This situation is similar to German economic situation in the 19th century, where a reliance on banks for external financing limited opportunities for innovation and growth. The findings suggest that enhancing the competitiveness of the EU necessitates a concerted effort to develop a robust Capital Markets Union. This initiative aims to diversify funding sources, thereby reducing the banking system's dominance and enabling SMEs to access financing more readily. By integrating capital markets across Member States, the EU can foster risk-sharing and create a more dynamic economic environment conducive to growth. Moving forward, the successful realisation of the CMU is imperative for the European Union to maintain its competitiveness in an increasingly interconnected global economy. Recent initiatives, such as the 2021 and 2022 legislative packages aimed at enhancing the EU's capital markets, lay a foundation for this transformation. However, the implementation of strategic policies should also focus on addressing challenges such as fragmentation, limited liquidity, and the relatively low participation of households and non-financial companies in capital markets. It is vital to promote a cohesive and efficient capital market framework that enables the EU to channel its collective resources effectively, attract investment, and empower innovative firms. Incorporating this strategic direction will not only bolster the EU's economic resilience but also enhance its status as a key player in global innovation and competitiveness. Ultimately, the integration of market-based mechanisms alongside the stability offered by bank-based systems could pave the way for a more vibrant European economy, capable of confronting the complexities of the future with confidence and agility.

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STATUTORY INTEREST IN HIGH-INFLATION ECONOMIES: RETHINKING METHODOLOGIES THROUGH FINANCIAL VALUATION PRINCIPLES

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ABSTRACT

In business, every company does business with other businesses and at some point payment delays occur, putting businesses at risk of running into cash shortages or depleting their working capital, which is especially the case in times of high inflation. Such situations are difficult to reduce to the application of statutory interest rates, which are often credit-friendly and at odds with economic reality. In the case of late payments, the legal position is clear: the creditor is entitled to statutory interest rate for late payment, i.e. interest or costs for keeping the money owed to him and at the same time an incentive for the debtor to pay his debt. This paper examines the limitations of current methods of calculating statutory interest and in the context of Directive 2011/7/EU on combating late payment in commercial transactions, which aims to help normalize and harmonize commercial practices. The methodology includes a comparison of the statutory interest provisions of all EU member states to determine which provisions and practices are most advisable and which gaps in the rules exist. In addition, a case study is presented on Croatia, a country that has struggled with inflationary pressures during its economic transition. The results show that there is a need to develop a static model for the statutory interest rate that captures real economic realities and is applicable in both cash and accrual systems while ensuring fairness in business transactions. Practical implications for policy makers, financial institutions and regulators arise from the proposed dynamic approach, which varies with inflation across the EU. It is an approach that aims to improve the stability of the financial system and the economic fairness of outcomes in the presence of high inflation.

Keywords: *Directive 2011/7/EU, Inflation, Statutory interest*

1. INTRODUCTION

Sometimes the company may be exposed to the risk of illiquidity or even a liquidity disruption, even in times of high inflation (Visconti, 2011). Such situations pose a significant problem for the application of statutory interest rates, which very often lead to a discrepancy between the compensation received by the creditor and the actual situation on the market. In the event of late payments, creditors are entitled to statutory interest to compensate them for the loss suffered and to encourage debtors to pay their debts as they fall due. This paper examines the limitations of current methods of calculating statutory interest with particular reference to Directive 2011/7/EU of the European Parliament and of the Council of 16 February 2011 on the protection of consumers in respect of certain aspects of contracts for the standardization and improvement of commercial practices in relation to the sale of financial services. To achieve this, the new study compares the statutory interest rate provisions of the EU member states and identifies the most effective statistical loopholes that Croatia has with the current systems. Experience with economic transitions and inflationary pressures.

The results show that the existing model of statutory interest rates is tedious and should be replaced by a model that takes inflation into account. real Based on the economic environment and the results, the authors recommend a modified dynamic approach to the calculation of statutory interest rates that would allow EU policy makers, financial institutions and regulators to adjust the statutory interest rate rules to inflation levels in order to preserve the stability of the financial system and the fairness of the contract. (DeAngelo and Masulis, 1980) (Modigliani and Cohn, 1979) (Visconti, 2011) (Parnaudeau, 2008)

2. STATUTORY INTEREST AND ITS PURPOSE

The available literature examines the overall implications of inflation on corporate governance and financial practices. The importance of strong monitoring and robust contractual design has also been preposed in order to mitigate inflation risk, along with the use of appropriate and flexible financial modelling (Visconti, 2011). While surveys have revealed the occurrence of late payment problems and possible causes, there has been scarce empirical investigation of firms' payment decision-making processes, namely, qualitative and quantitative approaches (Howorth and Wilson, 1998). Statutory interest acts as a discursive device to prevent late payments, hence, encouraging borrowers to pay their moneyback as soon as possible. It is its main function to provide compensation to the creditors for the financial loss that results from the delay in the payment. These losses may include:

1. Loss of Interest Income: When a borrower defaults on a loan, the lender is denied the opportunity to earn interest on the principal amount for the duration of the default period, which is a direct financial cost (Gunnarsson, 2017).
2. Increased Risk of Non-Payment: which The can defaulting result customers in increase significant the financial risk loss. of This the increased lender default losing risk the makes amount it borrowed difficult from for them the in lender full, to manage their credit portfolio effectively (Guttentag and Herring, 1984).
3. Administrative Costs: Lenders also have other costs of doing business, which include the costs of dealing with delinquent accounts, such as the cost of legal services, collection services and write off, which reduce the lender's revenue (Aguilar et al., 2018).

On the one hand, statutory interest also serves the purpose of:

1. Encouraging Timely Repayment: Imposing a financial penalty through statutory interest is, therefore, intended to encourage borrowers to stick to the scheduled repayment plan so as to maintain the stability of the lending market (Zhao, 2019).
2. Reflecting Risk: The rate of statutory interest is usually a function of the risk type of the borrower or the type of loan, which allows the lender to incorporate risk in the pricing of the credit and, in so doing, enhance the functioning of the credit market (Aguilar et al., 2018).

3. LEGAL FRAMEWORKS GOVERNING STATUTORY INTEREST RATES

The European Directive on combating late payment in commercial transactions has attempted to solve these problems by creating a harmonised framework for statutory interest rates in the EU. However, the effectiveness of this directive has been questioned, particularly in a hyperinflationary environment where traditional interest methods may not be sufficient to

adequately compensate creditors or incentivize prompt repayment (Visconti, 2011). As (Lefebvre, 2023) notes, the benefits of longer payment terms may outweigh the costs of providing trade credit to small and medium-sized enterprises, pointing to the need for a more nuanced approach to statutory interest rates that takes into account the broader economic context. In addition, research has highlighted the impact of inflation on economic margins and cash flow, which are important strategic parameters of a business (Visconti, 2011). According to Directive 2011/7/EU, statutory default interest should be calculated on a daily basis as simple interest in accordance with Council Regulation No. 1182/71 of June 3, 1971 determining the rules applicable to periods, dates and time limits. Late payment means that payment is not made within the contractual or statutory payment period. When calculating the statutory default interest, a rate is used which corresponds to the sum of the reference rate and at least 8 percentage points. The 'reference rate' is one of the following rates: for a Member State whose currency is the euro, the rate applied by the European Central Bank to its last main refinancing operation (Brand, Bielecki and Penalver, 2018) carried out before the first calendar day of the half-year in question, or for a Member State whose currency is not the euro, the corresponding rate set by its national central bank. However, the Directive does not explicitly address how statutory interest rates should be adjusted for inflation, which leaves a gap in the applicability of the Directive in times of high inflation. Sibneschi (2016) distinguishes between conventional and statutory interest rates. Conventional interest rates are agreed by the parties, while legal interest rates are prescribed by regulators. The latter are often inflexible and do not take into account the dynamic nature of economic variables such as inflation. This rigidity undermines the ability of statutory interest rates to provide adequate compensation in times of rapid economic change. Manojlović (2020) also criticises the historical development of statutory interest rates, noting that they are applied inconsistently across jurisdictions. These inconsistencies pose a major challenge for international transactions, especially when different statutory interest rates interact with each other.

3.1. Legal Framework for Calculating Statutory Interest Rates in Croatia

Before Croatia adopted the euro on January 1, 2023, the country's statutory interest regulation was contained in the Obligations Act. This law regulated the way in which creditors were to be compensated in the event of late payment. The statutory interest rate for commercial transactions was calculated according to the following formula Statutory interest rate = reference interest rate + 8 percentage points. A lower margin of 5 percentage points was applied for non-commercial transactions. The semi-annual average interest rate of the Croatian National Bank for loans to non-financial institutions was used as the reference interest rate. This allowed for a consistent approach to late payments, but did not take inflation into account, so it was not very good in conditions of high economic volatility. With Croatia's changeover to the euro on January 1, 2023, the calculation of the statutory interest rate was adapted to the provisions of EU Directive 2011/7/EU, bringing the country's legal framework in line with European standards. The formula for calculating the statutory interest rate remained unchanged, but the reference rate was redefined as the interest rate at which the European Central Bank conducted its last main refinancing operation before the beginning of the half-year in question. This change has ensured that there is no currency risk and that the statutory interest rates are in line with the ECB's other monetary policies.

4. FINANCIAL VALUATION AND THE TIME VALUE OF MONEY

Financial valuation theory refers to the methods used to determine the market value of an asset or a company. There are different methods, and each method has its own advantages and disadvantages. The time value of money is a central idea in many of these methods. This is the idea that money available today is more valuable than the same amount of money available at a later date due to its return potential (Cote, 2022). This concept takes into account the fact that a present amount of money can be invested profitably and is therefore worth more than a future amount. In the context of late payments, the time value of money is important as it determines the amount a creditor should receive for the late receipt of funds.

Normally, the legal interest rate is based on a fixed interest rate that does not fluctuate with changes in the economy. However, in a high inflation environment, the purchasing power of money can be undermined, reducing the value of late payments. This can result in the creditor bearing the loss and not receiving adequate compensation through statutory interest, making statutory interest ineffective in promoting timely payments and ensuring fairness in business transactions. One of the most commonly used valuation methods is discounted cash flow analysis. DCF models estimate value by discounting future cash flows to their present value using a discount rate that reflects the risk of the cash flows. Incidentally, this method recognizes that future cash flows are worth less than current cash flows, which is TVM. DCF analysis is most useful in valuing businesses with predictable cash flows, such as established businesses with relatively stable operations. However, it can be sensitive to assumptions about growth rates and discount rates.

5. METHODOLOGY

This study also took a comprehensive approach to the comparative analysis of statutory interest rate systems in the EU Member States. Secondary sources include European Commission reports, academic studies and industry publications (Howorth and Reber, 2003) (Directive 2011/7/EU) (Howorth and Wilson, 1998) (Lefebvre, 2023). In order to identify the best practices and regulatory gaps that cause current methods to be ineffective for the legal interest, a number of best practices and regulatory gaps were identified by analyzing a variety of secondary data sources. In addition, the study also used secondary data from the Eurostat database to strengthen the analysis. The analysis draws on secondary data from other reputable sources. The monthly harmonized consumer price index (HCIP) for the period from January 2022 to June 2023 was taken from the Eurostat database. The information on statutory interest rates comes from the national central banks and the official reports of the European Commission with a focus on the implementation of Directive 2011/7/EU.

The relevance for the calculation of statutory interest rates and inflation trends in the EU Member States were the criteria for the selection of data. The reports and studies selected for the analysis focused on the regulatory framework with an emphasis on the mechanisms of the statutory interest rate. In addition, the paper includes an in-depth case study on Croatia, the country facing the greatest inflationary pressures in the transition to a new economic model. The case study of this paper offers practical advice and challenges that may arise from the application of statutory interest rate mechanisms in a situation of high inflation.

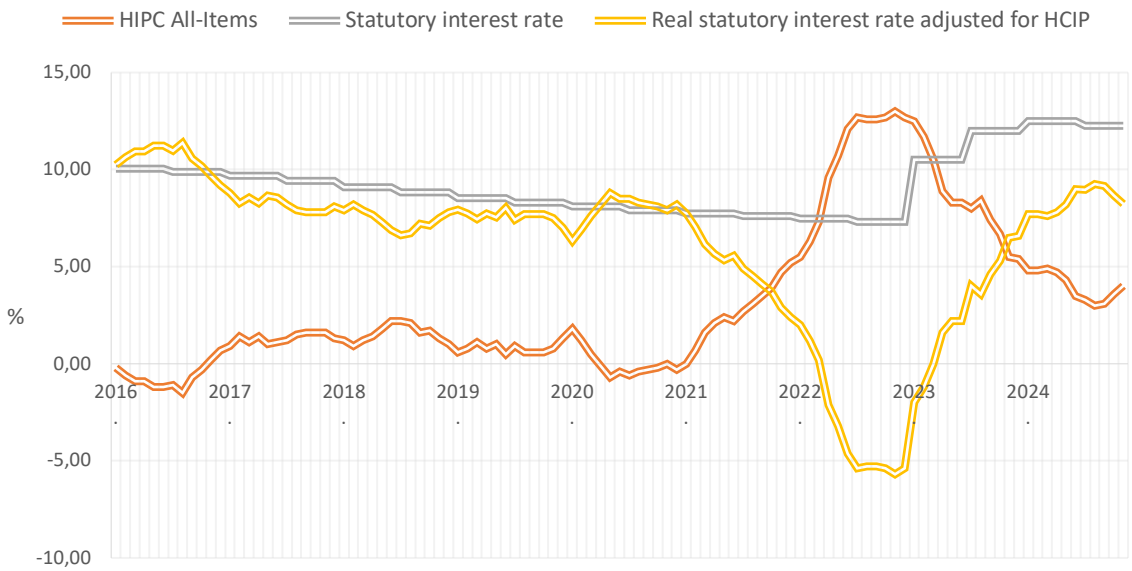

Figure 1. Development of inflation, default interest and the real statutory interest rate in Croatia from 2016 to the end of 2024

(Source: Eurostat, author calculation)

The orange HICP line illustrates the inflation trends in Croatia. It shows a gradual increase before peaking around 2022 and then slowing down. In contrast, the gray statutory interest rate remains relatively stable from 2016 to 2021 and then rises noticeably at the end of 2022 and into 2023. The yellow line, which represents the real statutory interest rate adjusted for the HICP, dips into negative territory when inflation exceeds the statutory interest rate— - a sign of the eroded purchasing power of creditors. When inflation falls and the statutory interest rate rises, the real interest rate moves back into positive territory. Overall, the chart underlines the importance of adjusting statutory interest rates to inflation in order to protect creditors' real assets. To ensure that the results are rigorous and valid, the researcher has incorporated the principles of financial valuation theory in relation to the impact of inflation on real interest rates and creditor compensation. This approach allows for the development of a dynamic, inflation-adjusted model for calculating statutory interest rates that better reflects economic realities.
To take account of changes in the number of days in a month (i.e. 28, 30 or 31 days), the interest rate was adjusted using a formula based on the duration of the month in question.

$$Adjusted\ Real\ Statutory\ Interest\ Rate = \frac{\text{Real statutory Interest x Days in Month}}{365}$$

This approach resulted in a more precise real monthly interest rate and corresponding changes in the principal amounts.

$$Real\ principal\ value = 100\ \text{x}\left(1 + \frac{Adjusted\ Real\ Statutory\ Interest\ Rate}{100}\right)$$

This table provides a detailed analysis of how statutory interest rates and inflation (HCIP - Harmonized Consumer Price Index) affect the real value of a €100 principal over the course of different months, all while considering the number of days in each month. The structured data in the table allows for a more detailed examination of how real statutory interest rates change over time and, in turn, affect financial value.

Time	Days in Month	Statutary Interest (SI) Yearly	HCIP	Real Statutary Interest Adjusted by HCIP	Adjusted Real Statutary Interest Monthly	Real Principal Value
2022-01	31	7,49	5,5	1,99	1,69	101,69
2022-02	28	7,49	6,3	1,19	0,91	100,91
2022-03	31	7,49	7,3	0,19	0,16	100,16
2022-04	30	7,49	9,6	**-2,11**	**-1,74**	**98,26**
2022-05	31	7,49	10,7	**-3,21**	**-2,73**	**97,27**
2022-06	30	7,49	12,1	**-4,61**	**-3,79**	**96,21**
2022-07	31	7,31	12,7	**-5,39**	**-4,58**	**95,42**
2022-08	31	7,31	12,6	**-5,29**	**-4,49**	**95,51**
2022-09	30	7,31	12,6	**-5,29**	**-4,35**	**95,65**
2022-10	31	7,31	12,7	**-5,39**	**-4,58**	**95,42**
2022-11	30	7,31	13	**-5,69**	**-4,68**	**95,32**
2022-12	31	7,31	12,7	**-5,39**	**-4,58**	**95,42**
2023-01	31	10,5	12,5	**-2**	**-1,69**	**98,31**
2023-02	28	10,5	11,7	**-1,2**	**-0,94**	**99,06**
2023-03	31	10,5	10,5	0	0	100
2023-04	30	10,5	8,9	1,6	1,32	101,32
2023-05	31	10,5	8,3	2,2	1,86	101,86
2023-06	30	10,5	8,3	2,2	1,81	101,81

Table 1. Real Adjusted Statutory Interest Rates and Principal Value Dynamics Under Inflationary Conditions
(Source:Eurostat, author calculation)

During the analysis period, the statutory interest rate was constant in certain periods, while the HCIP fluctuated strongly, which led to a dynamic between the two interest rates. The statutory interest rate of 7.49% (5.5%) in and the first of February (6.3%), half of the results 2022 in was positively higher than the real interest rates. HCIP in January, however, 12.7% as in inflation July accelerated 2022), (9.6% it exceeded in April the 2022, legal interest rate, resulting in negative real legal interest rates, which shrank the real value of capital. The gap between the statutory interest rate and the HCIP was 12% and most of the widely observed statutory interest rates between the July rate and only November 7.31%, the 2022 sharply when negative the real

HCIP interest rates exceeded the 2023 rates, (for example, with the –5.39% statutory interest rate July rate 2022). rising In come to 10.5% and the HCIP (12.5% in January, 10.5% in March), the gap narrowed to such an extent that stabilization and the resumption of positive statutory real interest rates became possible (1.60% in April 2023).Looking at the development of the capital value over the entire analysis period, it becomes clear that the adjusted statutory real interest rates were decisive for the preservation or decline of the real value of the capital. In the first half of 2022, positive adjusted real interest rates, such as 1.69% in January 2022, lead to a slight increase in the capital value to € 101.69. From April onwards, however, the value falls continuously. The 2022 largest inflation loss was about the adjusted real interest rates of negative, July, resulting in November, the capital value 2022, where negative adjusted interest rates to and including €95.42, –4.58% from its original in July. The Value of these large periods of high inflation showed that nominal interest rates where fixed purchasing power was preserved did not vary by creditor. As with the changing early economic 2023, situations in which inflation did not decline sufficiently and the legal interest rate rose to 10.5%, negative adjusted interest rates gradually declined, which did not cause the value of capital to fall. In March 2023, the adjusted real interest rate was 0.00%, the adjusted interest rate remained at 1.86%, which increased the value of the capital to €100; in May the value was €101.86. 2023, This shows a positive recovery and how creditors can adapt to the inflation environment. The interest rates in the table could also be helpful in supporting the idea that policy makers and regulators should revise their methods of setting legal interest rates, especially in a high inflation environment.

6. CONCLUSION

This analysis shows how difficult it is to make accurate monthly adjustments to avoid the consequences of inaccurate calculations when inflation is high. It also explains how inaccurate calculations in times of high inflation can lead to an erosion of the real value of capital for the creditor. Therefore, policy makers need to consider these interactions when setting statutory interest rates to ensure that they do not erode the real value of the creditor and cause financial instability. Key issues are:

1. Mismatch between statutory interest rates and economic realities: Analysis shows that fixed statutory interest rates have not responded to the changing economic environment during periods of high inflation.

2. Erosion of real asset value for creditors: The negative adjusted real interest rates resulting from the divergence between statutory interest rates and inflation mean that the real value of capital is continuously devalued, which is a problem for creditors.

3. Inappropriateness of the existing framework conditions: Statutory interest rates were set by EU Directive 2011/7/EU and did not provide sufficient protection for creditors or ensure fairness in trading.

This analysis suggests that Directive 2011/7/EU should move to a more dynamic approach to statutory interest rates to reflect inflation and ensure that creditors are guaranteed a minimum real rate of return. This could be done through a mechanism linked to the HICP or through real minimum interest rates or through regular adjustments to economic developments. This will improve the fairness and robustness of the system in protecting creditors' rights. In addition, the Directive could also include a retroactive adjustment clause allowing for an increase in statutory interest rates if they are deemed insufficient in times of high inflation.

This provision would allow creditors to receive additional compensation for the period between the HKIP and the statutory interest rate. For example, if the HKIP for July 2022 is 12.7% and the statutory rate is 7.31%, the difference of 5.39% would be calculated retrospectively and paid to creditors. The inclusion of these measures would better reflect economic realities to preserve the real value of assets and boost confidence in the financial and capital markets in times of inflation.

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CRITICAL ANALYSIS OF WEALTH DISTRIBUTION THEORY: CONTRIBUTIONS AND LIMITATIONS

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ABSTRACT

The persistent issue of wealth inequality has long been the subject of economic thought studies, aiming to understand the origin of wealth and its distribution among different economic agents. To address this question, several theories have been developed from the 18th century until today, originating from various schools of thought. These theories, beginning mainly with Adam Smith & David Ricardo and later reformed by Marx in the 19th century and Simon Kuznets & Nicholas Kaldor in the 20th century, provide a rich foundation of contributions. The present paper aims to analyze the theoretical contributions and empirical limitations in addressing the problem of unjust wealth distribution. By adopting a qualitative methodology, using the explorative method to examine the strengths and weaknesses of existing wealth redistribution theories. The qualitative results of this research revealed that the classical, social, and neoclassical wealth redistribution contributions are purely theoretical, with a lack of empirical evidence, and are limited in their temporal scope. On the other hand, the new theories present an empirical advancement, but these no longer hold. A new approach is needed.

Keywords: *Critical analysis, Socio economic inequality, New theories, Unjust wealth distribution, Wealth distribution Theory*

1. INTRODUCTION

The question of wealth distribution has long been a subject of study in the history of economic thought, with the main objective being to understand the origin of wealth accumulation and their allocation among different economic agents. To address this question, several theories have been developed from the 18th century to nowadays, originating from different schools of thought. These theories, primarily starting with Adam Smith and David Ricardo, were later reformed by Marx in the 19th century and Kuznets & Kaldor in the 20th century. However, wealth distribution in the 21st century does not differ much from that of the 19th century, and inequalities persist despite the research conducted in this field (Piketty, 2019). According to studies conducted by Milanovic (2009, 2016), the world experienced a 64% increase in inequalities, as measured by the Gini index, between the 19th and 21st centuries. Nevertheless, this study aims to present a historical and critical analysis of conventional wealth distribution theories to better understand past developments and current research contributions on this subject. This paper adopted a qualitative research methodology to explore the contributions and limitations of wealth distribution theories. This involves a detailed examination of existing literature, theoretical frameworks, and empirical studies related to wealth distribution. The qualitative data methods are based on literature review that involves a comparative analysis.

The first section of this paper will focus on the main contributions to wealth distribution theories from the 18th to the 20th century. The second section will provide a critical analysis of each theory, including the classical, neoclassical, and social schools, as well as the theories proposed by 20th-century economists. The third section will aim to explore the existing literature on wealth distribution in the 21st century. Finally, the fourth section will discuss the research results, examine gaps in literature, and suggest potential directions for future research.

2. CONTRIBUTION OF WEALTH DISTRIBUTION THEORY: XVIII – XX CENTURY

During the birth of classical economics, at the end of the 18th century and the beginning of the 19th century, the question of distribution was already at the center of all analyses. However, how did conventional economic theorists analyze the question of wealth distribution? And what solutions did they propose to address inequalities? This is the subject of this chapter

2.1. Contribution of Classical wealth distribution theories

The contribution of wealth distribution of classical economists is primarily based on the Supply analysis. However, alongside Adam Smith's (1776) optimistic vision, there is the pessimistic view of David Ricardo (1817) and Malthus (1789), who predict the evolution of the capitalist system towards a stationary state. In fact, these economists were content to observe and analyze what happens in society. According to them, wealth is naturally distributed in society through wages, profits, interest in capital, rent or land rend (Tsoulfidis, L., Tsaliki, P., 2019). Smith divides economic activity into exchange and income distribution. Regarding the distribution of wealth, the interests of social classes become opposed. Distribution is then conceived as a zero-sum game, where what one gains, the other loses (James C. A, 1999). Moreover, Smith admit that wages and profits, interest and rents, are the elements of the natural price of everything, and at the same time the sources of all kinds of income, which thus proceed from labor directly or indirectly ((Bordaz. R, 1938). Malthus as a disciple of Adam Smith. Like his master, he observes that wealth is naturally distributed in society through rent, profit, and wages (Eugène, 1888). However, according to him, the "Overpopulation principle" represents the main threat to the equal distribution of wealth (Vernon M. B, 1998). However, Malthus had seen that the increase in production in England, at that period, made the majority of the population poorer as consumers and understood that growth without any relation to demand would lead to immense crisis (Piketty, 2014). This is why he urged the rich to spend as much as possible to restore the balance between supply and demand. According to Serge. S, et al. (2014), Malthus, believed that the Luxury of the upper classes could consume the surplus products and reward the labor provided by workers, thereby remedying the disorder in production. David Ricardo's theory of wealth distribution differs from Adam Smith's optimistic approach in two main points (Leroy-Beaulieu, 1881):

- Rent is not absolute, related to the monopoly of land, but differential, related to the unequal fertility of the land.
- There is an inverse relationship between wages and profits.

On his book "Principles of Political Economy and Taxation" (1817), Ricardo believes that as the growth of workers and production continues over time, land tends to become increasingly scarce relative to other goods. Thus, the law of supply and demand will lead to a continuous rise in the price of land and the rents paid to landowners. Consequently, landowners will receive an increasingly larger share of the national income, while the rest of the population will receive an increasingly smaller share (Heinz D. Kurz, 2009).

2.2. Contribution of Socialism Wealth distibution theories

One of the most striking facts of the 19th century is misery of the industrial proletariat. Piketty (2013), argues that the workers were the only victims with long working days for very lo wages. It's on the basis of this context that the first socialist movements developed. It's on this paradox that Marx focuses this research and publishes the first volume of 'Capital' in 1876, to justify the collapse of capitalism. In this context, several theories were elaborate by other socialists, mainly Saint Simon and Fourier. According to Claude-Henri de Rouvroy, Comte de Saint-Simon, as belonging to an aristocratic community, the State is the only owner of the land, capital and all instruments of labor (Bernstein, S. 1948). The State alone capitalizes, makes reserves, accumulates wealth according to its needs. Indeed, the worker can spend their income according to their needs, save it, and make savings, but can never invest their savings and create value (Vidal, 1846). According to Vidal (1846), Saint Simon summarizes the distribution of wealth as follows: *"To each according to hit capacity, to each capacity according to its works"*.

The socialist Fourier advocates for democracy to prevail, for the existence of liberty, each according to their tastes, obeying their natural vocation. Fourier's approach to distribution argues that all members of society are in solidarity (Cunliffe, J. et Al. 2001). Distribution is carried out among workers, capitalists, and talented individuals, not baes on the specific product of a particular industry or branch of branch of industry but on the general benefit of society (Gareth, S. & Ian, P., 1996). On the other hand, Marx intends to distinguish himself from both bourgeois economists and utopian socialists, who, according to him, merely denounce the misery of workers without offering a scientific study of the economic processes (Gordon, D.M, 1987). According to Hansjorg. H (2018), Marx is pessimistic only regarding capitalism but optimistic about the evolution of human society. Marx highlights several contributions related to wealth distribution presented on his book The capital' (1867), mainly:

- Marx's Labor Theory of value argues that capital accumulation refers to the reinvestment of surplus value into production to generate more profit, and consequently, this process leads to the concentration of wealth in the hands of a minority, increasing economic inequality (Marx, 1867).
- Marx Law of increasing pauperization and exploitation, conduct that the introduction of machines to replace humans can be harmful to wrokers, while the less powerfu entrepreneurs also become proletarians. Thus, massive unemployment helps to keep wages at the lowest levels (Ramaux, C., 2003).

For Marx, the capitalist mode of production remains incompatible with the prospect of a stationary state, but rather oriented towards a destabilized system. Marx (1865, p.31) shows that overproduction driven by capitalists is not to the benefit of workers, he says in this sense: *'The general tendency of capitalist production is not to raise the average normal wage, but to lower it'*.

2.3. Contribtion of Neoclassical wealth distibution theories

The neoclassical theory of wealth distribution is mainly based on J.B. Clark's conducted at the end of the 19th century, in his work "The Distribution of Wealth" in 1899. The essence of the neoclassical theory revolves around the concept of "Marginal Productivity", which, according to some authors (Piketty, 2014), dates back to the classical school through David Ricardo. J.B. Clark develops the concept of marginal productivity through his theorem of "The exhaustion of the product".

The remuneration method, according to marginal productivity, is based on the idea that each person receives the equivalent of their contribution. According to Guerrien (2016), if the remuneration were higher, it would mean that a production factor had not been taken into account, and if it were lower, production would be at a loss.
On his book, "Distribution of Wealth", Clark (1899) said: '*It is the purpose of this work to show that the distribution of income to society is controlled by a natural law, and that this law, if it worked without friction, would give to every agent of production the amount of wealth which that agent creates'.*
Clark traces the distribution of income back to a 'Natural Law' which, if allowed to operate, leads to a balanced society where everyone is remunerated according to their contribution. He develops his theorem by considering two factors of production, labor and capital, whose quantities he varies separately (Sato. K, 1966). Thus, the "exhaustion of the product" means that the product is equivalent to the sum of the incomes of labor and capital provided.

2.4. Contribution of Kuznets and Kaldor wealth distribution theories

The economists Kuznets (1955) and Lorenz (1905) proposes the first empirical studies on wealth distribution, introducing two famous theories. One involves the creation of an inequality measurement index, known as the Gini Coefficient, and the other aims to explain the origin of wealth distribution inequalities through the growth theory modeled by the Kuznets Curve. *"How is wealth, whether in terms of assets or income, distributed within a given population?"*

This is the kind of question that the American economist and statistician Max Otto Lorenz sought to answer at the beginning of the 20th century, through his 1905 article 'Methods of Measuring the Concentration of Wealth,' when he intuitively represented the distribution of wealth in his country using a curve that now bears his name (Aberge, 2000). After that, in 1955, Kuznets developed the growth theory modeled by the inverted U-shaped curve, known as the 'Kuznets Curve' (Kuznets, 1955). The Kuznets Curve shows an inverted U, where the y-axis represents the level of inequality indicated by the Gini Coefficient, and the x-axis represents the level of economic development indicated by GDP per capita. According to this theory, inequalities are expected to follow a bell-shaped curve, meaning they first increase and then decrease (Michael. A, 2010).

Kuznets' logic is based on the idea that inequalities increase during the early phases of industrialization (where only a minority can benefit from the new wealth brought by industrialization), before spontaneously decreasing during the advanced stages of development (as a growing fraction of the population joins the most prosperous sectors, leading to a spontaneous reduction in inequalities) (Galor. O & Tsiddon, D., 1996). On the other hand, Kaldor's (1956) distribution theory suggests that income distribution between wages and profits is determined by the savings behavior of workers and capitalists. He posited that capitalists save a larger proportion of their income, leading to higher investment and economic growth (Johan. O, 1987). Building on Kaldor's work, Luigi Pasinetti extended the analysis to show that the long-term equilibrium distribution of income depends on the savings rates of workers and capitalist (Béraud A., 2011).

3. LIMITATIONS OF WEALTH DISTRIBUTION THEORIES: XVIII – XX CENTURY

After presenting the main contributions of wealth distribution theories between 18th century and 20th century, it's important to conduct a critical analysis of each school of thought. This is the main purpose of this chapter, subdivided on four subchapters.

3.1. Critical analyses of Classical wealth distribution theory

Several studies aim to examine the limitations of Adam Smith theories. Regarding Smith wealth distribution theories, Brown & Ivring (1954), conduct that his analyses are based only on economics observations, without proposing practical solutions to wealth inequality problem that marked the 18th century. According to Robert du Var (1845), Smith considers rent as a monopoly income, and therefore, it's the most difficult type of profit to justify morally and economically since it represents no effort and tends to make the landowner increasingly rich and the workers increasingly poor. Smith pretend that workers are generally lazy when their wages are above the minimum subsistence wage, which forces capitalists to avoid any wage increases despite economic growth (Nova. A, et al., 2005)

In this sense, Vidal (1846) askes the following question: *'Is it just, is it ethical, is it even a sound policy, that all increases in social wealth, all improvements, all work results and universal activity, should exclusively to benefit of the rentiers, to the benefit of owners?'*

The Malthus's theory of Luxury Goods reinforces the idea that capitalists enrich nations and sustain peoples without considering that the capitalist's wealth comes from the worker's labor. Vidal (1846) advance that this approach requires increasing rich spending of the rich so that the poor work more to create wealth that will be accumulated by the upper classes. Piketty (2013), shows that the theory of Luxury Goods established as a way to balance production and consumption, was practiced by ancient peoples, where production was carried out by slaves or tributaries, and the rich who lived oof the luxury don't contribute to production and could accumulate unlimited wealth.

According to Borja. M & Marcos. G (2020), Malthusian theory was no longer applicable after the industrial revolution due to technological progress. On the other hand, David Ricardo theory couldn't anticipate the extent of technological progress and industrial growth that would occur in the coming century (Siddiqui. K, 2018). The critical analyze of classical economics theories lead us to conduct the limitation of their thoughts. As marked by Lero-Bealieu (1881) in his book 'Essay on the distribution of wealth', that we can be surprised by the gaps in the intelligence of Malthus and Ricardo, profound minds but singularly narrow, who fail to extend the horizon of their thought and to anticipate future progress in their imagination.

3.2. Critical analyses of socialism wealth distibution theories

The socialism thought, notably the Saint-Simonain approach had the glory of raising all social problems, changing ideas with a revolutionary spirit. However, its theory remains limited in time and space (Mykola, K. & Uliana, M., 2023). Firstly, workers can in no way become investors and increase their wealth. Secondly, while it's difficult to measure capacities than evaluate works, Simon argues that the superior should judges capacities, assigns functions, classifies individuals, and appreciates works according to his discretion. He determines, in fact the distribution that suites him and judges without request (Vidal, 1846).

The Saint-Simonain thought, revealed about wage, that "To each person according to his capacity and according to his works", on the other hand, Fourier's disciples say that "To each person according to his capital, his work, and his talent". The Fourier and Simon theories differ on two points: - The first one admits capital and the other doesn't – One has works and capacities are judged by peers and the other by authority (Piketty, 2013). However, the main limitation of Fourier approach, is the utopian socialism of the guaranteed well-being ensured for all members of society without exception or restrictions (Gareth, S. & Ian, P., 1996). Despite the importance of the theories brought by Marx, especially in a context of inequality between capitalist and workers, Piketty (2013), present some limitations of Marx's wealth distribution theories: - Marx worked on a limited empirical basis du to the restricted English Fiscal data during this period (1840 – 1860) – Like Ricardo, Marx neglected the possibility of technical progress and continuous productivity growth – He lacked statistics to refine his predictions. To summarize, socialists recognize that people are unequal in strengths, needs, and life quality, but they maintain that all are equal in rights and should met their needs. However, this difference does not grant any privilege in wealth distribution. Meadowcraft. J, (2023), Argues that the socialism of the rich does not reflect a deep desire to make society more equal.

3.3. Critical analysis of Neoclassical wealth distibution theory

The neoclassical theory remains limited when it comes to the subject of wealth distribution, generally criticized for its normative bias that does not seek to explain the real world (Hansjorg. H, 2019). Donald. J (1981), criticized the concept of Marginal productivity for its arbitrary nature. However, the basic assumptions of the neoclassical theory of income distribution have given rise to numerous debates regarding their justification in microeconomic and macroeconomic coherence (K. Sato, 1966). To summarize, the neoclassical theory of wealth distribution lacks logical consistency and has weak foundations, as has been revealed by the several critical analyses interested to the neoclassical production function (Luigi. L, 2012).

3.4. Critical analyses of Kuznets and Kaldor theories

The growth theory proposed by Simon Kuznets, based on the Kuznets curve, aims to demonstrate mechanically the reduction of inequalities with increasing economic growth of a country. However, this approach it's discussed both theoretically and empirically (Ravi. K & Joseph.S, 2015). Kuznets is fully aware of the highly speculative nature of his theory, as himself states (Kuznets, 1955): *"This is perhaps 5 per cent empirical information and 95 per cent speculation, some of it possibly tainted by wishful thinking"*. Kuznets bases his theory on data from different countries but from the same period, which prevents analyzing the data over time to observe long-term progressions (Sumner, A. 2016). The empirical Inconsistency was examined by several authors, Angel. J et Al. (2010), highlighting Kuznets curve (KC) limitations in explaining income distribution dynamics. While Piketty (2014) challenges the KC, showing that, based on French and American data, the reduction of inequalities is not mechanically linked to GDP growth (as Kuznets claimed). On the other hand, Nicholas Kaldor's (1957) theory emphasizes the role of savings and investment in income distribution, suggesting that capitalists save more and thus accumulate wealth faster than workers (Johan. O, 1987). The assumption of a constant savings rates is one of the principal limitations of Kaldor's theory, this one assumes that savings rates are constant across different income groups, which may not be accurate in real-world scenarios (Luiz. G, 2022). To summarize, Ravi Kanbur and Nobelist Joe Stiglitz (2015) argues that, the Wealth and income theories focus on the Kaldor & Kuznets stylized facts, no longer hold.

4. EMPIRICAL ADVANCEMENTS ABOUT WEALTH DISTRIBUTION: XXI CENTURY

The empirical literature on economic inequality offers a multidimensional view of the trends and determinants of income and wealth disparities.

Authors	Variables	Model	Sample	Result
Piketty, T. (2014)	Rate of return on capital (rr), economic growth (gg), share of wealth held by the top 1%.	Time series with descriptive analysis	1820-2010	Inequalities are increasing structurally
Saez, E., & Zucman, G. (2016)	Net wealth, wealth shares by fractiles (1%, 10%)	Capitalisation of income from assets to estimate wealth	1913-2013	The wealth of the richest 1% has doubled since the 1980s.
Alvaredo, F., et al. (2018)	Income before/after taxes, net wealth, Gini index	Descriptives regressions	1980-2017	Inequalities are increasing in most countries, with regional disparities
Milanovic, B. (2016)	Household income, GDP per capital	Quantiles regression	1988-2008	Inequalities between countries reduced, but internal inequalities increased.
Chetty, R., et al. (2014)	Intergenerational mobility, family income	Hierarchical linear regressions	1996-2012	Mobility varies across regions, influenced by segregation and education
Davies, J. B., et al. (2011)	Household wealth, financial assets	Calibrated general equilibrium	2000s	50% of global wealth is held by 1% of the population
Blanchet, T., Chancel, L., & Gethin, A. (2022)	Income, public social spending, taxation	Fixed effects panel model	1950-2020	European fiscal and social systems reduce inequalities more effectively
Lakner, C., & Milanovic, B. (2013)	Income by quantiles, global Gini index	Quantile regressions and Gini indices	1988-2008	Growth for the middle classes in emerging countries and stagnation of low incomes in rich countries.
Solt, F. (2020)	Gini indices before and after redistribution	Harmonized estimation of Gini indices (SWIID)	1960-2020	Increasing inequalities in most countries

Auten, G., & Splinter, D. (2019)	Adjusted incomes, social transfers	Dynamic models with adjustment for social transfers	1960-2015	Inequalities are less pronounced after adjusting for transfers.
Heathcote, J., Perri, F., & Violante, G. L. (2010)	Income, consumption, savings	VAR (Vector Autoregressif)	1967-2006	Consumption inequalities increase less than income inequalities.
Wolff, E. N. (2017)	Financial assets, household wealth	Descriptive regressions and simulations	1917-2013	Increased concentration at the top, linked to financial assets
Atkinson, A. B., Piketty, T., & Saez, E. (2011)	Share of income held by the top 1%, marginal tax rates	Time series with linear regressions	1900-2005	Decreases in marginal tax rates contributed to the increase in income shares at the top
Jäntti, M., & Jenkins, S. P. (2015)	Income mobility across quintiles, household income	Markov transition models	1980-2010	Nordic countries exhibit higher intergenerational mobility compared to the United States.
Morelli, S., Smeeding, T., & Thompson, J. P. (2015)	Gini index, income before/after redistribution	Panel regressions with fiscal and survey data	1970-2010	Inequalities have significantly increased in English-speaking countries after 1980
Morelli, S., Smeeding, T., & Thompson, J. P. (2015)	Gini index, income before/after redistribution	Panel regressions with fiscal and survey data	1970-2010	Inequalities have significantly increased in English-speaking countries after 1980
Hassler, J., & Rodriguez-Mora, J. V. (2010)	Social mobility, economic growth, skills	Nonlinear regressions with dynamic simulations	20st century	Increased mobility reduces inequality and stimulates long-term economic growth
OECD (2021)	Income before and after taxes, social transfers	Descriptive regressions, indicator calculations (Gini, Palma ratio)	1990-2020	Social transfers reduce inequality by 20-30% in OECD countries.
Aghion, P., Caroli, E., &	GDP growth rate, inequality indices (Gini, Theil)	Panel linear regressions	1960-1990	Inequality negatively impacts growth in

García-Peñalosa, C. (1999)				developed economies.
Stiglitz, J. E. (2012)	Economic growth, share of income of the top 1%	Simple regressions (empirical illustrations)	2000s	Excessive inequality hinders growth through weakened demand
Oxfam (2023)	Income, net wealth, taxation	Descriptive regressions on fiscal and wealth data	2000-2022	Billionaire wealth increased by 300% from 2010 to 2020, exacerbating inequality.
Chancel, L. (2022)	CO2 emissions by income quintile, income before/after redistribution	Descriptive regressions	1980-2020	The top 10% are responsible for 50% of global CO2 emissions
Lahjouji. H & Monzer. K (2021)	Poverty gap index, Resources shortfall, Potential Zakat (Islamic instrument of wealth distribution) based on Q4 and Q5	Distribution of Estimated potential Zakat collection	1998-2013	Potential zakat collection can fill the resources shortfall for the poverty alleviation under 1.9$ and 3.2$ a day, eliminate extreme poverty and generate a surplus
Haddad, A. & El Mosaid. F (2024)	Zakat, wealth distribution simulation, Wilensky Model of Simple Economy	Agent Based Modeling		Wealth distribution is more equal and the gap between rich and poor is less significant when Zakat is applied

Table 1: Empirical research evidence in the last twenty-four years (Sources: Authors analysis)

Piketty (2014) highlights capital accumulation as a driver of inequality, particularly when the return on capital exceeds economic growth. Saez and Zucman (2016), using capitalised tax data, show and increase in the share of wealth held by the richest 1% in the United States. These conclusions are reinforced by the work of Alvaredo et al (2013), which highlights the key role of tax policies in reducing or amplifying inequalities, particularly in an international context. In Europe, Blanchet, Chancel and Gethin (2022) attribute a lower concentration of wealth to more robust social protection systems and progressive tax policies, while Milanovic (2016) explores the evolution of global inequality, revealing income convergence between countries while documenting an increase in domestic inequality. From a methodological point of view, these studies rely on a varied range of econometric techniques.

For example, Atkinson, Piketty and Saez (2011) use time series regressions to analyse the impact of economic shocks and tax policies on high incomes, while Blanchet et al. (2022) use panel models with fixed effects to include institutional and demographic variables. Milanovic (2016) and Lakner and Milanovic (2013) use quantile regressions to capture the differential effects of growth on different income groups. Other works, such as those by Wolff (2017) and Chetty et al. (2014), adopt a microeconomic perspective by studying household assets or intergenerational mobility using structural models or linear regressions. Finally, recent approaches, such as those presented by Piketty, Saez and Zucman (2018), combine tax data, historical series and distributed national accounts to provide detailed estimates of inequality and simulate the redistributive effects of public policies. These works converge on a fundamental point: inequalities are shaped by a mixture of structural dynamics, such as returns to capital and technological developments, and political choices, particularly in terms of taxation and redistribution. On the other hand, Lahjouji. H & Monzer, K. (2021) and Haddad. A & El Mosaid. F (2024) conduct empirical studies to investigate the effect of Islamic wealth distribution instrument 'Zakat' on poverty alleviation and reduction of the gap between the rich and the poor.

5. RESULTS AND DISCUSSIONS

The figure (Fig.1) below shows the timeline evolution of wealth distribution from the 18th century until today, presenting the principal schools of thought, main authors, and research particularities of each decade.

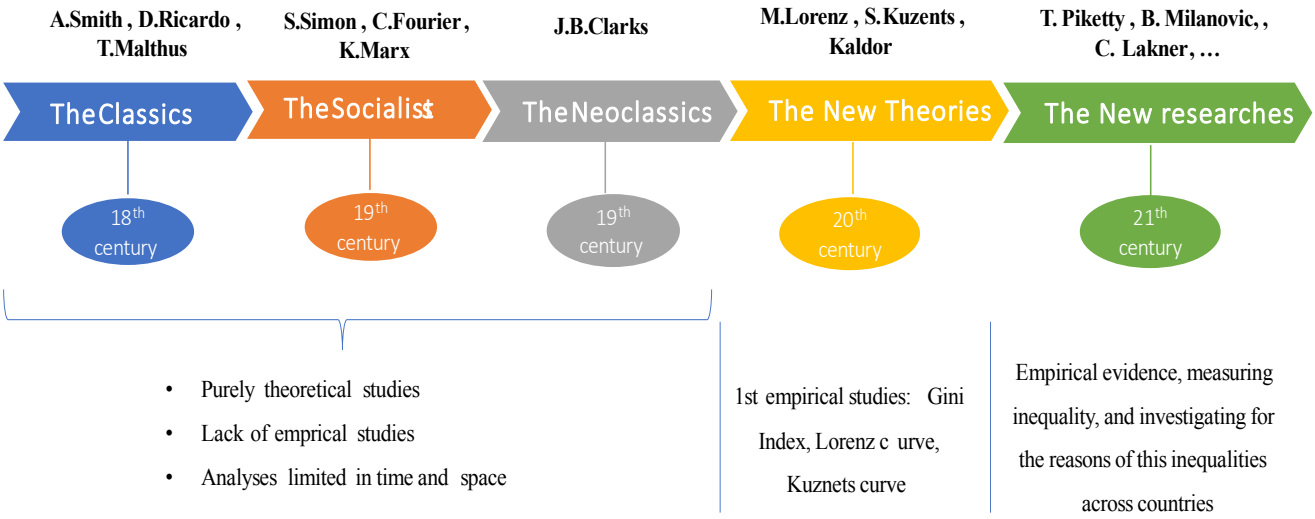

Figure 1: Timeline evolution of wealth distribution theories
(Source: Conducted by authors)

As a result, the 18th and 19th centuries were marked by purely theoretical studies based on observations of wealth distribution and inequalities. The first empirical studies were initiated in the 20th century by Lorenz and Kuznets. Finally, contemporary 'New Research' presents empirical advancements based on several models to measure and analyze the origins of inequalities.

6. CONCLUSION

In conclusion, the conventional theory of wealth distribution emerged with classical economists such as Smith, Ricardo, and Malthus, who posited that wealth is naturally distributed within society. Their theories were primarily based on observations of their surroundings. Socialists, on the other hand, acknowledged human inequality and developed an idealized conception of justice and equity. However, they failed to propose realistic and absolute solutions to resolve this paradox. The neoclassical theory of wealth distribution revolves around the concept of marginal productivity, developed through the "exhaustion of the product" theorem. This theory remains limited by its normative bias, which does not seek to explain the real world.In the 20th century, Kuznets and Lorenz conducted the first empirical studies on wealth distribution. They attempted to explain the origins of inequality through the Kuznets curve and the Gini index, which aims to measure these inequalities. The Gini index has become the most widely used tool at both national and international levels for measuring wealth distribution inequalities. On the other hand, the new theories present an empirical advancement that aims to quantitatively investigate factors of wealth inequality. However, these theories no longer hold. A new approach is needed to propose practical modes of wealth distribution that could reduce socioeconomic inequalities.

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CREATING INTELLIGENT LIVING SPACES: THE ROLE OF DIGITAL TWINS IN SMART HOME SYSTEM OPTIMIZATION

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ABSTRACT

In the context of smart homes, digital twins enable real-time simulation, optimization, and predictive analysis, fostering more efficient and intelligent living environments. This research explores the application of digital twins in smart homes to enhance the quality of life and elevate living standards. Leveraging Internet of Things (IoT) devices and purpose-built applications, it becomes feasible to monitor and manage the daily operations of a smart home. Digital twins facilitate real-time tracking of home conditions, offering immediate feedback and actionable insights to optimize home settings. The difference between digital twins and simulations is that simulations use historical data, while digital twins communicate with the real world in real time, receiving and processing data collected in real time so that decisions can be made in time. The concept of the digital twin is excellent for making predictions in advance, when relevant information about events is needed before they occur. In the context of smart homes, the concept of the digital twin is proving invaluable for prediction, providing relevant insights and actionable information about potential events before they occur, improving the efficiency of property management and decision making. Research provides a comprehensive exploration of the role of digital twins in optimizing smart home systems. The study begins by introducing the concept of digital twins and their use for the purpose of smart home systems. The research presents use cases of digital twins in smart homes, utilizing IoT devices and specialized applications for seamless information exchange. By combining a literature review with practical examples, this paper highlights the transformative role of digital twins in creating smarter and more user-friendly living spaces.

Keywords: *Digital twin, IoT, Simulation, Smart Home*

1. INTRODUCTION

Digital twin (DT) represent a technology that bridges the physical and virtual worlds through the integration of data, simulations, and real-time analysis. First introduced as a concept in 2002, DT enable the monitoring, analysis, and optimization of physical systems through their virtual counterparts (Ghosh & Banerji, 2023). Their applications span various industries, including manufacturing, healthcare, construction, and energy, and they are increasingly being used in the context of smart homes. At their core, DT utilize real-time data collected via IoT devices to monitor conditions and system functionalities. Unlike traditional simulations that rely on historical data, DT maintain continuous connectivity with physical systems, allowing for rapid adaptation and real-time decision-making (Cotti et al., 2024).

The application of DT in smart homes opens new opportunities for improving quality of life and managing resources more efficiently. By integrating with IoT sensors, these systems can monitor parameters such as energy consumption, air quality, and security conditions, while providing relevant recommendations for optimization (Chen et al., 2024). For instance, research shows that the use of DT can significantly enhance a home's energy efficiency and reduce operational costs (Zahedi et al., 2024). Although the potential of DT in smart homes is growing, their implementation presents challenges. Collecting and processing large volumes of data requires substantial computational power, while security and user privacy remain key concerns (Padmapriya & Srivenkatesh, 2023; Chen et al., 2024). This paper explores the role of DT in optimizing smart homes, analyzing their practical applications, benefits, and challenges. The goal is to illustrate, through a review of existing research and practical examples, how DT can transform modern living spaces and improve everyday operations. The research questions are:

1. How can DTs of smart home systems be utilized to enhance energy efficiency and promote environmental sustainability?
2. What are the key challenges in developing and integrating DTs with IoT devices and cloud-based systems in smart home ecosystems?
3. How can the implementation of DTs in smart homes, supported by IoT devices and cloud platforms, drive innovation and align with broader trends in smart city development?

In this paper, two use cases are presented to show how intelligent living spaces can be created and how continuous optimization of the smart home system can be ensured. The first use case shows the use of the devices from the Internet of Things, in particular the humidity and temperature sensors, to achieve an optimal temperature and humidity level in the rooms of the home and thus prevent the spread of mould. The second use case shows the use of solar cells on the roof of a house to generate electricity. The idea is to raise awareness of the use of renewable energy sources.

2. RELATED WORKS

For the purpose of the research, a preliminary literature review was conducted, and Scopus and Web of Science databases were searched. The narrative review focused primarily on studies with the key phrases "Digital twins," "Energy Efficiency," "Smart Homes/Buildings," “Smart Cities,” "Sustainability," and "IoT." The basic query used was:
"Digital twins" AND ("Smart Home" OR "Intelligent Living Spaces").

DT have emerged as a transformative technology in the context of smart homes, addressing energy efficiency, security, and user-centric optimization challenges. Studies such as Sayed et al. (2025) and Um-e-Habiba et al. (2024) demonstrate how DT systems leverage IoT sensors for real-time monitoring and decision-making, enhancing energy consumption management and cyber resilience. These works establish the foundational role of DTs in improving operational efficiency and sustainability. A significant focus in recent literature has been on integrating DTs with machine learning (ML) to achieve adaptive and predictive management. Cotti et al. (2024) introduced ML-powered DT frameworks that personalize energy usage patterns, offering end-users actionable insights for optimization. Similarly, Liu et al. (2023) explored reinforcement learning-driven DTs, emphasizing predictive energy management and grid optimization in smart homes. The user-centric potential of DTs is further explored by Bouchabou et al. (2023), who highlighted how DTs could assist in recognizing daily living activities, enhancing both safety and convenience.

Complementing this, Zhao et al. (2023) proposed collaborative systems for elderly care, integrating DTs with remote monitoring technologies to provide real-time alerts and interaction. Energy optimization remains a central theme in DT research. Zahedi et al. (2024) and Chen et al. (2024) explored multi-system integration within homes to reduce costs and energy consumption. Their findings align with works by Bioul et al. (2024), who proposed fall detection and behavioral monitoring systems using DT frameworks. This approach emphasizes the growing role of DTs in managing safety and personalized care in smart homes. Several studies address the scalability and interoperability of DT systems. Chen et al. (2024) and Walczyk et al. (2024) discussed how DTs could unify disparate IoT networks within a single framework, promoting seamless device communication. Meanwhile, Ghosh et al. (2023) examined DT implementations in urban environments, suggesting that scaling these technologies from individual homes to city-wide applications could maximize their impact. Security and privacy are recurring concerns in DT applications. Ghosh et al. (2023) and Padmapriya et al. (2023) emphasized the importance of robust cybersecurity measures to protect data integrity within DT ecosystems. Their studies suggest multi-layered approaches, including encryption and intrusion detection systems, to mitigate risks. Studies also have explored the application of DTs for predictive maintenance and proactive decision-making in smart homes. Shin et al. (2024) developed a real-time network evaluation model powered by DTs to predict system failures and optimize resource allocation dynamically. Similarly, Alhaidari et al. (2024) demonstrated the utility of DT-driven task assignment systems for household maintenance, focusing on automating routine activities while ensuring system reliability. These studies align with existing research on leveraging DTs to anticipate and mitigate operational disruptions. Also, the concept of smart cities has garnered significant attention in recent years, aiming to enhance urban living through the integration of advanced technologies and data-driven solutions. A smart city utilizes information and communication technologies (ICT) to improve the quality of life for its citizens, increase the efficiency of urban operations and services, and promote sustainable development. Smart homes are increasingly contributing to the concept of smart cities, prompting an analysis of literature focused on smart city development. Studies illustrate the transformative role of DTs in advancing smart city innovation, highlighting their capacity for real-time data management, system integration, and predictive analytics. Therias & Rafiee (2023) emphasize that DTs enable enhanced urban resilience by simulating real-time scenarios for disaster management and resource allocation, providing actionable insights for city planners. Building on this, Sohail et al. (2023) discuss how DTs can model and predict urban dynamics, such as energy demand and traffic flow, optimizing city-wide operations. The integration of IoT with DTs, as highlighted Matei & Cocoșatu (2024) facilitates seamless data collection from urban infrastructures, allowing for adaptive and efficient energy management. Mazzeto (2024) focus on the interoperability of DT systems, demonstrating how they unify disparate urban infrastructures into cohesive frameworks that scale effectively with city growth. The role of advanced technologies like machine learning is further explored by Joshi & Badola (2024), who provide an overview of how DT serve as a bridge between physical and virtual urban systems, enabling real-time monitoring, predictive modeling, and efficient resource allocation. These studies were analyzed to illustrate the connection between smart homes and smart cities, showing that the success of DTs in smart cities depends on their ability to integrate real-time data, ensure interoperability, and address security challenges. An important insight is that DTs not only enhance operational efficiency but also facilitate long-term urban sustainability by enabling data-driven decision-making and predictive planning (Joshi & Badola, 2024; Mazzeto, 2024).

The integration of smart homes as micro-scale DTs within larger smart city ecosystems emerges as a promising area of research, where seamless interaction between individual homes and urban infrastructures can drive innovation in energy optimization, resource management, and urban resilience.

3. METHODOLOGY

This section presents the research methodology used for the implementation and functionality of smart home systems, focusing on two specific use cases. The methodology describes the tools and technologies used to explore these scenarios. The first use case examined the integration of IoT devices for monitoring and controlling environmental conditions in a smart home. To achieve a smart home management solution in the first use case, following tools were used:

- *Home Assistant* platform served as the central platform for managing IoT devices. This open source application was chosen because of its community support and compatibility with various smart home devices (Home Assistant, 2025).
- Sensors for humidity and temperature were deployed to collect environmental data in real-time. These sensors provide important insights into the home's indoor conditions.
- As regards infrastructure, Linux-based system was used as the host operating system, ensuring stability and flexibility for the research environment.
- In combination with Linux, Docker was used to deploy *Home Assistant* in a virtualized environment. This approach enhanced modularity and ease of setup, allowing for quick experimentation and reconfiguration.

In the first use case, in order to achieve the smart home system optimization, the *Home Assistant* platform was installed within a Docker container on the Linux system. IoT sensors were configured and paired with *Home Assistant* to enable real-time monitoring of humidity and temperature. Data collected by the sensors was visualized through *Home Assistant*'s dashboard, enabling analysis of environmental trends and their potential influence on energy efficiency.
The second use case focused on integrating solar energy systems into the smart home ecosystem and monitoring energy production and consumption. The tools used to conduct the research in the second use case were:

- *FusionSolar*, cloud-based application used to monitor and manage the solar energy system. *FusionSolar* provided a comprehensive dashboard to visualize energy generation, consumption, and system performance in real-time (FusionSolar, 2025).
- Solar panels and inverter. Solar panels equipped with an Internet-connected inverter were deployed. The inverter acted as a bridge between the solar panels and the home's electrical system, transmitting data about energy generation and usage.
- Cloud integration. Energy data, including the amount of energy generated by the panels and consumed by the household, was recorded and stored in the cloud-based platform, *FusionSolar*.

In the second use case, the inverter was connected to the cloud to enable seamless data synchronization. Data on energy generation and consumption was retrieved from the cloud using the inverter's application programming interface (API). *FusionSolar* had role in aggregating this data and presenting it in an accessible format for analysis. Additionally, analysis focused on identifying patterns in energy usage and assessing the balance between energy production and consumption to improve overall efficiency.

4. OUTCOMES OF IMPLEMENTING DTS IN LIVING SPACES

This chapter presents the results of the use cases developed in this study, which demonstrate DTs of smart homes. The first use case focuses on improving the quality of life within the home by preventing mold growth. This is achieved through the use of temperature and humidity sensors to monitor and manage indoor conditions. The second use case highlights the management of energy consumption from solar panels, aiming to promote awareness of renewable energy use and encourage sustainable living practices. The implementation of DTs for living spaces, or intelligent living environments, leads to enhanced quality of life and the adoption of more sustainable energy usage practices.

4.1. Temperature and humidity control in smart homes: Use case

The first use case focused on managing the temperature and humidity levels within a household to prevent mold growth. By carefully monitoring and controlling these factors, homeowners could maintain optimal indoor conditions, ensuring the space remained free of mold. This allowed them to take timely actions, such as ventilating or heating the home, to create a consistent environment that inhibits mold formation and spread. To accomplish this, *the Home Assistant* application was utilized alongside multiple humidity and temperature sensors placed in the rooms most frequently used by the homeowners. These sensors provided real-time data about the household's conditions, enabling the homeowners to monitor their environment continuously. This setup qualifies as a DT of a smart home, as it replicates the actual state of the home in real-time, allowing the homeowners to respond promptly to any changes or unfavorable conditions. Figure 1 illustrates the temperature variations in the living room through the day. The homeowners typically maintain the room temperature at approximately 22 degrees Celsius, which they consider ideal for their comfort and for creating conditions that prevent mold growth in the space. If the temperature falls below 22 degrees Celsius, the heating system is automatically activated.

Figure 1: Living room temperature monitoring using HomeAssistant

To effectively maintain the temperature and humidity in their rooms, the homeowners rely on monitoring via the *Home Assistant* application's dashboard. As shown in Figure 2, they aim to keep the room temperature around 22 degrees Celsius and the humidity at approximately 60%.

These levels are considered optimal given the specific conditions of the building they live in. Furthermore, Figure 2 illustrates how the homeowners use the *Home Assistant* application to monitor various aspects of their home, including whether the doors are open or closed, the status of the front door lock, the condition of the balcony doors, as well as the lights, windows, and other similar elements.

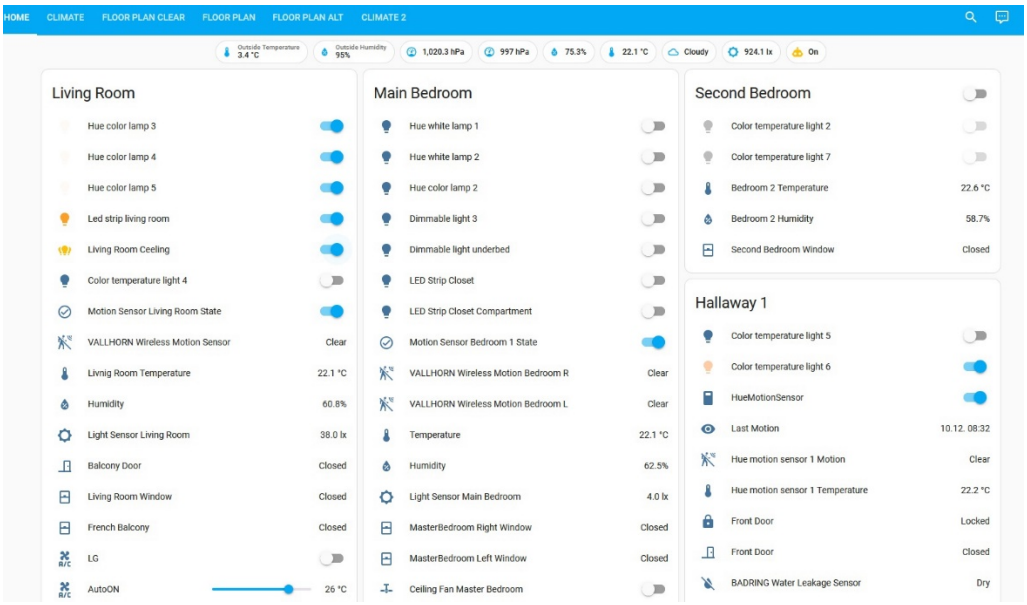

Figure 2: Monitoring of living conditions in the premises of a smart home

The first use case is an example of a DT in the context of a smart home, where real-time data from environmental sensors is continuously integrated into a virtual model to mirror the physical state of the home. By monitoring temperature and humidity levels, the system enables dynamic control to prevent mold growth, a critical aspect of maintaining indoor air quality and structural integrity. The DT of the home, as realized through the *HomeAssistant* application and its sensors, serves as a real-time representation of the household's conditions, providing homeowners with actionable insights to ensure optimal living conditions. The ability to automatically adjust the heating system based on real-time temperature data, and to monitor humidity levels through a dashboard, highlights the value of DTs in proactive decision-making. From a smart home perspective, this setup facilitates energy efficiency, and maintenance by allowing homeowners to remotely manage and respond to environmental changes. The integration of such technologies into the household infrastructure not only highlights the growing importance of real-time monitoring but also demonstrates how DTs can enhance the user experience by providing continuous feedback and enabling automatic system responses.

4.2. Optimizing energy consumption with solar-powered smart homes: Use case

The second use case demonstrates how a household uses solar panels to generate electricity, showcasing a practical example of a smart home in action. Solar panels enable the home to produce electricity year-round, relying solely on sunlight rather than seasonal conditions. This means the system functions effectively whether it's warm or cold outside, as long as there is sufficient sunlight. By utilizing renewable energy, this smart home setup not only reduces reliance on traditional power sources but also promotes sustainability and energy independence. Figures 3 and 4 present an overview of how electricity generated by solar panels is used and managed. The data was accessed using the *FusionSolar* application.

Figure 3: Statistics of electricity consumption per day

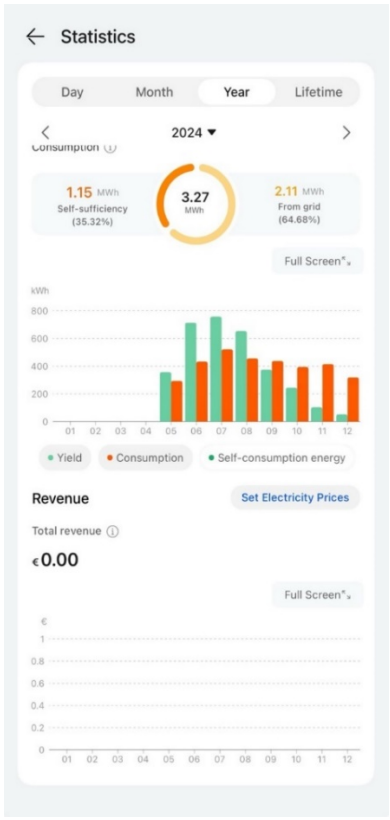

Figure 4: Statistics of electricity consumption per year

Figure 3 provides detailed statistics, including electricity usage for the current month, the current year, and the total lifetime of the solar panels. It also displays daily energy yield and consumption data. Meanwhile, Figure 4 focuses on yearly consumption patterns, offering insights into how much electricity the solar panels produce and the household uses through year. Together, these figures help illustrate both short-term and long-term energy usage trends and the overall efficiency of the solar energy system. This use case is significant in the context of DTs because it highlights how real-time data from solar panels can be integrated into a digital representation of the household's energy system. A DT of this setup would monitor and simulate the energy production and consumption patterns, providing insights into the efficiency and sustainability of the household's energy use. By continuously tracking sunlight availability, energy storage levels, and consumption rates, the DT enables predictive analysis and optimization of energy usage. For instance, it could suggest the best times to use high-energy appliances or charge batteries based on forecasted sunlight, ensuring energy efficiency and cost savings. Additionally, this DT can identify potential issues with the solar panels or system performance, enabling proactive maintenance. This capability highlights the role of DTs in enhancing smart home technologies by providing real-time feedback, improving resource utilization, and supporting sustainable living practices. Considering the outcomes presented from the two use cases, the second research question: "*What are the key challenges in developing and integrating DTs with IoT devices and cloud-based systems in smart home ecosystems?*" can be answered. Developing and integrating DTs with IoT devices and cloud systems in smart homes faces several key challenges. Ensuring real-time data integration and interoperability between various devices and platforms is essential for seamless operation.

As the systems become more complex, it's important to ensure they can handle growth effectively. At the same time, protecting data security and privacy is essential because household information is sensitive. Advanced predictive analytics are needed to optimize energy use and environmental conditions. Additionally, the cost of implementation, system reliability, and user-friendly interfaces remain significant obstacles. Overcoming these challenges is important in order to fully exploit the potential of DTs in smart home ecosystems.

5. IMPACTS OF INTEGRATING DTS IN SMART HOME SYSTEMS ON SMART CITY DEVELOPMENT AND RECOMMENDATIONS FOR CREATING A SMART CITY THROUGH CONNECTED SMART HOMES

The implementation of DTs in smart homes, supported by IoT devices and cloud platforms, has the potential to significantly foster innovation and align with broader trends in smart city development. DTs offer a transformative approach to manage and optimize the functionality of individual homes by creating real-time, virtual models of physical spaces. This virtual representation allows constant monitoring, predictive analytics, and dynamic control of household systems such as energy consumption, environmental conditions, and security. When combined with IoT devices, these systems can provide continuous feedback to homeowners, allowing for more informed decision-making and enhanced operational efficiency. By leveraging cloud platforms, the data generated from IoT devices can be processed and analyzed on a large scale, enabling the integration of multiple homes into a broader smart city infrastructure. This integration of DTs into the smart home ecosystem can support various innovation drivers, particularly in terms of sustainability, energy efficiency, and resource optimization. Smart homes equipped with DTs can autonomously adjust systems such as heating, cooling, and lighting based on real-time environmental data, reducing energy consumption and promoting more sustainable living practices. By scaling this technology to a city-wide level, towns and cities can optimize the management of energy resources, waste systems, and public infrastructure. Additionally, the data collected from smart homes can inform urban planning decisions, improving traffic flow, public safety, and the allocation of resources. The ability to create a seamless connection between individual smart homes and larger city systems encourages collaboration between technology providers, city planners, and homeowners. This drives innovations in the way urban environments are designed and managed. Furthermore, DTs in smart homes can support a transition toward more sustainable cities by enabling proactive monitoring and management of key resources. In particular, energy management, waste reduction, and the deployment of renewable energy sources such as solar panels can be optimized through the insights derived from DTs. With predictive analytics and machine learning models, smart homes can contribute to grid optimization, identifying the best times for energy use or storage based on available solar power, for example. This approach not only reduces the carbon footprint of individual homes but also aligns with global efforts to promote sustainability and reduce the environmental impact of urban development. To create a smart city through connected smart homes, it is important to adequately combine the capabilities of DTs, IoT devices, and cloud platforms (Joshi & Badola, 2024; Mazzaeto, 2024). Smart homes should prioritize interoperability by adopting open standards and protocols and ensuring seamless communication between devices. Predictive analytics can have a significant impact in resource optimization, as demonstrated in the first use case, where trends in environmental parameters were analyzed to improve home automation. This approach can be scaled to optimize city-wide management of energy. Similarly, the second use case highlighted the potential of correlating energy consumption patterns with solar energy generation. At the city level, this requires encouraging renewable energy adoption.

Real-time decision-making should also be enabled by deploying centralized platforms that analyze data from connected homes to improve resource allocation. Cooperation among technology providers, urban planners, and residents must be achieved to ensure successful implementation and data security to build public trust. By following these recommendations, connected smart homes can serve as the foundation for smarter, more sustainable urban environments.

6. CONCLUSION

DTs of smart homes provide an innovative way to enhance the management and efficiency of individual homes by generating real-time virtual models of physical spaces. These virtual representations enable continuous monitoring, predictive analysis, and dynamic control of household systems, such as energy usage and indoor environmental conditions, as demonstrated in this research. The practical application of DTs in smart homes is demonstrated using two use cases. In both use cases, the data collected from IoT devices and the cloud was analyzed to generate practical recommendations. In first use case, trends in environmental parameters were evaluated to optimize home automation rules. In second use case, energy consumption patterns were correlated with solar energy generation to enhance energy efficiency.

The first research question, "*How can DTs of smart home systems be utilized to enhance energy efficiency and promote environmental sustainability?*" was addressed in chapter *4. Outcomes of implementing DTs in living spaces*. Through two use cases, this chapter demonstrated how DTs can support sustainable electricity usage and effectively manage environmental conditions by helping to create optimal living environments.

The second research question, "*What are the key challenges in developing and integrating DTs with IoT devices and cloud-based systems in smart home ecosystems?*" was answered in chapter 4 also. Developing and integrating DTs in smart homes involves challenges such as real-time data integration, scalability, and ensuring data security and privacy. Additionally, factors like implementation costs, system reliability, and user-friendly interfaces should be addressed to unlock their potential.

The third research question: "*How can the implementation of DTs in smart homes, supported by IoT devices and cloud platforms, drive innovation and align with broader trends in smart city development?*" was answered in chapter *5. Impacts of integrating DTs in smart home systems on smart city development and recommendations for creating a smart city through connected smart homes*. With the rise of smart homes that implement DTs and their connection to a single network, it is possible to develop a smart city that is easier to manage and achieves higher levels of sustainability, energy efficiency and resource optimization.

Future research should focus on extending the integration of DTs from individual smart homes to interconnected networks that form the foundation of smart cities. Building on the results of this study, the next step would be to explore how data from multiple smart homes, such as energy production from solar panels or environmental conditions managed through IoT devices, can be aggregated and analyzed at a city-wide scale. This could enable more efficient resource allocation, such as balancing energy supply and demand across neighborhoods and improving urban sustainability. Developing standardized protocols for data sharing between smart homes and city infrastructure would be crucial to ensure seamless interoperability and scalability.

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THE IMPACT OF DIGITAL INNOVATION ON BUSINESS COMMUNICATION AND MANAGEMENT

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ABSTRACT

This research examines the impact of digitalization on business communication, focusing on the use of tools and platforms such as email and social media. It explores how these technologies enhance communication efficiency, support decision-making, and foster collaboration, with particular attention to the changes driven by digital transformation and the COVID-19 pandemic. The study aims to identify the benefits and challenges associated with these tools in professional contexts. An anonymous survey was conducted among IT professionals and students in informatics and computer science to collect data on usage patterns, effectiveness, and challenges of digital communication tools. Participants reported their experiences during routine operations and under the unique circumstances of the pandemic. Key areas of focus included the frequency of tool usage, productivity improvements, and adaptations in workplace communication. The findings highlight significant adoption of digital tools, with participants emphasizing improved collaboration, faster decision-making, and increased workplace flexibility. The pandemic accelerated these trends, reinforcing the critical role of digital technologies in ensuring operational continuity. However, challenges such as security risks, technological limitations, and user adaptation were also identified, affecting the efficiency and reliability of these tools. This research contributes to understanding contemporary trends in business communication, particularly in the IT sector, and offers practical recommendations for optimizing digital tools. It provides a basis for future studies on the long-term implications of digitalization on work processes, organizational culture, and communication strategies, emphasizing the transformative role of digital platforms in modern professional environments.

Keywords*: Business communication, COVID, digitalization, influence, informatization, organization, technology*

1. INTRODUCTION

This study aims to identify key trends and insights regarding the impact of digitalization on business communication. It will explore the most represented age group within the survey demographics, their current occupations, and the number of respondents who classified their status. Special attention will be given to assessing the overall influence of digital tools on organizational communication, including which tools are most commonly used. Furthermore, the study will evaluate improvements in communication efficiency, the effect of digitalization on decision-making speed, and how technology contributes to organizational success.Challenges associated with increased use of digital tools will also be analyzed, including their impact on collaboration and which aspects of communication have been most positively affected.

The prevalence of technical issues in organizations where digital tools are standard will be examined.Finally, the study will address future trends, emphasizing how to sustain human relationships in a technology-driven environment. It will conclude with predictions about whether digitalization has advanced corporate communication positively or negatively and its role in improving information flow management and fostering development moving forward.

2. THE CONCEPT OF INFORMATIZATION IN THE BUSINESS ENVIRONMENT

Informatization, the integration of information and communication technology (ICT) into business operations, is essential for organizational efficiency, competitiveness, and strategic growth. By leveraging digitalization, businesses optimize decision-making, enhance processes, and adapt to globalization and the digital economy. **The Role of Information Managers** Information managers oversee IT strategy, implementation, and security, ensuring that systems provide timely and relevant data to support decision-making. By aligning technology with business goals, they enhance competitiveness and mitigate cybersecurity risks. **Evolution of Communication Technologies** Digital communication tools, from email to cloud-based platforms, have transformed business interactions. Social media and global networking facilitate real-time engagement, improving operational efficiency and customer relations. Organizations must continuously adapt to emerging technologies to maintain a competitive edge in an evolving digital landscape. As businesses expand globally, digital communication tools play a crucial role in coordinating operations, managing distributed teams, and maintaining client relationships. Organizations have developed specialized communication strategies to engage target markets effectively. The shift from traditional to digital communication has significantly improved business interactions and operational efficiency. With ongoing technological advancements, companies must continuously adapt to emerging communication trends to remain competitive in the dynamic global marketplace.

3. THE HISTORY OF BUSINESS COMMUNICATION IN DIGITALIZATION

The rise of digital technology has profoundly impacted the evolution of corporate communication. This transition has reshaped how companies engage both internally and externally, resulting in more efficient and effective communication processes. This study examines the shift from traditional communication methods to the digital age, highlighting key milestones and their broader implications. **Digital revolution** Initially, commercial communication mainly occurred through personal meetings, written correspondence, and later, telephone conversations. These approaches were hindered by geographical limitations and time delays. According to Jonuzi (2019, p. 46): "Modern technology has both positive and negative sides, but one thing is certain: thanks to the Internet and social media, everything can be done immediately and now." Written correspondence, such as letters and memorandums, was the dominant form of official communication, while phones offered a faster, yet still limited, method of verbal contact.The digital revolution marked a fundamental shift in commercial communication. The emergence of email, the internet, and mobile technology enabled rapid communication over long distances. Digitalization not only accelerated communication but also introduced new forms of engagement, such as video conferencing, social media, and collaboration platforms. These tools enhanced businesses' ability to share information and interact efficiently. According to Moravski (2019, p. 36): "Organization is considered one of the fundamental determinants of society, essential for the functioning of the community, society, and business organizations. For any organization to survive and sustain itself, communication is necessary."

4. REASEARCH

This survey aims to explore how digital technologies have influenced business communication within the organizations of respondents who completed the survey. Their answers will help us understand the advantages and challenges brought by digitalization and how it shapes everyday business processes. The survey is anonymous and takes an average of about three minutes to complete. It was sent to students at the Faculty of Engineering in Pula, as well as IT students and companies in the Istria County area. The number of responses is 53, while the estimated number of individuals who received the questionnaire is around 200. The target group included employees and students in the IT field, with a response rate of 26.5% (53 responses out of 200 individuals).

4.1. Which age group do you belong to? The largest number of responses came from the 25–34 age group, accounting for 56.6% of respondents. This group is most commonly found among employees in the IT sector, reflecting a professional demographic that is more inclined to participate in studies about digital tools and technologies. The goal of this question (Example 1) was to identify which group shows greater interest in the impact of digitalization on their business communication..

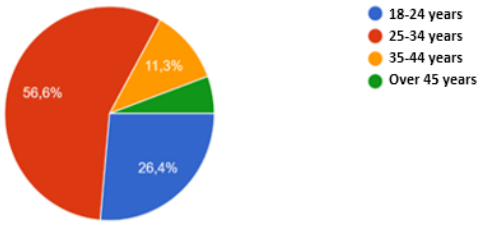

Figure 3. Age Groups Example 1 (Source: Author)

4.2. What is your current occupation? The majority of respondents identified as "Employee" for their current occupation, with 71.7% of responses (Example 2). This group includes IT industry professionals and professionals from other industries, suggesting that individuals with expertise in various work environments and a need for digital tools dominate. The aim was to assess the respondents' current occupations, providing insights into their professional environments and highlighting the ubiquity of digital tools across professions. This emphasizes the importance of understanding how different industries and job categories utilize digital technologies to better tailor technological solutions to the diverse workforce's requirements.

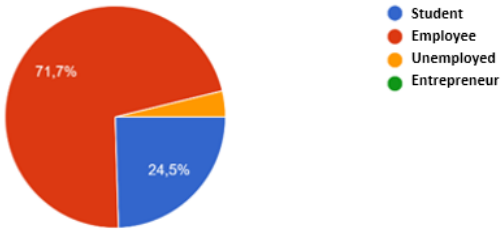

Figure 4. Current Occupations Example 2 (Source: Author)

4.3. Select the option that applies to your current status: With 66% of responses, the majority classified themselves as "I work in the IT sector" for their current job (Example 3). This group includes IT professionals and professionals from other industries, suggesting that individuals with expertise in various work scenarios and a need for digital tools dominate. Additionally, 20.8% classified themselves as "I am studying computer science/informatics." The study aimed to assess the participants' current employment to better understand the professional environment and the widespread use of digital technologies across various sectors. A smaller portion, 9.4% of respondents, selected "I work in another field." This indicates that a few participants use digital tools even if they work in industries or roles not directly associated with IT.

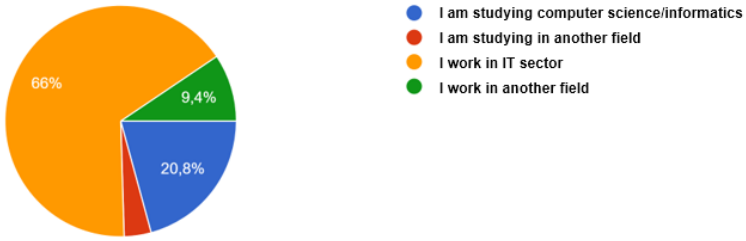

Figure 5. Your Current Status Example 3(Source: Author)

A smaller portion, 9.4% of respondents, selected "I work in another field." This indicates that a few participants use digital tools even if they work in industries or roles not directly associated with IT.

4.4. How would you rate the overall impact of digitalization on business communication in your organization? With 43.4% of respondents, the largest percentage rated the impact of digitalization as 4 (on a scale of 1 to 5). According to this evaluation (Example 4), most people believe that although digitalization has not entirely transformed corporate communication, it has significantly improved it.

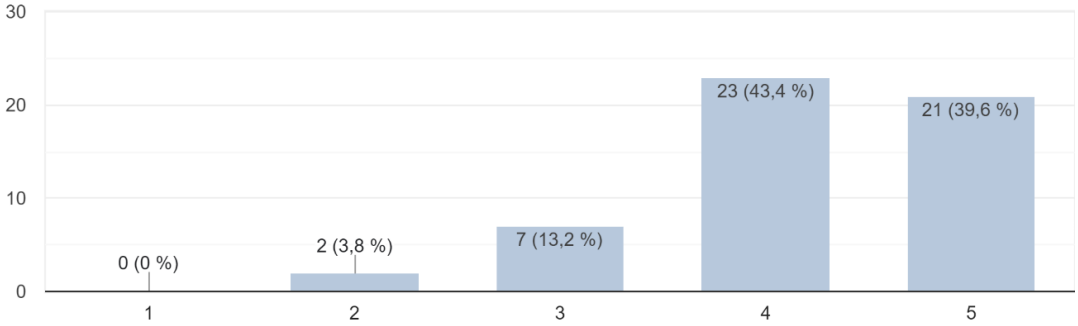

Figure 6. Rating of the Overall Impact of Informatization on Business Communication Example 4 (Source: Author)

The goal was to assess the perception of digitalization's impact on corporate communication. This question implies widespread acceptance of technology's benefits in enhancing communication processes, even though the impact is not yet complete or wholly transformative.

4.5. Which digital communication tools are most commonly used in your organization? Messaging apps, such as Slack and Microsoft Teams, are the most commonly used technologies, with 96.2% of responses. These tools are preferred for enabling quick and effective team communication. Email is the second most popular option, selected by 67.9% of respondents. Identifying and evaluating the most commonly used communication technologies in businesses was the aim of this survey. The findings (Example 5) highlight the importance of messaging apps for efficient team communication while also showcasing email's ongoing relevance for formal communication

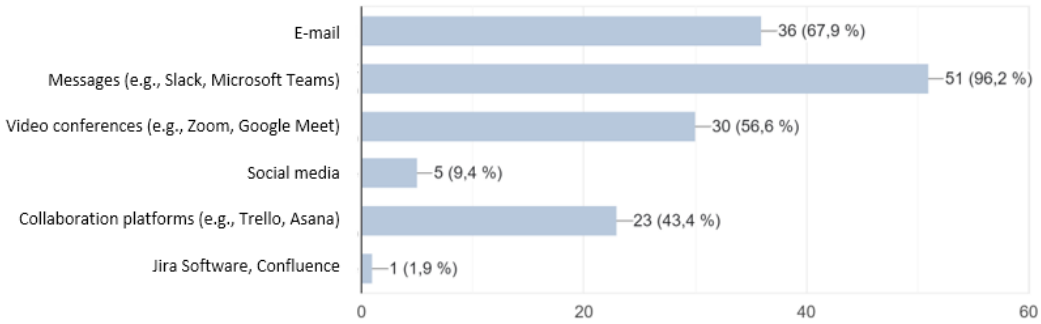

Figure 7. Most Frequently Used Digital Communication Tools Example 5 (Source: Author)

4.6. To what extent has digitalization improved communication efficiency in your organization? Most respondents rated communication efficiency improvements as 4 or 5, with 37.7% selecting five and 41.5% selecting four. This indicates that digitalization significantly enhances communication efficiency, even if it doesn't always achieve the highest level of improvement. This question (Example 6) aimed to determine how people perceive digitalization's improvement of communication operations. The graph shows a significant overall improvement in communication efficiency, though there is still room for future advancements.

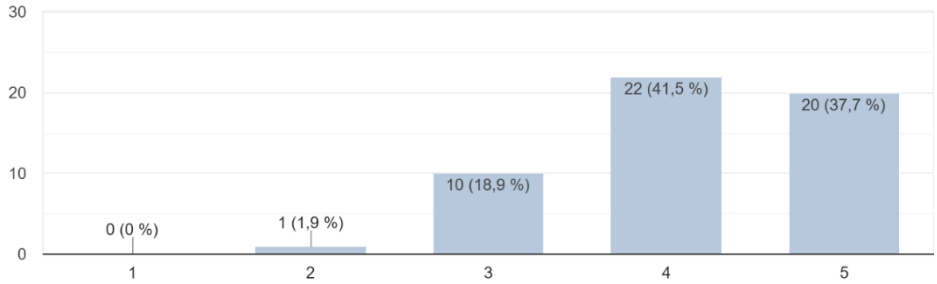

Figure 8. Measure of Communication Effectiveness in the Organization Example 6 (Source: Author)

4.7. How has digitalization impacted the speed of decision-making in your organization? When asked to rate the impact of digitalization on decision-making speed, 39.6% of respondents rated it a 4. According to this question (Example 7), digital technologies significantly help accelerate organizational decision-making processes. Additionally, 34% rated the impact a five, indicating that while digitalization significantly speeds up decision-making, more work is needed to achieve optimal efficiency.

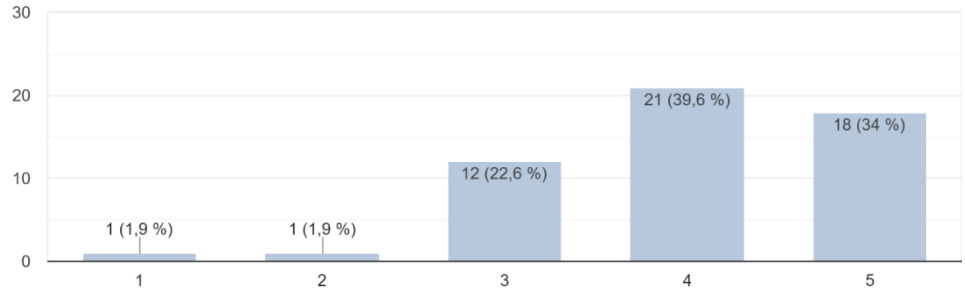

Figure 9. Decision-Making Example 7 (Source: Author)

The goal was to evaluate the impact of digital tools on decision-making speed, offering insights into how technology enhances organizational processes and areas where further development could be beneficial.

4.8. What challenges have you faced with increased use of digital communication tools? "Information overload" was the most commonly mentioned difficulty, accounting for 35.8% of responses (Example 8). Using multiple digital tools can lead to notification and information overload, which is a fundamental cause of this issue. Additionally, 28.3% of respondents cited technical difficulties, indicating that technological issues with digital tools remain a significant challenge. Furthermore, 26.4% of respondents expressed concerns about a lack of interpersonal engagement, suggesting that digital tools may reduce personal communication, potentially impacting team dynamics and collaboration. However, 35.8% of respondents stated they had not encountered significant challenges, suggesting that for some, the use of digital tools is often seamless and successful.

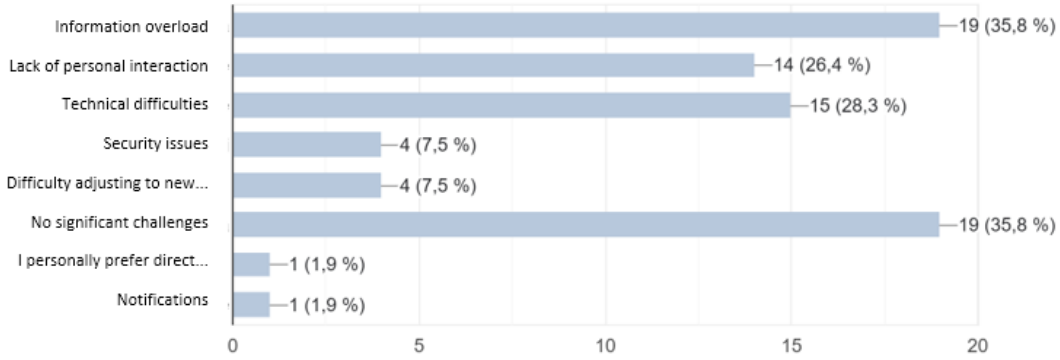

Figure 8. Challenges Encountered with Digital Communication Tools Example 8 (Source: Author)

This comprehensive evaluation continues, detailing each aspect's responses and providing insights into the trends, advantages, and challenges associated with the digitalization of business communication. Let me know if you'd like me to translate or elaborate on any specific section further.

4.9. Has digitalization improved collaboration among team members? A total of 45.3% of respondents agreed that digitalization enhances teamwork (Example 9). However, 13.2% disagreed, and 28.3% remained neutral, indicating that while digital tools improve collaboration, perceptions of their effectiveness vary.

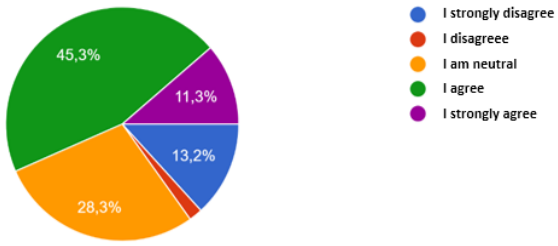

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Figure 9. Informatization Leading to Better Collaboration Example 9 (Source: Author)

4.10. How has the COVID-19 pandemic affected the adoption of digital communication tools in your organization? The pandemic accelerated the adoption of digital communication tools (Example 10) for 37.7% of respondents, with 24.5% reporting a significant acceleration. However, 20.8% stated that the pandemic had no effect, suggesting that some organizations were already technologically advanced.

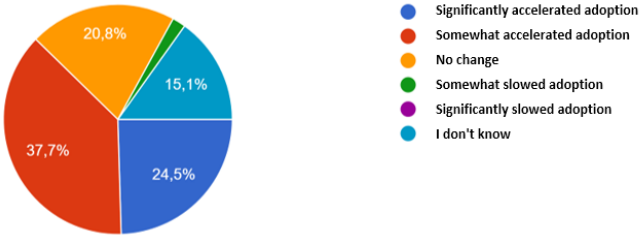

Figure 20. Impact of COVID-19 on Digital Communication Tools Example 10 (Source: Author)

4.11. Which aspect of business communication has benefited the most from digitalization? In some critical areas of corporate communication, digitalization has had a distinctly beneficial effect. According to research results (Example 11), a significant share of participants, specifically 79.2%, believe that digitalization has most favorably impacted the speed of communication and accessibility of information. According to this survey, digital technologies have enabled faster and more efficient information exchange.Additionally, although to a lesser extent, 32.1% of respondents acknowledged that digitalization had a beneficial impact on collaboration efficiency.

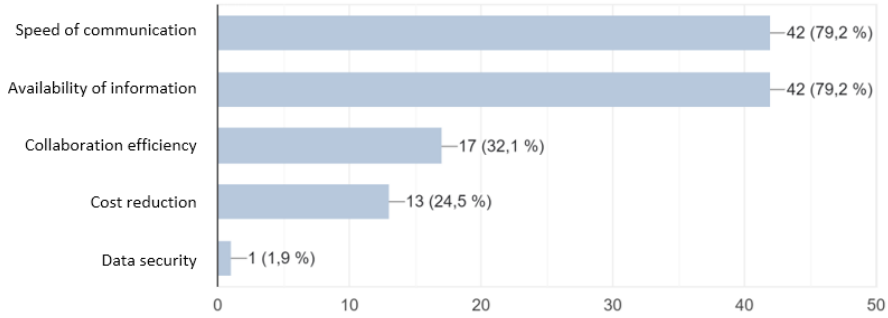

Figure 11. Assessment of Aspects of Business Communication Example 11 (Source: Author)

This finding suggests that, while digital technologies facilitate better collaboration, there are still challenges in fully integrating them into workflows, indicating that digitalization can result in financial savings, though cost reduction may not be the primary goal for all organizations—24.5% of respondents identified it as a positive element.

Conversely, only 1.9% of respondents highlighted that digitalization positively influenced data security, making it the least recognized benefit. This could mean that, despite all the advantages of digitalization, companies still perceive data security as an issue requiring more attention.

4.12. How often do you experience technical issues with digital communication tools? Although the use of digital communication tools has become standard practice in many organizations, there are evident technological shortcomings. Most respondents (66%) in the study reported that they rarely encounter technical problems with these tools (Example 12). This is encouraging, as it shows that companies have generally succeeded in maintaining robust and reliable communication networks.Nevertheless, 28.3% of respondents said they occasionally face technological issues, indicating that technology-related problems are not entirely resolved and that there are still instances where things don't work as they should. Importantly, only 3.8% of respondents reported frequent technical problems, and no one said they constantly experience issues with digital tools.

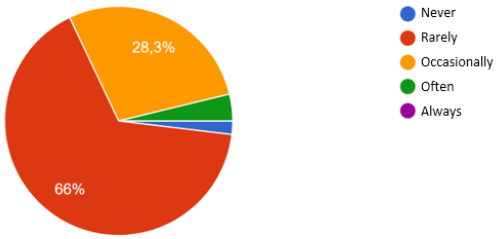

Figure 13. Technical Issues with Digital Communication Tools Example 12 (Source: Author)

This suggests that digital communication technologies are generally reliable, with sporadic problems that do not significantly disrupt work activities.All these facts point to the necessity of digital tools for business communication, especially in light of the pandemic, and the fact that most organizations have effectively overcome technological obstacles to maintain productivity and business continuity.

4.13. What are the major future trends in digitalization for business communication?"Greater integration of AI and automation," as stated by 83% of respondents, is the most significant trend (Example 13). This indicates that companies are increasingly seeking to use cutting-edge technologies to boost productivity, automate repetitive operations, and leverage data analytics to uncover deeper insights. Automation and artificial intelligence (AI) are considered key drivers of development that will help companies remain competitive in a changing market.

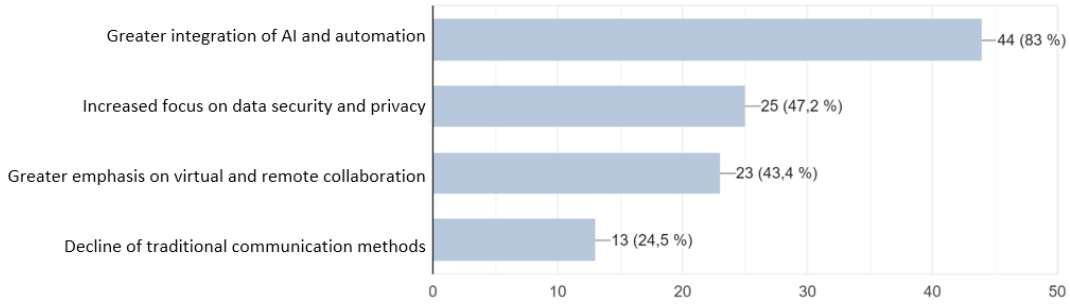

Figure 14. Future Trends of Informatization in Business Communication Example 13 (Source: Author)

Another significant trend mentioned by 47.2% of participants was "Increased focus on virtual and remote collaboration." Additionally, 43.4% of participants anticipate "Greater emphasis on privacy and data security." Concerns about protecting sensitive data and ensuring compliance with data protection laws are becoming increasingly important as organizations adopt more digital technologies. This illustrates how people are becoming more aware of the dangers posed by cyberattacks and the importance of having strong security measures. As a final prediction, 24.5% of participants expect a "Decline in traditional communication methods." Conventional communication methods, such as in-person meetings and phone calls, may become less popular as digital technologies proliferate. This shift points to a broader trend toward more efficient technology-driven communication but also raises the question of how to maintain human relationships in a future dominated by digital technology.

5. CONCLUSION

The research results clearly show that business communication within organizations is significantly influenced by digitalization and affect managerial decisions. The findings indicate that most participants, particularly those belonging to the largest demographic group aged 25 to 34, believe that digital platforms such as Microsoft Teams and Slack have greatly improved communication efficiency and accelerated decision-making. Collaboration has become easier and faster thanks to these technologies, which is especially beneficial in fast-paced work environments. However, there are also drawbacks to this digitalization. The sheer volume of data these technologies provide sometimes leaves respondents feeling overwhelmed, which can occasionally hinder productivity. Furthermore, although technical issues with these tools are rare, they can occasionally present challenges that need to be addressed to ensure seamless operation. The COVID-19 pandemic has significantly accelerated the adoption of digital tools and highlighted the urgent need for more thorough integration of technology into business operations. This trend is likely to continue, with an increasing focus on utilizing automation, virtual collaboration, and artificial intelligence as key elements of modern commercial processes. In conclusion, it is undeniable that digitalization has accelerated and enhanced corporate communication, affectin as well management strategies. However, to effectively benefit from digital technologies, organizations must focus on improving the management of information flow and addressing any technological challenges. The tools and how we use them will continue to evolve as technology advances. The pandemic underscored the need for flexibility and forced companies to embrace online operations, which is a significant step forward. Further **quantitative research is necessary** to provide a more in-depth analysis of the topic; however, this study highlights its significance and offers initial insights.

ACKNOWLEDGEMENT: *I would like to express my sincere gratitude to everyone who contributed to the completion of this research and supported me throughout this journey.First and foremost, I would like to thank my supervisor for their invaluable guidance, insight, and encouragement. Their constant support and constructive feedback were crucial in shaping the direction of this research and in helping me achieve the best possible outcome.*

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IMPORTANCE OF ICT IN HUMAN RESOURCES MANAGEMENT AND EVALUATION IN EVENTS MANAGEMENT

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ABSTRACT
One of the areas where communication and information technology can be used effectively is Events. Electronic human resources management is the use of information technology for human resources applications that enable easy interaction between employees and employers. The possibilities of technology for human resources management are endless. Today, this is strongly felt through the stages of event management, especially through human resources management. In principle, all human resources processes are supported by technology. The paper describes how communication and information technology can be used effectively in the planning and management of human resources in the organization of events.
Keywords: *Event management, Human resources, Organization of Event, ICT, Electronic human resource management*

1. INTRODUCTION

What is event management? According to Getz (2005), "event management encompasses the planning and production of all types of events." Another definition is that given by Goldblatt (2002), who defines event management as "an occupation that requires public gatherings for the purposes of celebration, education, marketing, and reunion." The author argues that the word purpose is key in event management. In fact, it is said that event managers determine a purpose and direct their efforts to achieve that purpose. The author thus highlights four different purposes:

- celebration – includes festivities such as fairs, festivals, and other social events
- education – includes events such as promotions, alumni events, meetings
- marketing – events can be used as marketing tools to raise awareness and increase sales, a practice known as event marketing
- reunion – includes an event with the purpose of remembering or rekindling old contacts and friendships.

Goldblatt (2002) defines an event manager as "a person responsible for researching, designing, planning, coordinating, and evaluating an event." Stakeholders are "individuals or financial organizations that have an emotional or personal connection to an event." Events have played an important role in societies for thousands of years, from sporting events and feasts to religious celebrations. The event industry has experienced tremendous growth in the size and importance

of events over the past decade. As a result, colleges, universities, and universities are placing greater emphasis on this subject, which is contributing to the proliferation of more educated and versatile event managers. In fact, today's event managers have skills that can be used for events in many different settings. When planning an event, event managers will also need to consider the 5Ws, known as the elements of an event (who, where, when, what, why). Many theorists, especially those in journalism and the media industry, also introduce an H (how).

Who? It refers to the target audience of the event. This can vary depending on the specific event, and event planners need to know who will be attending the event. What needs to be included is knowledge of age groups, gender, whether they are singles/couples/families, whether they know each other, and the expected number of attendees. Their basic characteristics will influence decisions about the location and time of the event, for example.

What? It refers to the type of event and will influence the way it is planned and designed. Event planners need to specify the type of event: is it a social event, a corporate event, a charity event, or a fundraising event?

When? Event planners need to define when the event will take place – the time of day, date, time, week, and time of year. Moreover, the length of the event must also be specified (Wolf, Wolf, & Levine, 2005). Event planners need to carefully select the time of day, which depends on the audience and the type of event (Hoyle, 2002).
In addition, care should be taken to ensure that the event does not disrupt the natural, predetermined rhythm of events determined by the local population.

Where? The location of the event has a key impact on its success. Several factors should be considered when choosing a location: capacity, logistics, and proximity (Wolf, Wolf, & Levine, 2005). Events can be organized indoors or outdoors.

Why? The purpose/reason for the event should be stated. For an event to be successful, it needs to have a strong purpose. Good examples are commemorating important events from the past, opening ceremonies, and hosting a sporting even.

Table 1. Event elements

Why?	emphasize the benefits describe the reasons for the event apply a personal approach refer to the needs
Who?	national, regional, state, local audience disciplined audience and audience interests awareness of the nature of the event experience level (from novice, uninitiated to expert)
When?	market schedules/patterns time of day days of the week time of year (season)
Where?	uniqueness of the place convenience travel accessibility availability of local support explain the purpose of the event set and create expectations prioritize and identify program features
Whot?	explain the purpose of the event set and create expectations prioritize and identify program features

The project will go through several phases or stages. Golblatt (2002) organizes the phases or stages that a project should go through as follows:

1. research and design
2. planning
3. organization and coordination of teams
4. evaluation.

2. STARTING THE PROJECT INITIATION

The first phase of project management, initiation, is characterized by the idea of developing an event and setting goals. It may be a vague idea at the moment, for example, that the city should organize a certain festival, promote a heritage resource, whether fixed or movable, or that it could be the promoter of a concert for the preservation of the sea, rivers and protected areas, or organize a celebration of Victory and Homeland Gratitude Day, but this idea needs to be translated into a project. Each phase of initiation may include a feasibility study. The feasibility study of the project will report on the sustainability of the event and the management required to implement it. It may include suggestions for locations and dates, possible sponsors and supporters, a draft budget, possible risks, necessary management and logistics of the event. The feasibility study may include a number of alternative event configurations so that the client or sponsor can choose the best options that will suit them. The initiation phase is linked to and overlaps with the strategic planning process, as explained below, and with the involvement of participants. The project goals will relate to the goals of the host, those for whom it is being done, and the protection of the event sponsors. The end of the initiation phase is characterized by the decision itself as to whether it is wise to continue the project or not.

2.1.Planning

Planning is characterized by the elaboration of what needs to be done in a project and how it will all fit together. The main role of project management is to integrate all these plans. For this reason, they are often called basic plans and are considered a starting point, not a finished plan. Once these plans have been developed, they need to be implemented through event management strategies. The event is widely recognized as a presentation opportunity, as a powerful economic and tourism generator, as a bringer of new products to the community and as a creator of social benefits for the host destination.

2.2.Implementation

The characteristics of implementation in project management itself are:

• implementing all plans, such as hiring staff, sending out requests for bids, confirming contractors and implementing the promotional schedule
• monitoring and control – testing plans and checking how relevant they are as the organization progresses
• making decisions based on a comparison between plans and reality
• reporting progress to key stakeholders
• active risk management.

2.3.Event

Unlike civil engineering project management, the event manager works on a project during the event. During the event, tasks and responsibilities continue continuously, regardless of what management wants to happen. The number of staff during the event, including volunteers, can increase dramatically.

The short duration and presence of key stakeholders, audiences and participants means that management cannot rely on the same management techniques that are used during the preparation for the event. This is recognised in all cases where the activity manager, artistic director or stage manager takes over the management of the event. In theatre, at an agreed time before the performance, the stage manager is considered the ultimate authority. At a certain time before the event, the management team will go into 'operational mode', which could mean leaving the office and preparing for the event. Monitoring and supervision are then transferred to other teams and management now runs the event themselves, looking for errors along the way and making decisions on the spot.

2.4.Closing the project

The event manager will be responsible for closing the event. This is the final stage and requires a separate set of tasks and responsibilities. There are specific tools and techniques for the project closure phase. Management will scale back activities and return to the pre-event formation. This phase includes on-site closure and management completion. Closure plans will be developed during the planning phase, and closure is the ideal execution of all plans. The closure phase can take an event from an initial, apparent success to a complete failure if management does not act correctly at the time of closure. Closure involves preparation for the next event.

3. HUMAN RESOURCES MANAGEMENT IN THE EVENT INDUSTRY

Human Resources Management in the Event Industry provides insight into the processes and practices of human resources management that are characteristic and applicable to event organization (staffing, training, management, employee and volunteer motivation). The necessity of a special look at human resources management in event organization and production is justified by the differences between the discourses of conventional business organization and event organization. The event category differs from the classic business context by the intermittent, pulsating and instantaneous nature of its organization.

Human resources and time are among the most important components of the success of any event manager. If you can manage your time and your people in today's event environment, your chances of success are increasing rapidly and give you the opportunity to survive and succeed as an event manager in today's fast-paced world. It's never too late to start implementing new time management techniques, invent new employee reward programs, or simply sit down with your employees to develop better, more quality procedures, such as supplier contracts. The possibilities are endless if you are creative and open to positive criticism. It is very important to evaluate the current situation, think objectively about the situation and determine what is needed in the internal organization for improvement and what you can do to contribute to this improvement. Human resource management in the event management industry is first and foremost a service industry, and therefore its vital part consists of intangible things such as customer service. You can't touch it, you can't smell it, but it is there, and what is more, it can make or break your event. You are paid to create memorable, positive experiences that will stay with every guest, and you and your staff are a key resource that makes that experience memorable. Issues of human resource organization, training, and employee retention are extremely important if you want to remain competitive. For example, most and event management companies offer similar services, but it is the people who make the difference. If we take a particular organization as an example, and more or less true for all, it is unlikely that Lions Club members will attend next year's convention if they had a bad experience this year, and without trained and experienced people it is impossible to succeed.

Therefore, you should always remember that you and your colleagues are the most important asset of any event organization. The global human resources sector has undergone major changes in recent years, with the large European market becoming increasingly closer and more accessible. Given the growth of the global economy, labor turnover has increased in many areas, including the event management field. The average five-year employee retention rate has decreased to about a year and a half per employee. This high turnover has become a challenge for human resources and department managers. In these circumstances, motivating employees and trying to provide them with a more generous offer through various soft benefits and, if possible, with monetary rewards is more important than ever. Benefits such as travel, employee meals, subsidized parking in major cities, appreciation for a well-run event, performance awards, and company-paid training and entertainment are no longer uncommon. In many cases, you can greatly motivate your employees by creating opportunities for growth and learning, supporting promotions, and creating valuable titles. An effective event manager looks for opportunities to celebrate the individual and the success of the company. Your team will readily recognize that any good deed can be rewarded if you are willing to take the time to notice it and mark the occasion. This is especially true for volunteers who work for long periods without financial compensation. Currently, women are significantly more represented in the profession than men. However, this could change in the future to better represent gender equality.

4. COMMUNICATION SKILLS

While communication is a critical component of the entire event process, it is also the single biggest culprit when it comes to problems that can arise. How many times has a lack of communication or, more commonly, miscommunication resulted in a missed opportunity, a mistake, an oversight, or even a dangerous situation? While an event manager doesn't have to be particularly articulate or even eloquent, they do need to be an excellent communicator. Communication is a continuous process that involves both sending (transmitting) and receiving information. This information can be verbal, written, or even abstract symbols, such as body language. An event manager must be able to receive and convey complex information to multiple stakeholders throughout the event process. Therefore, an event manager must be an excellent communicator from the research process through to evaluation. Here are the most common communication problems that can affect the event management planning process and suggestions for how to correct them:

- Stakeholders are not receiving communication – acknowledge receipt.
- Stakeholders misunderstand communication – ask questions.
- Communication between stakeholders is blocked – promote open communication.

Without open and continuous communication, event stakeholders cannot form the collaborative team needed to achieve common goals. Open communication needs to be encouraged, and the event manager must listen, analyze, and act. To listen effectively, the event manager must be intuitive, set specific criteria for analyzing the facts, and, if necessary, act quickly and decisively to unblock communication between stakeholders.

5. EMERGING TECHNOLOGICAL TOOLS IN EVENT MANAGEMENT

Knowing event technology trends and adopting the most valuable and effective ones to run various types of events successfully gives planners and developers new approaches and venues for a competitive advantage over their rivals. Technology makes more versatile applications to appeal to all kind of event consumers. The technology also can improve organized events, attract more customers and allows automation at a certain access points.

Apps help event planners create a customized visitor experience. The event companies are changing their mindset for transforming themselves to suit and appeal the consumers with new event technology. Companies are using technology to stay closer to their customers, using social media to create awareness and using websites to share information and improve and grow collaboration among partners and stakeholders (Kang, Tang & Fiore, 2014). Due to the rapid growth, development and competition surrounding of many events (Goldblatt, 2008) technological applications are being widely used throughout all the phases of event management (Sherlock & O'Connor, 2014). Technology is constantly evolving. Digital transformation using digital technology to automate standard processes is an essential and viable trend in every phase of our daily life and life of all businesses. Technology is not only transforming the way we do business but also helping people to lead more comfortable lifes with more affordable gadgets and applications. With technology becoming increasingly dominant in society and in the events industry, the shape and procedures have changed due the innovations and developments in event technologies (Bizzabo, 2019). The role of technology in the events industry is becoming increasingly important with the dominance of technology. Technology in recent years has gained a dominant role in developing and planning events (Peacock, 1995) and had a major part to play in the growth, development and feasibility of many events (Goldblatt, 2008). Utilizing technology in the events industry means more professional planning, more reliable and flexible execution, new products, services and offerings for every needs and expectations of costumers and superior transport along with the benefit of globalization (Krugman & Wright, 2007). Recent development in technology has been incomparably astonishing, cutting across all area of human lifestyle. It ranges from series of events like technology meetings and trade shows to techno shows where robots, artificial intelligence and new equipments meets the every expectation of attendees. And many of these event trends keep exhibiting new innovations (Hindman, 2018). While Information and Communication Technologies create a difference for event planners around the world, it is important to consider how it changes the event industry. Events become some of the top priority businesses for marketers. There is a continuously increasing demand and supply of events. They help to generate new businesses at destinations, create new jobs and help improve the image of destinations.

Event organizers are now able to capture data from preferences of interest in various sessions at congress and develop products and services accordingly. Successful event management needs distinct sets of activities from each other and needs different skills to develop, plan, structure and run an event, what are widely regarded as the functions of management. Efficient management of large crowded events has been always a challenging situation. Successful management of such events largely depends on the effective use of technologies. The advances in technology, communication technology, the linking of information and the internet (Goldblatt, 2008) along with other innovations, have affected the marketing of events and created a global opportunity to enter new markets (Bowdin et al., 2011; Getz, 2012). There are many business cases where the use of latest technology can vastly improve their management. In recent times, many types of artificial and sensor devices, including RFID tags, have been developed and effectively used in event environments. Such technologies, combined with appropriate systems, can be used to improve the crowds and flow of event at every step. It is important that event developers employ advance technology to gather insights, use this information to improve customer experience, and monitor and track results. In order to achieve this end, businesses need a detailed digital strategy that covers all aspects of the event

6. CONCLUSION

Electronic human resources management is the use of information technology for human resources applications that enable easy interaction between employees and employers. The possibilities of technology for human resources management are endless. Today, this is strongly felt through the stages of event management, especially through human resources management. In principle, all human resources processes are supported by technology. The paper describes how communication and information technology can be used effectively in the planning and management of human resources in the organization of events. Also, the complexity of managing employees and volunteers is closely linked to the dynamic nature of the organization and therefore requires constant review throughout the event cycle so that short-term changes can be made in response to common fluctuations in customer presence and different transitions through the event phases. Employee retention can be facilitated through learning and development processes, all in line with the strategic requirements of the event and its organizers.

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SUSTAINABILITY PAYS OFF: THE CASE FOR ECO-FRIENDLY PACKAGING

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ABSTRACT

Amid the ever-increasing pressure on industries to adopt more sustainable practices, the transition to sustainable packaging represents both a big challenge and a great opportunity. This article emphasizes the transformative potential of packaging that deals with the environmental problem as well as the profit headroom, and thus, reshaping the food sector. The analysis sheds light on the emerging green revolution in packaging, examining groundbreaking materials by taking cellulose as a solid example, as well as their positive ecological impact. The article brings forth the mythical notion of high sustainability costs being debunked by asserting that packaging made from eco-friendly materials, in the long run, is much cheaper, use fewer resources, and create new market opportunities. Backed by financial and environmental metrics, like the infamous ROI (Return On Investment) and life cycle assessment through an LCC analysis (Life Cycle Costing), we present the way that businesses are able to track the dual benefits of both sustainability and profitability. The article-induced examples of successful projects that were conducted jointly by researchers and companies motivate other companies to implement the sustainable packaging as a key strategy for growing their business in the future, experiencing the benefits of it as the strategic and reputational advantages of the company. Finally, the article finishes with a call to collaborate in the development of the Mediterranean model for sustainable packaging innovation via initiatives like EVOLVEPACK.

Keywords*: Sustainability, Packaging, Profitability, Life Cycle Costing*

1. INTRODUCTION

« What if adopting environmentally-friendly packaging also became the key to sustainable, long-term profitability? »

A question as provocative as it is thought-provoking, urging us to reconsider the correlation between ecologically sustainable practices and economically performance boosters. Enterprises can no longer choose to overlook the imperative of transitioning to more environmentally responsible practices when faced with the global challenges of climate change, dwindling

natural resources and rapid societal expectations. In this regard, the food packaging sector is a key player. At the crossroads of environmental, social and economic considerations, it embodies an area where innovation can transform constraints into strategic opportunities. However, the belief that ecological choices can also generate financial benefits is often framed as a paradox. This research, supported by the EVOLVEPACK project, endeavors to lift this veil of uncertainty by demonstrating that sustainable packaging is not only good for the planet, but can also be a source of lasting profitability.

Through the combination of quantitative assessments and strategic evaluations, the ambit of this study is to answer a fundamental question: how can companies achieve a balance between profitability and sustainability, and what lessons can be learned to build a more resilient and inclusive economic future?

2. THEORETICAL FRAMEWORK: THE EVOLUTION OF SUSTAINABILITY & ITS CONTEMPORARY RELEVANCE

Although the concept of sustainability has been gaining traction in the past few decades, its origins lie in a centuries-old intellectual tradition that has been altered by changes in scientific knowledge, philosophical inquiry, and societal priorities. Sustainability has evolved into an extensive paradigm that takes into consideration ecological, social, and economic factors. What started out as a pragmatic concern for the long-term durability of resources has since developed into a fundamental idea that pushes sectors to reconsider their long-standing traditional practices. In particular, conventional packaging—once thought to be a harmless necessity—is now recognized as an ecological dead end. The increasing demands of waste accumulation, resource depletion, and environmental degradation in the packaging sector have demonstrated the unsustainable nature of existing packing practices, calling for swift and drastic change.

2.1 Integration and Multidimensionality

Initially, sustainability was the answer to the need of the natural environment preservation and protection and thus it sprouted through the responsible resource management. Ancient civilizations that depended on nature understood the limitations of their resources, and adopted strategies that were to balance the ecosystem. By way of illustration, Mesopotamia was one of the world's first urban societies where canals were dug to make the unpredictable water supply more reliable and manageable. Similarly, in the Nile Valley, the Egyptians understood the seasonal nature of flooding and implemented agricultural methods that were in sync with the river's annual inundation, ensuring the fertility of the land for future generations (Butzer, 2020)[1]. These early practices, although lacking modern scientific knowledge, were based on a deep awareness and recognition of resource constraints and the need to prevent decline. Today, sustainability goes beyond environmental issues to include economic and social aspects. The development was captured by John Elkington's Triple Bottom Line (TBL) approach developed in 1997, which emphasizes the necessity of finding & achieving a balance between profit, people, and the environment, calling them the 3Ps (Profit, People & Planet). The Sustainable Development Goals (SDGs) of the UN are a formalization of this integrated approach as they cover a wide variety of global issues from gender equality to climate action. In addition to these frameworks, corporate responsibility models have become more popular, guaranteeing that companies match their social and environmental projects with long-term financial objectives.

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Another concept supporting this shift is the circular economy, it focuses on minimizing waste and maximizing resource reuse. Its principles challenge the linear line of thought pillared on the «take, make, dispose» approach by encouraging the redesign of systems and products for longevity and reusability, and eventually, forming a regenerative system (Geissdoerfer et al., 2017)[2]. One key sector impacted by this transition is the food packaging industry, where the adoption of bioplastics and plant-based materials is reducing the reliance on conventional plastic packaging and promoting circularity. An example of such is that biodegradable packaging materials such as **PLA (polylactic acid)** and **PHA (polyhydroxyalkanoates)** which are progressively gaining traction not only due to their environmental advantages, but also their integration back into the natural cycles which, in part, reduces waste (Geyer et al., 2017)[3]. These innovations exemplify how sustainable practices can yield economic returns through waste minimization and product innovation. (Wautelet, 2018)[4]

Businesses reducing their ecological footprint while simultaneously unlocking economic opportunities is exactly what the project at hand, EVOLVEPACK, offers. As the *Triple Bottom Line* (TBL) approach asserts, sustainability in business is not just about environmental responsibility but also involves creating value for society and securing long-term profitability. Companies that align their operations with TBL principles can leverage sustainability as a strategic tool, enhancing their competitive edge while contributing to broader societal goals.
Another approach that furthers enriches the said opportunity is Life Cycle Costing (LCC) providing a comprehensive view of a product's costs over its entire lifecycle. We can trace back its origins to the mid-1960s when it was introduced by the United States Department of Defense as a decision-making tool. In 1971, The Royal Institution of Chartered Surveyors (RICS) developed a method for collecting data on building operational costs, known as the Building Maintenance Cost Information Service (BMCIS). Subsequently, the British Ministry of Industry expanded on this with the 1977 publication Lifecycle Costing in the Management of Assets.

Ulrich Bogenstätter later emphasized the value of active LCC calculations in early design phases, proposing a model that incorporated standardized typological figures. (Bogenstätter 2000)[5] These advancements culminated in the acceptance of LCC as a British Standard in 1992, further refined with its inclusion in ISO 15686 Part 1 - Service Life Planning in 2000.

Defined by **ISO 15686**, LCC is described as *« a technique which enables comparative cost assessments to be made over a specified period of time, taking into account all relevant economic factors both in terms of initial costs and future operational costs. »* This comprehensive perspective allows stakeholders to make informed decisions by balancing immediate expenditures with long-term financial implications. The LCC's importance becomes more evident when evaluating the cost-effectiveness of sustainable packaging alternatives, which may have higher upfront costs but yield long-term savings and environmental benefits.

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A concrete and recent example of how an LCC can be performed is the figure below showing the lifecycle stages of a cellulose based form of sustainable packaging; trays, developed by our partners in the EVOLVEPACK project.

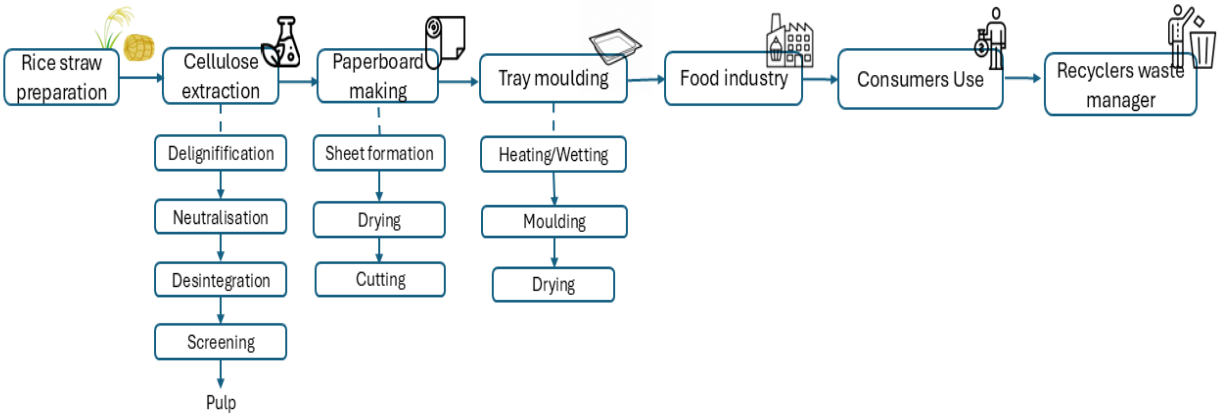

Figure 1: Lifecycle Stages of the cellulose-based trays
Source: our partners within the EVOLVEPACK project

The Life Cycle Cost (LCC) analysis of cellulose-based trays spans all seven stages of the product's lifecycle. To streamline this analysis, the development of a robust model is crucial. A particularly effective yet underutilized approach involves harnessing the econometric modeling intricacies inherent in the LCC framework.

2.2 Stakeholder Theory and Corporate Responsibility

Stakeholder theory is the most well-known of the deeper theoretical frameworks that support the shift to circular economy models and sustainability-driven packaging practices, in addition to being a reactive response to environmental concerns (Freeman, 1984)[6]. According to this idea, companies should take into account not only the interests of shareholders but also the demands and preferences of other significant stakeholders, such as suppliers, customers, employees, and—most importantly—the environment. Aligning these divergent interests is essential to achieving sustained growth because it encourages a well-rounded approach that is advantageous to all stakeholders. In the packaging realm, this alignment is essential. Businesses adopting circular economy models must go further than simply comply with environmental regulations or succumb to public pressure. When sustainability is included in the foundation of corporate strategy, when ecological and financial goals are in alliance, that is exactly where the real promise of circular economy lies. To exemplify, businesses cut waste, minimize the raw materials' costs and improve their brand reputation by labeling themselves as an ecologically conscious, forward-thinking organization through the development of items for longevity, reuse and eventual recyclability.

2.3 Harnessing the Power of the Triple Bottom Line (TBL) for Transformative Impact in EVOLVEPACK

A comprehensive and multifaceted strategic approach to evaluating the wider effects of sustainability-driven initiatives, especially in industries like packaging, is offered by the Triple Bottom Line (TBL) framework. As mentioned, TBL allows companies to concurrently pursue economic growth, social equity, and environmental stewardship by assessing business

[6] **Freeman, R. E. (1984).** Strategic Management: A Stakeholder Approach. *Cambridge University Press.*

performance across its three essential pillars: profit, people, and planet. A more nuanced and balanced understanding of the value created by sustainable practices is made possible by this holistic approach, which goes beyond the specific parameters of financial returns to take into account larger societal and environmental factors. TBL serves as both a methodological lens and a strategic foundation for programs such as EVOLVEPACK, providing a thorough framework for evaluating the economic viability, social ramifications, and environmental impact of implementing sustainable packaging solutions.

Economic Sustainability: Profit as a Driver of Long-term Viability

Economic sustainability, which highlights the significance of long-term financial viability attained through strategic investments, cost optimization, and effective resource use, is at the heart of the TBL framework. This pillar highlights how sustainable packaging options have the potential to eventually spur economic growth in the context of EVOLVEPACK. These alternatives frequently result in significant long-term savings through decreased waste, resource conservation, and improved market positioning, even though they might require larger upfront investments. Furthermore, companies implementing sustainable practices are better positioned to profit from this expanding market segment as consumers become more and more conscientious, precisely in the millennial & Gen Z generations. By analyzing the entire lifecycle of these innovations—from the initial investment in alternative materials to the long-term financial and reputational benefits of reduced environmental impact—EVOLVEPACK aims to shed light on the economic feasibility of sustainable packaging. This initiative provides vital insights into how businesses can attain profitability while concurrently advancing environmental goals by evaluating the cost-benefit dynamics inherent in the adoption of sustainable packaging.

Social Sustainability: Empowering Communities and Promoting Equity

The significance of business practices that enhance societal well-being is emphasized by TBL's second pillar, People, representing social sustainability. This aspect shows just how important it is to promote moral behavior, provide fair working conditions, and foster community involvement. Social sustainability is not a side concern in EVOLVEPACK; rather, it is an integral part of the initiative's architecture. The project addresses the broader social impact by focusing on eco-friendly packaging, particularly in relation to underrepresented groups as well as small and medium-sized enterprises (SMEs). Through sustainable packaging solutions, new job prospects in green technology and materials can lead to better working conditions in local economies. For example, the move to sustainable packaging could lead to the creation of jobs in packaging design and bioplastic production, prioritizing support for undervalued groups like the female workforce as well as the low-income communities. EVOLVEPACK chose to not shy away from the transformative potential of sustainability in both environmental and social contexts, but acknowledge it and lean into it. The eco-conscious initiative promotes inclusive growth that doesn’t only value corporate profit margins, but takes it a step further by demonstrating how sustainable business practices are able to support more just, equitable and fairly treated communities, offering an ideal win-win situation.

Environmental Sustainability: Reducing Ecological Impact through Circular Economy Principles

Last but not least, the environmental pillar of TBL. The latter urges the need for businesses to minimize their ecological footprint, thereby promoting sustainability through resource conservation, waste reduction, and the application of circular economy principles.

EVOLVEPACK aligns with this pillar as well by focusing on the food packaging industry's environmental impact, particularly in the transition from conventional, resource-intensive packaging to more sustainable alternatives such as bioplastics and compostable materials. Via the adoption of circular economy strategies, EVOLVEPACK aims to reduce the use of single-use plastics, lower carbon emissions, and promote recycling and reuse. This process not only mitigates the negative effects of packaging waste but also fosters a regenerative system where materials are continually cycled back into the economy, reducing waste and conserving natural resources. The initiative's accentuation on circularity reflects its commitment to reducing the overall environmental burden of food packaging and advancing the global transition toward sustainable consumption and production patterns.

2.4 Theoretical Framework: Between Orthodoxy & Heterodoxy

Sustainability, as the revolutionizing concept that it is, has long been the focus of intense academic debate, especially as it relates to environmental and social aspects. Two prominent but opposing theoretical paradigms have resulted of this debate over time: The **Orthodox** approach, which is based on market mechanisms and economic efficiency, and the **Heterodox** approach, which questions these same ideas by advocating for systemic change and reevaluating the connection between equity, growth, and the environment. Both of these paradigms represent real-world conflicts rather than only being academic abstractions, especially when considering recent initiatives like EVOLVEPACK, a project that is designed to establish and maintain a balance between sustainability and profitability. Gaining knowledge of the areas where these methods overlap and divide can help one better understand how sustainability might be formed, utilized, and analyzed.

Orthodox Approaches: Sustainability as a Strategic Business Imperative

At the core of the Orthodox perspective on sustainability lies the theory that economic growth and environmental protection are not mutually exclusive. This paradigm is largely rooted in traditional economic thought, which stresses efficiency, resource optimization, and the idea that market mechanisms can drive sustainable development. From this vantage point, sustainability is not a constraint but an opportunity—an opportunity for businesses to enhance their profitability, reduce costs, and maintain their competitive edge in an increasingly environmentally-conscious market. This belief is particularly evident in the adoption of frameworks like the Triple Bottom Line (TBL), which emphasizes the consideration of economic, social, and environmental dimensions into business strategies. In EVOLVEPACK, the TBL framework is used as an assessment tool of the profitability of sustainable packaging solutions, suggesting that the costs of implementing green technologies may initially be high, but ultimately result in long-term savings, enhanced market positioning, and greater consumer loyalty. For businesses, sustainability, in this Orthodox sense, becomes a way to reduce environmental harm while simultaneously advancing financial goals. This notion of sustainability as a source of economic value reflects a deeply embedded belief that human innovation and technological advancement can overcome ecological limits, allowing both economic growth and environmental preservation to coexist.

Heterodox Approaches: Rethinking Growth and Capitalism

The Heterodox paradigms of sustainability look at the problem of environmental and economic growth in a completely different way from the Orthodox view, which leads to a controversy on whether it will ever be possible to harmonize the two. Heterodox theories that stem from critiques of capitalism, post-growth economics, and ecological justice contend that the capitalist

system, despite its pursuit of profit and perpetual expansion, is fundamentally opposed to the clearly finite resources of the Earth. For Heterodox theorists, the genuine challenge to the sustainability involves not only the prevailing practices of distribution and consumption but also the economic structure being remolded instead of just incremental improvements or market-based solutions. Heterodox strategies, like those sparked by the degrowth movement, argue that we should abandon the relentless quest for growth and instead concentrate on cutting back on consumption, reassessing human needs, and more fairly allocating resources. A crucial area of agreement between these two schools of thinking is the circular economy idea that forms the backbone of EVOLVEPACK. Heterodox thinkers believe that the circular economy principles offer a systemic shift away from the conventional linear model of production, consumption and disposal. This said model must be one that sets the reuse, repair and regeneration approach higher on the priority list, higher than the never-ending pursuit of expansion and profit—while Orthodox theorists are increasingly adopting it as a workable solution to resource waste. The environmental pillar of EVOLVEPACK, a driving force for change in the packaging industry towards a sustainable, biodegradable, and circular solution, is the best example of this view. This method not only deals with environmental issues but also leads to a fairer distribution of resources, by fostering local economies such as small and medium-sized enterprises (SMEs), which in turn are usually the ones neglected in the preeminent capitalist machine. Heterodox sustainability frameworks that consider social issues strive for a more open and socially responsible economic operation.

Points of Convergence: A Shared Commitment to Sustainability

Despite their differences, Orthodox and Heterodox sustainability frameworks share significant common ground, particularly in their recognition of the vital need to cut down environmental harm and ensure social fairness. Both schools of thought are on the same page in arguing that the prevailing trajectory of global production and consumption is not viable, and they both advocate for more sustainable business practices. In EVOLVEPACK, we see the convergence of these ideas in the continuous efforts to explore sustainable packaging solutions that jointly address environmental, social, and economic concerns. The project provides a case in point for an increasing recognition that sustainability is a matter of not just damage reduction but of redesigning systems to deliver resilient, just, and regenerative planets. On the other hand, Orthodox theorists are concerned mainly with resource optimization and market development by adopting sustainable mechanisms, whereas EVOLVEPACK corresponds to a circular economy and thus it challenges the traditional consumption patterns. This dual pathway perceives sustainability as a result of the economic benefits delivered by increased productivity and cost savings, in addition to the change in the system that leads to less waste and more social resilience. The convergence of the two reflects a nuanced understanding of sustainability that incorporates both short-term and immediate economic benefits as well as long-term environmental and societal implications.

Points of Divergence: The Limits of Growth

The primary point of divergence between Orthodox and Heterodox approaches remains the question of economic growth. Orthodox views tend to label growth as essential for social welfare, with their belief in the power of continued innovation and market-based solutions to allow society to grow sustainably. In contrast, Heterodox perspectives consider growth itself as problematic—arguing that unending expansion of the economy is not feasible with environmental constraints and without social equity. This tension can easily be observed in projects like EVOLVEPACK, which seeks to balance the profitability of enterprises and on the

other hand taking the responsibilities of reducing environmental impacts and promoting social well-being. While EVOLVEPACK embraces the idea of sustainable packaging as an opportunity for market growth, it also acknowledges the potential contradictions inherent in pursuing growth within a system that often prioritizes profit over people and planet. Some Heterodox theorists might argue that, while initiatives like EVOLVEPACK take their share of the spot on the social recognition spectrum, they fail to target the root cause of the environmental issues—the relentless pursuit of growth. Bottom line for these theorists is that the true path to sustainability lies not just in perfecting the relied systems but in fundamentally changing what is the power structure of production that drives economic activity.

Navigating the Tensions between Orthodoxy and Heterodoxy

The theoretical framework of sustainability in which EVOLVEPACK is exemplified occupies a unique space between these two paradigms. It is in the midst of the traditional belief in growth and the other criticism that says such growth is impossible, trying to balance the real life of profit-making with the need for radical changes in the system. By engaging with both Orthodox and Heterodox frameworks, EVOLVEPACK puts together a sustainability model that is fully aware that aligning economic growth with environmental and social responsibility can be very hard to achieve, while also demonstrating the creative solutions that lead to a future that is circular, regenerative, and equitable. Ultimately, this theoretical framework invites us to go further than the traditional environmental angle in defining true sustainability, including social justice, economic justness and the restructuring of our world's governing systems.

3. DISCUSSION & ANALYSIS

The discussion section is crucial for the synthetization of the findings related to sustainable packaging models, examining profitability metrics, and analyzing strategic and reputational benefits. It emphasizes the integration of environmental, economic, and social dimensions, hence underlining the key drivers of business sustainability. Such analysis also lays the ground for future research opportunities, introduces the proposed model and provides an overview of challenges and opportunities in transitioning towards sustainable packaging.

3.1 Profitability Metrics: A Quantitative Perspective

For instance, sustainable packaging can be profitable if profitability considers far more than the traditional areas of finance, cost, and revenue for an integrated evaluation of long-term benefits considering LCC and ROI analysis. The LCC approach helps businesses assess the full spectrum of costs associated with packaging, from procurement of the raw material to disposal, ensuring that all environmental and social costs are taken into account (Ghisellini et al., 2016)[7]. This lifecycle-based analysis allows for a more accurate comparison between conventional and sustainable packaging options, offering insights into areas where cost efficiencies can be gained through resource optimization. For instance, it could be packaging made from bioplastic or cellulose, which, although costing more initially, can have long-term cost benefits related to waste reduction and lower disposal costs, according to Murray et al. (2017)[8]. ROI models, on the other hand, quantify the financial returns from investments in sustainable packaging, factoring in initial costs and long-term gains.

[7] **Ghisellini, P., Cialani, C., & Ulgiati, S. (2016).** A Review on Circular Economy: The Expected Transition to a Balanced Interplay of Environmental and Economic Systems. *Journal of Cleaner Production*, 114, 11–32.

[8] **Murray, A., Skene, K., & Haynes, K. (2017).** The Circular Economy: An Interdisciplinary Exploration of the Concept and Application in a Global Context. *Journal of Business Ethics*, 140(3), 369–380.

While sustainable packaging solutions may appear more expensive at the outset, a robust ROI analysis often reveals that the investments pay off in terms of reduced material costs, lower waste management expenditures, and the ability to command a premium price for eco-friendly products (Bocken et al., 2016)[9]. Moreover, the NPV and IRR metrics give an idea of the period over which these investments show results, thereby furnishing businesses with the information they need to make intelligent decisions about transitioning to sustainable packaging.

3.2 Strategic and Reputational Benefits

These advantages are not limited to one or two strategic areas but are quite multifaceted. First, the companies can benefit from increasing demand for environmentally responsible products on the consumer side. Behavioral economics, supported by Heshmati (2015)[10], proved that increasingly, consumers value sustainability and are ready to pay higher prices for goods perceived as eco-friendly. Companies that embrace green packaging, besides improving their reputation, ensure a stronger competitive position. This is especially so for companies whose target markets are millennial and Gen Z consumers who consider CSR and ethics very important in business operations (Dapi et Phiri 2015).[11]

Sustainability initiatives mean brand differentiation, making a firm different from those competitors that have not embraced the sustainability of packaging. Besides, the corporate reputation will improve with an assurance of environmental stewardship and social good (Ghisellini et al., 2016)[12]. Such positioning has long-term implications for market share development from two directions: via consumers and via enhanced brand loyalty. The reputational benefits also extend to investor relations. Firms that prioritize sustainability are often viewed more favorably by investors who value Environmental, Social, and Governance (ESG) factors in their investment decisions (Bocken et al., 2016)[13]. A focus on sustainable packaging can thus improve access to capital and foster stronger relationships with socially conscious investors. To quantify what has been presented so far, an accurate example would be Procter & Gamble (P&G), a global leader in consumer goods, has achieved notable milestones in reducing its environmental footprint through innovative packaging and waste management strategies. Numbers include [14]:

- ✓ **Recycled Resin in Plastics**: By 2020, P&G doubled its use of recycled resin in plastic packaging, utilizing 52,800 tons—exceeding its target of 52,000 tons.
- ✓ **Paper Packaging**: By 2020, 99.5% of P&G's paper packaging contained recycled or third-party-certified virgin content, with plans to address the remaining 0.5%.

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[9] **Bocken, N. M., de Pauw, I., Bakker, C., & van der Grinten, B. (2016).** Product Design and Business Model Strategies for a Circular Economy. *Journal of Industrial and Production Engineering*, 33(5), 308–320.

[10] **Heshmati, A. (2015).** A Review of the Circular Economy and its Implementation. *International Journal of Green Economics*, 9(2), 117–130.

[11] **Dapi, B., & Phiri, M. A. (2015).** The Impact of Corporate Social Responsibility on Brand Loyalty. *Journal of Governance and Regulation*, 4(4), 7–14. DOI: 10.22495/jgr_v4_i1_p1

[12] **Ghisellini, P., Cialani, C., & Ulgiati, S. (2016).** A Review on Circular Economy: The Expected Transition to a Balanced Interplay of Environmental and Economic Systems. *Journal of Cleaner Production*, 114, 11–32.

[13] **Bocken, N. M., de Pauw, I., Bakker, C., & van der Grinten, B. (2016).** Product Design and Business Model Strategies for a Circular Economy. *Journal of Industrial and Production Engineering*, 33(5), 308–320.

[14] P&G 2020 Citizenship Report
https://assets.ctfassets.net/oggad6svuzkv/v5Y40XzQfGpspdBQSnzVp/5c28a0da4f28790ff09d8300c45d03a9/citizenship_report_2020_executive_summary_FINAL_updated.pdf

- ✓ **Packaging Reduction**: Since 2010, P&G avoided using more than 200,000 metric tons of packaging, achieving a 12% reduction per consumer use.
- ✓ **Zero Waste**: All P&G manufacturing plants achieved zero waste to landfill by 2020, resulting in cumulative cost savings exceeding *$2 billion*.

Another example of sustainable initiatives, and according to a report published by IKEA, the company's shift to more sustainable packaging has yielded significant cost savings. For instance, the introduction of a new paper foot construction for pallets reduced material usage by 30%, increased strength by 20%, and cut costs by 30%[15]. This demonstrates how sustainable packaging innovations can align environmental benefits with enhanced financial performance.

3.3 Future Research and Limitations

A great deal still needs to be done to advance sustainable packaging research and offer sufficiently motivating reason for its support. One locus of research that remains uncharted is the trajectory of improvement of the Life Cycle Costing model to include social and economic implications to a more substantial extent, focusing more on smaller firms that would encounter several hurdles in recognizing sustainable packaging alternatives (Murray et al., 2017). Furthermore, behavioral aspects of the responses of consumers toward environmentally friendly packaging options require further investigation, alongside the impact of global supply chain dynamics on sustainability practices and financial viability (Bocken et al., 2016). Despite these systematic biases and shortcomings, existing models mainly concentrate on large companies and miss the financial and operational burdens that small and medium-sized enterprises (SMEs) experience in their attempts at transitioning to sustainable packaging. To mitigate this limitation, econometric models can be developed to rigorously quantify the financial and operational impacts of sustainable packaging solutions. **Profitability models** analyze key performance indicators such as Net Profit Value (NPV), Return On Investment (ROI), and Internal Rate of Return (IRR) to determine the economic feasibility of adopting sustainable alternatives. **Life Cycle Cost (LCC) models** provide a comprehensive evaluation of costs incurred at every stage of the product's lifecycle, including material sourcing, manufacturing, transportation, use, and end-of-life disposal, offering insights into long-term cost efficiencies. **Comparative models** use econometric techniques to statistically analyze and compare the performance metrics of sustainable versus conventional packaging, enabling the identification of cost-benefit trade-offs and externalities. These models are indispensable for developing evidence-based strategies, optimizing resource allocation, driving innovation in the field of sustainable packaging, and, eventually, proving to enterprises that sustainability does pay off.

4. EXPANSION ON THE ECONOMIC IMPLICATIONS OF SUSTAINABLE PACKAGING

The economic implications of adopting sustainable packaging go further than just direct profitability and extend into the greater ramifications affecting businesses, policymakers, and consumers alike. These factors should be considered if businesses are to stand a realistic chance of connecting sustainability to financial success.

4.1 The Role of Government Policy and Regulation

The economic feasibility of environmentally friendly packaging items is significantly impacted by government policies. Taking the Extended Producer Responsibility (EPR) policy as an

[15] IKEA FY21 Sustainability Report
ikea_sustainability_report_fy21_4d253ede75.pdf

example, which holds producers responsible for waste management and promotes sustainable practices (Ghisellini et al., 2016). In addition to promoting the use of substitute materials, regulatory frameworks based on recyclability and biodegradability norms gradually put downward pressure on the uptake of sustainable packaging options. On top of that, tax breaks or subsidies aimed at lessening the financial hardship of switching to sustainable packaging might hasten adoption, especially for small and medium-sized businesses that might have little cash (Murray et al., 2017). Additionally, international agreements on climate change and plastic waste management, such as the **Paris Climate Treaty**, compel governments to adopt stricter environmental regulations, thereby fostering a global push toward sustainable packaging practices. (Dapi et Phiri 2015)

4.2 Technological Innovations and Material Advancements

Technological advancements in materials science and packaging technology are fundamental to reducing the costs and improving the performance of sustainable packaging solutions. Innovations in **biodegradable plastics**, **plant-based fibers**, and **recycled materials** are making sustainable packaging options more accessible and economically feasible for businesses of all sizes (Murray et al., 2017). These innovations not only reduce the environmental impact of packaging but also lower the production costs associated with traditional materials, making sustainable alternatives increasingly attractive from both an economic and ecological perspective (Bocken et al., 2016). As the development of new materials continues to evolve, businesses will increasingly be able to leverage **circular economy principles** that encourage the use of reusable, recyclable, or biodegradable packaging, significantly reducing long-term material costs (Ghisellini et al., 2016). This will ultimately help to lower overall life cycle costs, making the switch to sustainable packaging more financially viable.

4.3 Behavioral Economics and Consumer Preferences

The growing importance of consumer preferences in shaping the economic landscape cannot be overstated. **Behavioral economics** suggests that consumers are not only motivated by price but also by the ethical considerations of their purchasing decisions. Studies have shown that consumers are willing to pay a premium for products that feature **eco-friendly packaging**, driven by increasing awareness of the environmental consequences of packaging waste (Heshmati, 2015). As shown in the graph below, according to which, people in 32 different countries, as many as 97% of the Indonesian population (ID), 94% of the Mexican population (MX) and 93% of the Ugandan population (UG) showed high levels of concern, supporting the ban of single-use plastics. Additionally, 86% of the population in France (FR) and Great Britain (GB), 83% in Brazil (BR), 82% in Germany (DE), 76% in India (IN), 73% in the United States (US), and 60% in Japan (JP) also expressed significant support for this environmental measure, with the 32-country average standing at 85%. The figure portrays how widespread awareness of the importance of adopting more sustainable practices is nowadays. Businesses that align their packaging with consumer values can capitalize on this arising recognition by fostering stronger customer loyalty and higher demand for sustainably packaged products (Bocken et al., 2016).

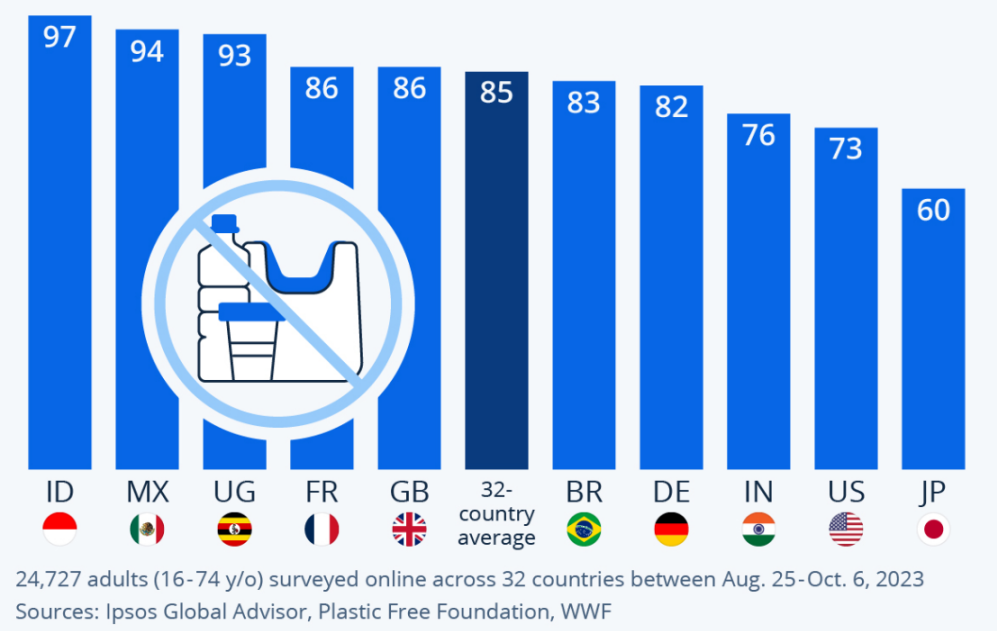

Figure 2: Graph summarizing the results of a survey conducted by Ipsos, categorized by country[16]

4.4 Financial Implications of the Transition

While transitioning to sustainable packaging entails both upfront costs and logistical challenges, the long-term financial implications are often positive. Initial costs associated with research, material procurement, and production process modifications are often offset by reduced waste disposal fees, lower material costs, and increased market share driven by consumer preference for eco-friendly products (Murray et al., 2017). Additionally, firms can benefit from **green marketing** strategies that emphasize their commitment to sustainability, which can help boost sales and build brand loyalty (Bocken et al., 2016).

5. INTEGRATING SUSTAINABILITY WITH PROFITABILITY

The integration of sustainability and profitability is a key challenge for businesses aiming to achieve long-term success while contributing positively to environmental and social goals. EVOLVEPACK proposes an approach that integrates **Life Cycle Costing (LCC)**, **ROI**, and **NPV** metrics to provide a comprehensive framework for businesses to assess the financial and environmental costs and benefits of adopting sustainable packaging. By accounting for both the direct financial returns and the long-term sustainability benefits, this model enables businesses to make data-driven decisions that align with both their profitability and sustainability goals (Ghisellini et al., 2016). The **life cycle analysis** embedded in the model helps companies identify opportunities for reducing costs through the use of recycled or biodegradable materials, while also accounting for the **reputational benefits** of adopting green packaging. In doing so, companies can simultaneously improve their financial performance and contribute to global sustainability targets.

6. CONCLUSION: THE PATH FORWARD

The transition to sustainable packaging signifies a paradigm shift in how companies balance environmental stewardship and revenue, not just a change in materials or procedures. Businesses can achieve both goals by integrating sustainability into their fundamental business

[16] https://www.statista.com/chart/32541/citizens-support-for-a-ban-on-unnecessary-single-use-plastic/

strategies: they can help meet global environmental targets while also gaining significant long-term financial and reputational advantages. Enterprises must use sustainable packaging to show their dedication to environmental responsibility and take advantage of new opportunities brought about by changing customer tastes, technology advancements, and developing regulations. Strategic foresight is necessary for this journey, utilizing sophisticated financial models and tools such as the suggested framework, which combines profitability analysis and sustainability metrics. Businesses may measure the economic viability of sustainable packaging and make data-driven decisions that meet the needs of the contemporary market by using such models. With the help of the approach mentioned in this study, businesses can efficiently anticipate returns on investment, evaluate life-cycle costs, and manage resources while navigating the challenges of sustainable transitions. Furthermore, the changing landscape depends heavily on the cooperation of governments, businesses, and academic institutions. Developments in biodegradable materials and green technology, together with policy frameworks like Extended Producer Responsibility and subsidies for sustainable activities, can greatly speed up adoption. In the end, companies that adopt sustainable practices now set themselves up as industry leaders in the future, balancing financial success with the demands of social and environmental responsibility. This multifaceted approach highlights the critical role of sustainability as a driver of innovation, resilience, and profitability. As businesses integrate sustainability into their operational ethos, they contribute to a broader vision of a regenerative economy—one that fosters growth without compromising the planet's future.

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ANALYSIS OF PROJECT MANAGEMENT IN THE IMPLEMENTATION OF A STEM DEVELOPMENT PROJECT IN A RURAL COMMUNITY

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ABSTRACT

Project management is crucial for the successful implementation of initiatives that bring social and economic benefits, particularly in sectors such as education and digital transformation. It encompasses the application of knowledge, skills, tools, and methodologies to effectively plan, execute, monitor, and complete projects within given constraints. Well-structured project management ensures that resources are utilized efficiently, risks are anticipated and mitigated, and stakeholders remain engaged throughout the project lifecycle. This paper analyzes the "AgroSTEM" project, carried out by the Association for Rural Development Ravni Kotari in Zadar County (Croatia), with the goal of promoting STEM in rural communities. The case study covers key aspects of project management, including planning, resource allocation, risk management, communication, and an analysis of project success indicators. The research methodology relies on secondary sources. The results indicate that effective resource management, efficient stakeholder communication, and adaptability are key success factors for such a project. This paper contributes to a better understanding of the challenges and best practices in managing projects aimed at STEM development in rural areas, with a particular focus on the civil sector and NGO-led initiatives. By analyzing "AgroSTEM", the study provides valuable lessons for future projects and offers recommendations for improving project sustainability, scalability, and impact on local communities.

Keywords: *Project Management, AgroSTEM, STEM, Civil Sector, Rural Development*

1. INTRODUCTION

Project management is defined as the application of knowledge, skills, tools, and techniques to project activities to meet project requirements. It involves planning, organizing, and executing tasks necessary to transform an idea into a tangible product, service, or outcome (PMI, 2023). According to the International Project Management Association (IPMA), project management is “the discipline of managing projects successfully through the application of competencies, methods, and techniques to achieve defined objectives within constraints such as time, cost, and scope” (IPMA, 2022). Effective project management is a key factor in the successful implementation of initiatives with social and economic significance, particularly in the context of developing STEM competencies among young people in rural areas.

One such project is "AgroSTEM", initiated by the Association for Rural Development Ravni Kotari. The project aimed to enhance STEM skills among children and young people in rural communities through free workshops in the fields of digital marketing and the IT sector. It included a range of educational activities such as interactive workshops, mentorship support, and the development of digital resources to promote digital literacy and improve young people's competitiveness in technology-related professions (AgroSTEM, 2023). This paper will explore the key project management elements that contribute to the success of initiatives focused on promoting STEM in rural areas. It will analyze planning strategies, resource allocation, risk management, and stakeholder communication, all of which are essential components of effective project execution as defined by both PMI and IPMA. Additionally, a SWOT analysis of the project will be conducted to identify strengths, weaknesses, opportunities, and threats in the context of project management within the civil sector. By integrating both PMI and IPMA frameworks, this paper contributes to a better understanding of the challenges and best practices in managing projects aimed at STEM development in rural areas, with a particular focus on the specific needs and obstacles in implementing a project led by a non-governmental organization (NGO). This research will provide insights into the role of structured project management methodologies in enhancing project efficiency and achieving long-term impact.

2. TEHEORETICAL BACKGROUND AND RESEARCH QUESTION

Project management is a structured approach to planning, organizing, and executing projects to achieve specific objectives within defined constraints, such as time, budget, and resources. It is a discipline that integrates various processes, including initiation, planning, execution, monitoring, and closure (Kerzner, 2022). According to the Project Management Institute (PMI), project management is *"the application of knowledge, skills, tools, and techniques to project activities to meet project requirements"* (PMI, 2023). Similarly, the International Project Management Association (IPMA) emphasizes that project management is a competency-based discipline that requires a systematic approach to planning, organizing, and leading projects to achieve defined objectives within dynamic and complex environments (IPMA, 2022). IPMA's Individual Competence Baseline (ICB4) provides a framework for managing projects based on three key competence areas: people, practice, and perspective (IPMA, 2022).

Some of key aspects of project management according to IPMA and PMI

1. Project Planning
    - Defining the project scope, objectives, and deliverables to align with stakeholder expectations.
    - IPMA (2022) highlights the importance of adaptive planning in managing uncertainties in projects, ensuring that objectives remain relevant despite changing conditions.
2. Resource Allocation
    - Managing financial, human, and technological resources efficiently to maximize project efficiency.
    - According to IPMA (2016), resource integration and optimization are essential for balancing competing project demands and ensuring long-term sustainability.

3. Risk Management
    - Identifying, assessing, and mitigating potential risks that could impact project success Khan, Z. (2013).
    - IPMA's Project Excellence Model (PEM) (IPMA, 2016) underscores the need for proactive risk assessment, integrating risk management into all project phases.
4. Stakeholder Communication
    - Ensuring effective collaboration among all project stakeholders, including sponsors, team members, and external partners.
    - IPMA (2022) stresses the role of stakeholder engagement strategies in fostering project success, particularly in multi-sector collaborations.
5. Performance Evaluation
    - Assessing the success and impact of the project using key performance indicators (KPIs).
    - IPMA (2022) advocates continuous learning and improvement, promoting the use of post-project reviews and knowledge management strategies.

By integrating methodologies from both PMI and IPMA, project managers can adopt a holistic and competency-driven approach that ensures project success while fostering innovation, adaptability, and stakeholder engagement. This competency-based approach is particularly relevant in NGO-led initiatives and social impact projects, where managing limited resources and external risks is essential to achieving sustainable outcomes. In the context of projects promoting STEM education in rural areas, effective project management is essential for ensuring the sustainability and impact of educational initiatives. It enables organizations, especially NGOs, to maximize the effectiveness of limited resources while addressing the unique challenges of rural development. STEM (Science, Technology, Engineering, and Mathematics) education is crucial for economic growth and competitiveness in the European Union. The European Commission has recognized the need to strengthen STEM skills to address challenges such as digital transformation and the green transition. A recent report by the Joint Research Centre (JRC) highlights that many students in the EU fail to reach minimum proficiency levels in key STEM subjects, particularly in mathematics and science. The report also emphasizes the shortage of qualified teachers and the need for further research to improve STEM education (European Commission, 2023). To address these challenges, the European Union is making significant investments in STEM development. For example:

- InvestAI Initiative: The EU plans to invest €200 billion in artificial intelligence, including the development of "gigafactories" to train advanced AI models (The Verge, 2024).
- Competitiveness Compass: A strategic framework aimed at simplifying regulations, supporting innovative companies, and reducing energy costs to enhance European industrial competitiveness (Financial Times, 2024).
- EU STEM Coalition: A European network shaping STEM education policies and practices to drive economic growth and innovation (STEM Coalition, 2024).

These initiatives demonstrate the EU's commitment to strengthening STEM education and skills, acknowledging their vital role in future development and global competitiveness.

Specifics of STEM Education in Rural Communities

Despite the EU's significant investments in STEM, rural areas often face challenges in accessing quality STEM education. These barriers include:

- Limited Infrastructure – lack of digital tools, laboratories, and internet access.
- Shortage of Qualified Educators – fewer STEM teachers and fewer training opportunities.
- Lower STEM Awareness – reduced exposure to STEM careers and skills.
- Economic Barriers – financial constraints that limit participation in specialized STEM programs.

To overcome these challenges, programs must focus on bridging the digital divide and increasing STEM engagement through innovative educational approaches such as:

- Online learning platforms and virtual classrooms.
- Hands-on workshops tailored to local industry needs.
- Community-based STEM initiatives that connect students with professionals.

The AgroSTEM project addressed these issues by offering free workshops in digital marketing and the IT sector to equip young people with essential skills for the job market and digital economy.

The role of the civil sector in STEM development

Non-governmental organizations (NGOs) and civil society play a crucial role in advancing STEM education, particularly in underserved areas. Unlike formal educational institutions, NGOs can (Udruga za ruralni razvoj Ravni Kotari, 2023):

- Develop flexible and community-driven programs tailored to local needs.
- Secure external funding and partnerships to expand resources.
- Provide non-formal education opportunities that complement school curricula.
- Advocate for policy changes and public awareness on the importance of STEM education.
-

NGO-led projects, such as AgroSTEM, demonstrate how the civil sector can bridge gaps in STEM education by providing free, high-quality training programs designed for rural communities. However, these initiatives often face challenges related to funding sustainability, project scalability, and stakeholder engagement, highlighting the need for strategic project management in the civil sector (Jokić M.,2023).

This paper will further analyze these challenges through a SWOT analysis, identifying the strengths, weaknesses, opportunities, and threats associated with managing an NGO-led STEM project in a rural setting.

Research Question

Based on the conducted theoretical background evaluation, the research question of this paper arises: What are the key challenges and opportunities in managing STEM education projects in rural areas, and how can NGOs optimize their project strategies to enhance impact and long-term viability?

3. METHODOLOGY, ANALYSIS AND RESULTS

METHODOLOGY

The methodology for analyzing the AgroSTEM project is based on a qualitative approach, relying exclusively on secondary sources to assess the project's implementation, effectiveness, and sustainability within the framework of project management in the civil sector. The research draws on a SWOT analysis, which identifies the project's strengths, weaknesses, opportunities, and threats. This analysis is supported by a review of secondary data, including publicly available online reports, project documentation, websites, and publications related to AgroSTEM. Additionally, literature on STEM education policies, project management frameworks (PMI and IPMA), and rural development initiatives was examined to provide contextual insights.By synthesizing information from reliable online sources, this research provides a comprehensive evaluation of the AgroSTEM project's management strategies, its role in promoting STEM education in rural areas, and recommendations for enhancing its long-term viability.

ANALYSIS

One of the biggest challenges in implementing the AgroSTEM project was maintaining financial liquidity, as the Association for Rural Development Ravni Kotari lacked a stable income source, posing risks to long-term sustainability. Strong multi-sector partnerships played a crucial role in overcoming these challenges. Municipality Zemunik Donji provided financial stability, while collaborations with University "Marko Marulić" and NGO Zajednica tehničke kulture Zadar County ensured educational quality. Additionally, NGO "Mali koraci" facilitated community outreach and participation, reinforcing the significance of integrating financial backing, academic expertise, and grassroots engagement to enhance the success of similar initiatives (European Commission, 2023; Carroll et al., 2019). Another key lesson was the need to diversify funding sources. While relying on Municipality Zemunik Donji provided initial stability, securing EU grants, corporate sponsorships, and crowdfunding initiatives would enhance financial resilience (Kerzner, 2022). Research suggests that financial diversification is a critical factor in nonprofit sustainability, particularly in education-focused initiatives (PMI, 2023). Furthermore, developing self-sustaining revenue models, such as paid workshops or certification programs, could reduce dependency on external donors while ensuring long-term project viability (Carroll et al., 2019). Despite financial constraints, AgroSTEM successfully empowered rural youth with digital marketing and IT skills, demonstrating that strategic project management, strong partnerships, and innovative funding solutions can overcome financial barriers and ensure the long-term impact of nonprofit STEM initiatives (TWFind, 2024).

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SWOT ANALYSIS

Strengths	Weaknesses
Strong partnership with Public authority (Municipality Zemunik Donji)	Lack of long-term funding stability
Utilization of partner infrastructures	Dependence on project-based funding
Experienced project management team	Shortage of STEM experts for live workshops
Clear stakeholder roles and coordination	Limited opportunity for in-person mentoring
Community engagement through NGOs	
Opportunities	Threats
Access to EU funds and private sponsorships	Uncertain long-term financial sustainability
Expansion to new rural regions	Potential cuts in public STEM funding
Networking with international STEM initiatives	Low digital literacy in target communities
Development of blended learning models	Brain drain of STEM professionals to cities

The SWOT analysis of the AgroSTEM project provides a comprehensive overview of its key strengths, weaknesses, opportunities, and threats within the framework of project management in the civil sector. The analysis focuses on resource management, stakeholder communication, adaptability, and innovation, highlighting both the project's advantages and the challenges it faces in ensuring long-term sustainability. One of the main strengths of the AgroSTEM project is its efficient resource management. A strong partnership with Municipality Zemunik Donji ensures financial stability, while leveraging the existing infrastructure of NGO Zajednica tehničke kulture Zadar County and University "Marko Marulić" optimizes educational activities. Additionally, the Ravni Kotari Association's experience in managing rural development projects contributes to the effective coordination and execution of the initiative. Another key strength is stakeholder communication, as clearly defined roles between the public, scientific, and civil sectors enhance coordination and cooperation. Furthermore, community engagement through NGO "Mali koraci" increases outreach and participation among children and young people. The project also demonstrates adaptability and innovation, with the ability to quickly adjust its content to meet participant needs, focusing on relevant areas such as digital marketing and the IT sector. The development of an online platform and mobile application ensures broader accessibility and long-term engagement with STEM content. However, the project faces several weaknesses, particularly regarding financial sustainability. The lack of stable, long-term funding sources makes it difficult to maintain continuous educational programs, as civil sector organizations often rely on project-based financing, creating uncertainty in long-term planning. Additionally, there is a shortage of STEM professionals willing to conduct in-person workshops in rural areas. While the online format addresses part of this issue, face-to-face mentoring opportunities remain limited, which can reduce the overall interactivity and effectiveness of educational activities.

Despite these challenges, the project has significant opportunities for growth and expansion. Securing additional funding sources through applications for EU funds, national STEM programs, and private sponsorships from the IT and digital marketing sectors could enhance financial security. Moreover, the project has the potential to expand into other rural regions in Croatia through new partnerships while establishing connections with international STEM initiatives and NGOs for knowledge exchange. Another promising opportunity lies in developing a hybrid education model, which would combine online resources with in-person learning experiences, ensuring greater reach and flexibility. Nonetheless, the project must navigate several threats that could impact its sustainability. Financial insecurity remains a major concern, as a lack of long-term partnerships and potential cuts in public funding could hinder future operations. Additionally, low digital literacy and resistance to change within local communities may limit engagement, as some educators and parents may struggle to adopt digital tools. Finally, competition from larger STEM initiatives poses a challenge, as better-funded projects may attract more resources and talent, potentially leading to a brain drain of skilled professionals from rural to urban areas.

RESULTS

In response to the research question—What are the key challenges and opportunities in managing STEM education projects in rural areas, and how can NGOs optimize their project strategies to enhance impact and long-term viability?—this analysis has identified both barriers and strategic solutions that influence the success of such initiatives. The AgroSTEM project exemplifies how effective resource allocation, quality stakeholder communication, and an innovative educational approach can create a sustainable STEM initiative in a rural setting. By integrating digital tools, community engagement, and adaptable learning methods, the project has successfully provided young people in underserved areas with valuable STEM competencies. However, financial stability remains a major challenge. Many rural STEM education projects, including AgroSTEM, face difficulties in securing long-term funding, as they often rely on short-term grants or donations. This financial uncertainty threatens the sustainability and scalability of the initiative.

4. CONCLUSION

The AgroSTEM project demonstrated how strategic project management can successfully promote STEM education in rural communities. Through effective resource allocation, strong stakeholder communication, and an innovative approach to digital education, the project addressed the digital skills gap and provided young people with free training in digital marketing and IT. However, the study also highlighted critical challenges in project sustainability, particularly in financial stability and the availability of STEM experts for in-person workshops. One of the key findings of this study is the importance of strong partnerships in ensuring project success. The involvement of Municipality Zemunik Donji as a financially stable partner played a crucial role in maintaining liquidity, while collaboration with scientific, public, and civil sector institutions, such as University "Marko Marulić", NGO Zajednica tehničke kulture Zadarske županije, and NGO "Mali koraci", created a well-rounded ecosystem that maximized the project's reach and impact. Despite this, financial sustainability remains a significant challenge, as NGOs typically rely on short-term project grants and lack stable funding sources. This underlines the need for diversified funding strategies, including EU grants, corporate sponsorships, and self-sustaining models such as paid advanced workshops or membership-based learning platforms.

The study also highlighted the potential of hybrid education models in maximizing the reach of STEM initiatives. The online platform and mobile application helped overcome geographic barriers, making STEM education accessible to a wider audience. However, a notable limitation was the lack of STEM experts available for in-person mentoring, which could have enhanced participant engagement and practical skill development. Strengthening mentorship programs and creating incentive structures to attract STEM professionals to rural areas would significantly improve future projects. Community engagement and awareness were also identified as vital elements for success. The collaboration with NGO "Mali koraci" played a key role in increasing youth participation, but further awareness campaigns are needed to enhance digital literacy in rural communities and ensure long-term interest in STEM fields. Future projects should focus on securing multi-year funding agreements with municipalities and private sector partners, expanding mentorship programs, and enhancing blended learning models that combine online resources with practical, hands-on learning experiences. This research has certain limitations, including its limited geographic scope, as it focuses on a specific project in Croatia, and the short-term nature of its evaluation, which does not provide insight into long-term outcomes. Additionally, while financial sustainability was identified as a key challenge, a more detailed analysis of funding models for NGO-led STEM initiatives would provide stronger strategic recommendations. Future research should explore the long-term impact of AgroSTEM on participants' career paths, compare different funding models for nonprofit STEM initiatives across Europe, and examine innovative public-private partnerships that could ensure the sustainability of STEM education projects. The AgroSTEM project serves as a valuable case study on how NGOs, public institutions, and academic partners can collaborate to promote STEM education in rural areas. While financial sustainability remains a challenge, strategic partnerships, blended learning models, and long-term funding strategies can help overcome these barriers. Future initiatives should build on these findings to develop scalable, sustainable, and impactful STEM education programs that empower young people in rural communities.

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THE ENTREPRENEURIAL INFRASTRUCTURE IN THE EXPLOITATION OF ENERGY RESOURCES IN THE CONTEXT OF THE GREEN TRANSITION – A CASE STUDY OF VARAŽDIN COUNTY

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ABSTRACT

In the context of increasing energy consumption and climate change, energy independence has become a key strategic task for the Republic of Croatia. To reduce greenhouse gas emissions through decarbonization and promote sustainable development, it is essential to explore the possibilities of utilizing renewable energy sources. Geothermal research, predominantly conducted through petroleum-geological studies, indicates significant potential, with capacity estimates exceeding 500 MWe and the potential for production ranging between 750 and 1300 MWt, alongside substantial reserves of natural gas. This form of energy offers multiple economic and environmental benefits, including reduced CO_2 emissions and contributions to the sustainability of energy development. The purpose and goal of this paper are to analyze the spatial and environmental aspects of exploiting energy resources in Varaždin County in the context of the green transition and the reduction of greenhouse gas emissions. Varaždin County, located in the Pannonian region of Croatia, is recognized as an area with high thermal gradients, indicative of the potential for utilizing geothermal energy. The history of geothermal resource research in this area is primarily based on geological studies, mainly focused on oil and gas deposits, which have revealed the presence of significant geothermal resources. Despite this, geothermal energy in Varaždin County has not yet been adequately exploited. Given the available geothermal resources, the area offers significant potential for energy production, which could substantially contribute to the region's energy independence and reduce reliance on fossil fuels. Research and exploitation activities, which are of strategic importance to the country, align with the State Spatial Development Plan, while at the local level, they are implemented according to the Varaždin County Spatial Plan (PPŽ), which defines areas designated for the exploration and exploitation of mineral resources. This approach ensures the long-term sustainability of geothermal energy use, environmental preservation, and the energy-secure development of Croatia, with a particular emphasis on Varaždin County, which possesses considerable geothermal potential that has yet to be fully utilized.

Keywords: *decarbonization, geothermal energy, renewable energy sources, Varaždin County, Green Transition*

1. INTRODUCTION

The Transition to a Neutral Energy System [1] refers to the process of shifting from traditional energy sources, which generate greenhouse gas emissions and contribute to global warming, to renewable and sustainable energy sources that produce no net greenhouse gas emissions. The goal of this transition is to achieve climate neutrality or net-zero greenhouse gas emissions. Geothermal energy, as a renewable energy source, plays a crucial role in the transition to a neutral energy system within the EU (Škrlec et al., 2019). The EU has recognized the importance of renewable energy sources and the reduction of greenhouse gas emissions to achieve carbon neutrality by mid-century. In this context, geothermal energy provides a reliable and sustainable energy source that can significantly contribute to this goal (Pavlović & Banovac, 2020). Geothermal energy offers several advantages in this process:

- Low greenhouse gas emissions: Electricity generation from geothermal energy produces very low greenhouse gas emissions, helping to reduce overall CO_2 emissions.
- Stable energy source: Geothermal energy is a stable energy source that is not affected by weather conditions, such as wind or sunlight. This is an advantage as it ensures a constant supply of electricity.
- Reduction of energy import dependency: By utilizing domestic geothermal resources, countries can reduce dependence on imported fossil fuels, contributing to greater energy independence.
- Boosting the local economy: The development of geothermal projects can create jobs and stimulate local economies, particularly in rural areas with abundant geothermal resources (Pavlović et al., 2024).

Some of the key initiatives and documents adopted by the EU to promote the use and development of geothermal energy include:

- *European Green Deal:* A key EU policy initiative that sets the ambitious goal of achieving climate neutrality by 2050. As part of this agreement, geothermal energy is highlighted as an important element in diversifying the energy mix and reducing greenhouse gas emissions.
- *EU Framework for Geothermal Energy:* The EU has developed a specific framework to encourage and promote the use of geothermal energy. This framework includes guidelines[2], legislation and financial instruments that encourage investments in geothermal projects and the research of technologies related to this energy source. This framework ensures stability and support for the development of geothermal projects across the EU.

[1] Crucial in the fight against climate change and in achieving the goal of global climate neutrality. For example, in the study "Analysis of Sustainable Energy Technologies for Achieving Carbon Neutrality: An Energy Transition Perspective" published in the journal Renewable and Sustainable Energy Reviews (2019), author A. Johnson examines the potential of renewable energy sources, including geothermal energy, in achieving carbon neutrality and states: "Renewable energy sources, such as geothermal energy, solar energy, and wind energy, play a key role in reducing greenhouse gas emissions and achieving global climate neutrality."

[2] In light of the urgent need for the EU's rapid transition to clean energy, Directive EU/2018/2001 on renewable energy underwent a thorough revision in 2023, marking a new phase in energy policy. The revised Directive EU/2023/2413, which came into effect on November 20, 2023, represents an ambitious step towards a sustainable future. Its implementation into national legislation is planned over a period of 18 months, with the exception of certain key provisions related to permits for renewable energy sources, for which the deadline is shortened to July 2024. The Directive sets clear guidelines, with the overall goal of achieving at least 42.5% renewable energy share at the EU level by 2030 (however, the ambition goes further, with a real target set at 45%).

- *Just Transition Fund:* This fund plays a key role in supporting projects related to geothermal energy and providing support for the construction of infrastructure that enables the use of this renewable energy source.
- *Horizon Europe Program:* The EU actively finances research and innovation in the field of energy, including geothermal energy, encouraging collaboration between scientists, industry, and institutions to advance technologies and increase the efficiency of geothermal energy use (Pavlović et al., 2024).

2. THE ROLE OF GEOTHERMAL ENERGY IN THE ENERGY TRANSITION

The energy transition is characterized by the gradual shift from non-renewable fossil energy sources to renewable energy sources. Given the significant differences between non-renewable and renewable energy sources, further increasing the share of renewable energy is expected to lead to a major shift in the paradigms of the energy system we know today. One of the main challenges of using the most common renewable energy sources today is their intermittency (Pavlović et al., 2018). Solar, wind, and hydro energy depend on the time of day, weather conditions, and seasonal changes. As the share of renewable energy increases, the integration of these sources into the electricity grid becomes a major challenge, particularly in terms of balancing electricity production and consumption. In recent decades, considerable attention has been focused on hydro energy and biomass, followed by wind and solar energy, which can be considered logical due to their potential, the degree of technological development, and the cost of the technology. However, when comparing potential and current utilization, it is essential to consider other renewable energy sources such as geothermal energy. It is a renewable energy source whose potential remains largely untapped (Srpak & Pavlović, 2023). It is constantly available with a very high load factor and long-term predictability of production. It can quickly adapt to various electricity needs, can be integrated with intermittent renewable energy sources, and is also suitable for use as a baseload energy source. Additionally, it requires very little space compared to other renewable energy sources and has a minimal negative impact on the environment. Apart from the electricity sector, geothermal energy can be extremely important for district heating and agriculture. Geothermal sources that are not suitable for electricity production due to lower temperatures can be used for district heating and a wide range of other industrial and agricultural activities. Geothermal energy represents an extremely important and sustainable energy source that harnesses the natural heat from the Earth's interior to generate electricity or provide thermal energy for heating and cooling (Barbier, 1997; Borović & Marković, 2015). The use of geothermal energy for balneological purposes and space heating has been known for thousands of years, and the beginning of electricity production from geothermal energy is linked to the year 1913 and the small Italian village of Larderello.[3] Geothermal energy is used worldwide today, but still to a fairly limited extent given its potential and in comparison to other renewable energy sources. According to statistics from the International Renewable Energy Agency (IRENA), the installed geothermal capacity worldwide reached around 14.9 gigawatts (GW) by the end of 2020. According to IRENA data for 2021, renewable energy sources account for about 19.5% of global energy consumption. Of this, 'modern' renewable energy sources make up about 11.4%, while geothermal energy still represents a relatively small share, approximately 0.2% of total global energy consumption.

[3] In 2023, the 110th anniversary of the first geothermal power plant in Larderello, Italy, is being celebrated. This power plant, which began operation in 1913, holds special significance in the history of geothermal energy as one of the first commercial examples of using geothermal energy for electricity generation. Larderello, located in the Tuscany region of Italy, has rich geothermal resources and has always been known as an area with great geothermal potential. The first geothermal power plant in Larderello marked a milestone in the use of geothermal energy for electricity production and laid the foundation for the further development of this renewable energy source.

Although this share seems almost negligible, interest in the development of geothermal projects is growing, and each year the installed capacity of geothermal plants as well as the production of electricity and thermal energy from geothermal sources increases. According to 2020 data, the largest geothermal capacities are in the United States (around 3.7 GW), Indonesia (around 2.1 GW), the Philippines (around 1.9 GW), and Turkey (around 1.3 GW). Over the years, these countries have made significant progress in the development of geothermal energy. **By 2023, a 28% increase in geothermal capacity is expected, reaching over 17 GW of total electricity generation capacity worldwide, along with a rise in the number of countries using geothermal energy.** In the use of geothermal energy for heating, countries like Iceland, Turkey, France, Germany, Hungary, and the Netherlands lead the way. It can be said that the use of geothermal energy for heating is significantly more widespread compared to its use for electricity generation. This is mainly due to the fact that geothermal sources of lower temperatures can be used for heating, and these sources are much more abundant. A geothermal system consists of the following elements: a heat source, a reservoir, a fluid that transfers heat, a surface for replenishment, and impermeable surface rocks that seal the aquifers. The heat source can be a magmatic intrusion of very high temperature (> 600 °C) that has reached relatively shallow depths (5 – 10 km) or, in some systems with low temperatures, the normal temperature of the Earth that increases with depth. The reservoir consists of permeable rocks from which circulating fluids (water or steam) extract heat. The reservoir is typically covered by primarily impermeable layers or rocks, resulting from the self-sealing phenomenon that occurs when minerals are deposited in cracks and pores of the rocks. The geothermal fluid is water, either in liquid form or as steam, depending on the temperature and pressure. Such water often contains minerals and gases such as CO_2, H_2S, etc. In **Figure 1,** a simplified diagram of an ideal geothermal system is shown.

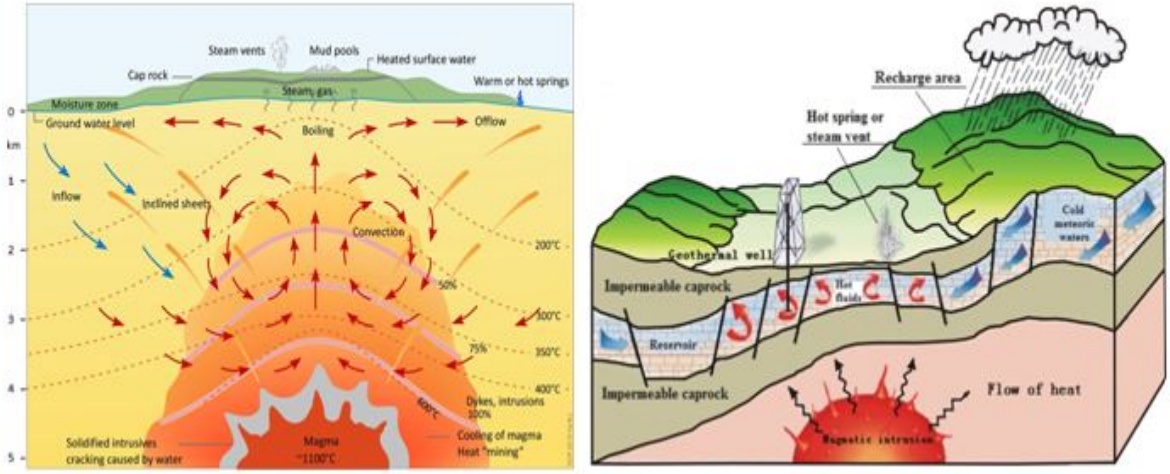

Figure 1: Two simplified models of geothermal systems
(Source: Author's adaptation from the original source – Jiaqi Liu, Xiaoyu Chen and Wenfeng Guo – UN Geothermal Training Program and Volcanic Natural Resources and Volcanic Landscape Protection)

Geothermal sources can be classified based on various criteria. One of the most common classification methods is based on the temperature of the geothermal medium (water or steam, or their mixture). Geothermal sources can be:

- Low-temperature (90 to 150°C) – These sources are characterized by lower temperatures of the geothermal medium and are usually used in heating systems, greenhouses, and other applications that require moderate heat.
- Medium-temperature (90 to 225°C) – This category includes sources with moderate temperatures of the geothermal medium (they are used in various industries, including electricity generation, heating residential and commercial spaces, and in industrial processes).
- High-temperature (150 to 225°C) – High-temperature sources represent significant potential for electricity generation and industrial applications that require high levels of heat (this category of sources is often used in geothermal power plants for generating electricity).

Geothermal potentials in the Republic of Croatia can be divided into three groups:
- Medium-temperature deposits (100 to 200°C): Velika Ciglena, Lunjkovec-Kutnjak
- Low-temperature deposits (65 to 100°C): Bizovac, Zagreb
- Geothermal sources with water temperature below 65°C.

3. SPATIAL CHARACTERISTICS AND POTENTIAL OF GEOTHERMAL ENERGY

Geothermal energy comes from the Earth's natural heat, primarily due to the decay of naturally radioactive isotopes of uranium, thorium, and potassium. Potential geothermal energy deposits are determined based on the geothermal gradient, the presence of which primarily influences the suitability of an area for the development of geothermal plants (Jelić et al., 1995). However, suitability also depends on the availability of necessary infrastructure and other specific physical-geographical characteristics of each area that determine the possibility of constructing an energy plant, and the degree of suitability varies depending on the level of technological development. Geothermal energy (in English: geothermal energy, in German: Geothermische Energie) in a narrower sense encompasses only that part of the energy from the Earth's depths that reaches the Earth's surface in the form of hot or warm geothermal media (water or steam) and is suitable for use in its original form (for bathing, therapy) or for conversion into other forms of energy – electrical energy or heat in heating systems. Geothermal energy is the result of various processes occurring deep within the Earth, where temperatures exceed 4000°C (Figure 2). It is estimated that the total thermal energy of the Earth is approximately 12.6×10^{24} MJ, with the Earth's crust containing 5.4×10^{21} MJ. The temperature of the Earth's interior increases with depth. Rocks with temperatures between 600 and 1200°C are found beneath the Earth's crust at depths of 80 to 100 km, and it is estimated that the temperature at the Earth's core, located about 6400 km deep, is around 5000°C.

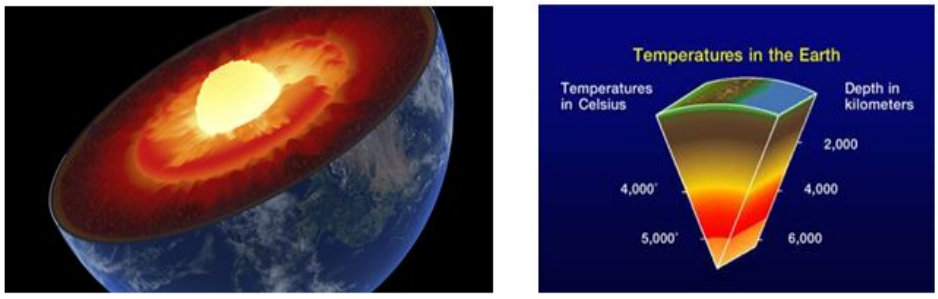

Figure 2: Earth's internal structure and temperatures in the earth (Source: Geothermal Energy Association)

Geothermal energy can be used directly (as thermal energy) or for electricity generation. Most projects combine electricity production with direct use of heat for other purposes to improve the project's economics and energy utilization (Kolbah et al., 2008; Grad, 2009). Since geothermal energy is constantly available due to continuous renewal through processes in the Earth's interior, the capacity factor of geothermal energy is higher compared to other renewable energy sources and ranges between 58% and 85%. Its value is comparable only to the capacity factor of biomass utilization (between 53% and 93%). The capacity factor for hydropower ranges between 36% and 61%, for solar photovoltaic systems between 12% and 26%, for solar thermal systems between 12 % and 31%, for onshore wind energy between 24% and 40%, and for offshore wind energy between 26 % and 36%. For comparison, the capacity factor for fossil fuels averages 53%, and for nuclear energy, it is 79%. It is crucial to highlight that a higher capacity factor of geothermal energy results in lower levelized cost of electricity production (LCOE), making geothermal energy highly competitive (Figure 3).

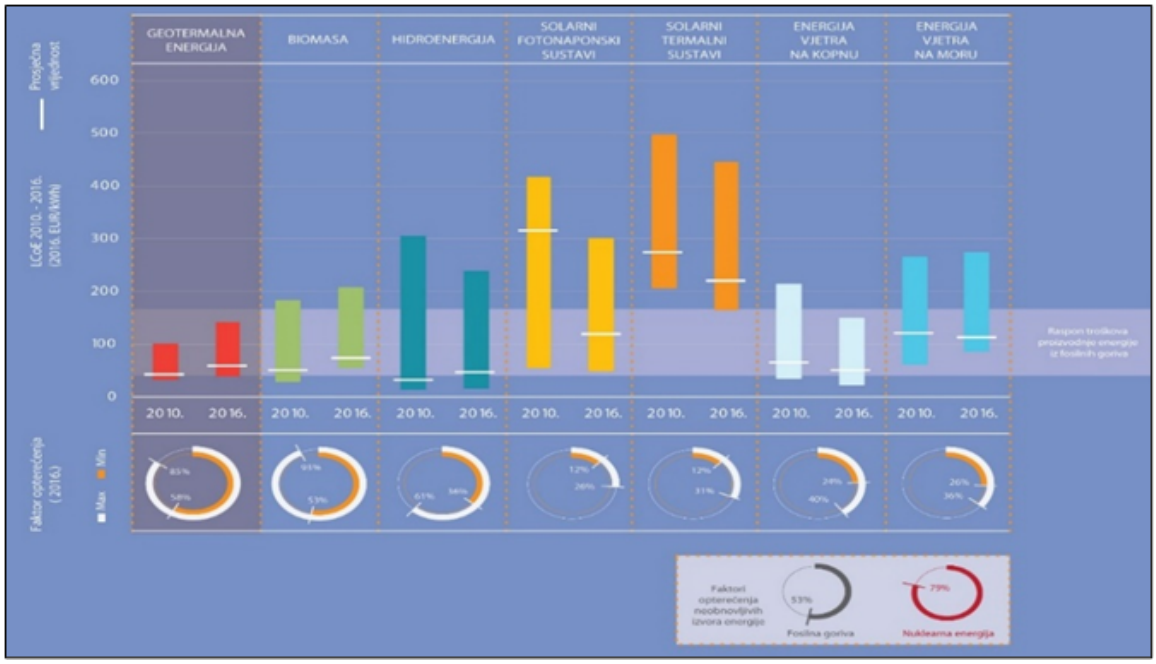

Figure 3: Comparison of capacity factors and LCOE of different renewable energy sources. (Source: Author's adaptation based on the source: Nádor, A. Transitional Danube Region Geothermal Strategy, DARLINGe-Danube Region Leading Geothermal Energy, European Regional Development Fund, 2018.)

The Levelized Cost of Energy (LCOE) is a complex financial indicator used for in-depth analysis and comparison of different energy sources and production technologies. This indicator allows for a deeper understanding of the economic viability of energy projects over their lifetime. LCOE is typically expressed in currency per unit of electricity produced, such as dollars per megawatt-hour (MWh) or cents per kilowatt-hour (kWh). Lower LCOE values indicate a more economically viable energy source, while higher values suggest higher electricity production costs. LCOE is a useful tool for making informed investment decisions in the energy sector and for planning energy strategies. The calculation of LCOE includes all costs associated with the construction, operation, and maintenance of the energy production system, as well as the expected energy output over its lifetime.

These costs include:

- Capital costs (CAPEX): These are the initial investment costs required for the construction and establishment of the energy system (equipment procurement, infrastructure costs).
- Operation and maintenance costs (O&M): These costs cover everything needed for the regular maintenance and management of the energy system throughout its lifetime. This includes monitoring, servicing, repairs, and all operational activities.
- Fuel costs (if applicable): For energy sources like fossil fuels, LCOE includes the fuel costs required to generate electricity.
- Expected lifespan: The expected lifetime of the energy system is estimated. This is important because a longer lifespan can help offset the initial capital costs (the estimated lifetime of the energy production system can vary significantly depending on the technology used).
- Discount rate: LCOE takes into account the present value of future revenues and costs using a chosen discount rate, which reflects the time value of money (considering the opportunity cost of investing in the project).

The formula for calculating the Levelized Cost of Energy (LCOE) is:

$$\text{LCOE} = \frac{\text{The present value of the produced energy}}{\text{Total present value of costs}} \qquad (1)$$

LCOE analysis is crucial in energy strategy planning and investment decision-making in the energy sector, with technological advancements and innovations playing a key role in reducing the LCOE for renewable energy sources and sustainable energy systems.

4. CURRENT POTENTIAL OF GEOTHERMAL LOCATIONS IN THE REPUBLIC OF CROATIA

In today's growing energy consumption, ensuring an adequate supply of energy while striving for energy independence is a task for every country, including the Republic of Croatia. When considering energy independence, climate change, and the energy transition towards decarbonization, the matter becomes significantly more complex. In this context, it is important to emphasize that renewable energy sources (RES), along with energy efficiency and the decarbonization of natural gas, and in the broader context of the energy transition and expected climate changes, today represent a very important element of energy security, sustainable energy, and climate change mitigation. The first step is to analyze potential energy sources on domestic soil. Given the relatively modest reserves of fossil fuels and the already mentioned decarbonization goals, it is necessary to consider the use of renewable energy sources in the Republic of Croatia. In the last few decades, significant attention has been directed first at hydroelectric power and biomass, and later at wind and solar energy, which can be considered logical due to their potential, technological maturity, and cost-effectiveness. However, when comparing potential and actual usage, it is necessary to take geothermal energy into account as well. In this regard, the Pannonian part of the Republic of Croatia possesses significant geothermal potential, which has been somewhat neglected. The majority of geothermal locations were discovered through oil and geological exploration during the last century. In addition to conventional geothermal fluid deposits, important geothermal energy resources include dry geothermal reservoirs with elevated temperatures and unconventional natural gas deposits dissolved in geothermal waters (Škrlec et al., 2019). The indicated geothermal potential of all locations in the Republic of Croatia could result in production capacity exceeding 500 MWe, between 750 and 1300 MWt, and significant reserves of natural gas. The utilization of geothermal energy offers numerous advantages in the context of sustainable

energy development and could have a multiplier effect on the economy of the Republic of Croatia. The Republic of Croatia has favorable natural conditions for exploiting renewable energy sources. Hydrocarbons, geothermal waters, geological structures suitable for natural gas storage, and permanent CO_2 storage are also of interest to Croatia and are specially protected. Their exploitation is regulated under the Hydrocarbon Exploration and Exploitation Act (NN 52/18, 52/19, and 30/21), as well as strategic documents such as the Energy Strategy of the Republic of Croatia by 2030 with a view to 2050 (NN 25/20) and the Geothermal Potential Development Plan of the Republic of Croatia by 2030 (2022). Most of the geothermal energy research in the Republic of Croatia has so far been based on natural thermal waters from deep geothermal reservoirs or oil and gas field aquifers (Macenić et al., 2022). Although the Pannonian region of Croatia has high temperature gradients, the potential of geothermal energy has not been adequately exploited. In the last decade, Europe has seen stagnation in the direct use of high-temperature deep geothermal potentials, but a significant increase in the use of shallow low-temperature potentials for heating and cooling purposes. Ground-source heat pump systems with borehole heat exchangers are among the most efficient and economically viable methods for utilizing this energy potential. The Republic of Croatia is covered by two sedimentary basins, the Pannonian Basin and the Dinarides with the Adriatic, which have significant differences in geothermal potentials

The chart shows that in the Republic of Croatia, 52% of the area is highly attractive for conducting geothermal research and the evelopment of geothermal facilities based on geothermal potential (Table 1).

COUNTY	NOT ATTRACTIVE (HA)	HIGHLY ATTRACTIVE (HA)
Bjelovarsko-bilogorska	0,0	263.861,7
Brodsko-posavska	0,0	202.827,8
Dubrovačko-neretvanska	178.261,2	0,0
Grad Zagreb	0,0	64.125,1
Karlovačka	246.010,9	116.432,7
Koprivničko-križevačka	0,0	174.792,9
Krapinsko-zagorska	0,0	122.961,3
Ličko-senjska	535.505,8	0,0
Međimurska	0,0	72.922,7
Osječko-baranjska	0,0	414.799,8
Požeško-slavonska	0,0	182.265,6
Primorsko-goranska	358.933,0	0,0
Sisačko-moslavačka	0,0	446.675,8
Splitsko-dalmatinska	453.832,7	0,0
Šibensko-kninska	296.858,7	0,0
Varaždinska	0,0	125.973,8
Virovitičko-podravska	0,0	202.258,7
Vukovarsko-srijemska	0,0	244.933,6
Zadarska	364.294,7	0,0
Zagrebačka	0,0	306.169,0
REPUBLIKA HRVATSKA	**2.715.143,1**	**2.941.000,5**

Table 1: Theoretical Geothermal Potential by Counties
(Source: Analysis of Spatial Capacities and Conditions for the Utilization of Renewable Energy Potentials in the Republic of Croatia, 2020.)

In addition to the presence of a favorable geothermal gradient, key criteria for determining the attractiveness of a location for utilizing geothermal potential are certain physical-geographical conditions, which limit the development of facilities for energy extraction, conversion, storage,

and distribution. The topography of the potential geothermal area is an important factor in designing and constructing drilling platforms, access roads, and surface installations. Since these areas occupy a large surface area (from 1 to 2 hectares), leveling steep terrains can be technically demanding and expensive, and may also lead to various problems, including landslides. The distance from the electricity grid is an important factor for power plants that generate electricity, as they are connected to the high-voltage grid (110 kV) or the medium-voltage grid (35 kV) depending on their production capacity. For plants generating thermal energy, proximity to consumers is crucial, whether they be agricultural farms, industrial plants, or settlements with an established gas heating network. A distance greater than 8 km is considered limiting for investment feasibility. Proximity to road infrastructure is another important criterion for the suitability of the location, as access is needed for each exploratory borehole and later for the plant itself. However, in Croatia, the road network, including unclassified roads, is sufficiently well developed, with few locations requiring the construction of significantly long access roads (Srpak et al., 2019; Srpak & Pavlović, 2020). In areas with a high likelihood of flooding, where the return period is 25 years, construction is not advisable, primarily due to the high risk of damage and the large investments required for flood prevention. Additionally, in areas with a medium probability of flooding, where the return period is 100 years, it is assumed that at least one flood will occur during the operational lifetime of the power plant, making such areas less suitable for construction. It should be noted that areas with a low probability of flooding, with a return period of 1000 years, also include the potential for accidental flooding caused by dam breaches or high levees (artificial flooding). Considering the intensity of the work and its impacts, construction in archaeological sites or areas with high susceptibility to soil erosion is unacceptable. In areas with medium and low susceptibility to erosion, land stabilization may be possible in certain parts, as the construction of the plant itself requires soil preparation with controlled values for settling and soil compaction (Srpak & Pavlović, 2024).

Considering certain specificities, the features of geothermal energy that can bring numerous advantages to the Republic of Croatia are:

- Geothermal energy is a renewable energy source.
- It is a significant and largely untapped potential.
- Utilizing the existing potential can have a multiplicative effect on development.
- The considerable dispersion of potential (especially in the Croatian part of the Pannonian Basin system).
- Its use undeniably increases supply security.
- In addition to electricity production, geothermal energy can be used in a cascading manner across a range of other activities, utilizing sources of different temperatures and capacities
- It is a constant source of energy (not conditioned by time of day, weather conditions, seasonality, raw material availability, etc.
- Long-term predictability of production.
- Higher capacity factor compared to other renewable energy sources (Figure 3).
- Lower levelized cost of electricity (LCOE – Figure 3).

5. EXPLOITATION OF HYDROCARBONS AND GEOTHERMAL WATERS FROM WHICH ACCUMULATED HEAT CAN BE USED FOR ENERGY PURPOSES, STORAGE OF NATURAL GAS, AND PERMANENT DISPOSAL OF CARBON DIOXIDE IN VARAŽDIN COUNTY

The implementation of mining activities is subject to restrictions and spatial conditions that ensure compliance with ecological and cultural values. Exploration and exploitation activities, which are of strategic importance to the state, are aligned with the National Spatial Development Plan, while at the local level, they are carried out in accordance with the Spatial Plan of Varaždin County ("Official Gazette of Varaždin County", nos. 08/00, 29/06, 16/09, and 96/21), which defines areas intended for the exploration and exploitation of mineral resources. This approach ensures the long-term sustainability of mining while preserving natural resources and protecting the environment. The Sector for Petroleum Mining and Geothermal Waters for Energy Purposes within the Ministry of Economy drafts proposals for laws and regulations related to the exploration and exploitation of hydrocarbons, geothermal waters, underground gas storage, and permanent disposal of carbon dioxide in geological structures, and monitors and aligns national legislation with EU directives. These activities are carried out in accordance with the Energy Development Strategy of the Republic of Croatia until 2030, with a view to 2050 ("Official Gazette", no. 25/20), the Framework Plan and Program for Hydrocarbon Exploration and Exploitation, and the Plan for the Development of Geothermal Potential of the Republic of Croatia until 2030. The Hydrocarbon Exploration and Exploitation Act regulates activities related to hydrocarbons, geothermal waters, gas storage, and permanent CO_2 disposal, both on land and in the underground of internal maritime waters, territorial seas, and the exclusive economic zone of the Adriatic Sea, in accordance with international law and Croatia's sovereign rights.

5.1. Hydrocarbons

According to data from the Ministry of Economy, Energy Directorate, the area of Varaždin County contains hydrocarbon exploration areas (Drava-02, SZH-01, SZH-05), the hydrocarbon exploitation field Cvetkovec, the geothermal water exploitation field "Lunjkovec-Kutnjak", the geothermal water exploration area Ludbreg, and potential geothermal water sites (Prelog, Međimurje 2, Slanje, Mali Bukovec, Križevci Vratno). The exploration of hydrocarbon reserves (oil, natural gas, gas condensate) and geothermal waters for energy purposes can be conducted throughout the county, subject to conditions defined in spatial plans and specific regulations (Srpak, 2022). Table 2 displays the planned areas for the exploitation of energy-related mineral resources in this county.

Following on the next page

R. No.	Location	Municipality	Coverage
1.	**CVETKOVEC**	City of Ludbreg	Covers the approved EPU Cvetkovec, in the part located in Varaždin County; the larger part of the EPU Cvetkovec is in Koprivničko-križevačka County.
2.	**DRAVA - 02**	Covers parts of the area of the City of Ludbreg and the Municipalities of Mali Bukovec and Veliki Bukovec	Covers the approved IPU in the part located in Varaždin County.
3.	**SJEVEROZAPADNA HRVATSKA - 01**	Covers parts of all cities and municipalities in Varaždin County, except the municipalities of Breznički Hum, Breznica, and Visoko	Covers the approved IPU in the part located in Varaždin County.
4.	**SJEVEROZAPADNA HRVATSKA - 05**	Covers parts of the areas of the cities of Lepoglava, Ivanec, and Novi Marof and the municipalities of Bednja, Ljubešćica, Breznički Hum, Breznica and Visoko	Covers the proposed IPU in the part located in Varaždin County.

Table 2: Planned Areas for the Exploitation of Energy Mineral Resources in Varaždin County - Hydrocarbons
(Source: Spatial Plan of Varaždin County (2000). "Official Gazette of Varaždin County", No. 08/00, 29/06, 16/09, 96/21.)

5.2. Geothermal waters from which accumulated heat can be used for energy purposes

On the entire area of Varaždin County, the exploration of geothermal waters from which accumulated heat can be used for energy purposes is permitted, including the formation of exploration areas, if in accordance with the geothermal potential established in the Mining-Geological Study of Varaždin County (Official Gazette of Varaždin County, No. 29/16).
The study identified potential zones according to structural-tectonic units, but the overall geological potential of the mineral resource of hydro-geothermal deposits of both high and low enthalpy was determined to cover almost the entire area of Varaždin County, making it entirely of interest for exploration and use. For the exploration and exploitation of geothermal water from which accumulated heat can be used for energy purposes in Varaždin County, the following areas have been highlighted:

- The area of the former exploration site "Mali Bukovec"
- The area of the exploitation field "Lunjkovec - Kutnjak"

Table 3 shows the planned areas for the exploitation of energy mineral resources in Varaždin County according to the Spatial Plan of Varaždin County.

Following on the next page

No.	Location	Local Government Unit	Coverage
1.	**LUNJKOVEC - KUTNJAK**	Parts of the areas of the Municipality of Mali Bukovec, Veliki Bukovec, and the City of Ludbreg	Covers the proposed Exploration Area in the Varaždin County area (formerly the Exploitation Field)
2.	**MALI BUKOVEC**	Parts of the areas of the Municipalities of Mali Bukovec, Veliki Bukovec, and Sveti Đurđ, and the City of Ludbreg	Covers the proposed Exploration Area in the Varaždin County area (formerly the Exploration Area)

Table 3: Planned Areas for the Exploitation of Energy Mineral Resources in Varaždin County - Geothermal Waters from Which Accumulated Heat Can Be Used for Energy Purposes
Source: Spatial Plan of Varaždin County (2000). "Official Gazette of Varaždin County," No. 08/00., 29/06., 16/09., and 96/21.

5.3. Use of Geothermal Waters and Waters for Therapeutic, Balneological, or Recreational Purposes

Exploitation of mineral waters and waters for therapeutic, balneological, recreational, and other purposes in Varaždin County is subject to the application of water regulations. In Varaždin County, there are thermal springs located in Varaždinske Toplice and Topličica (Madžarevo). Table 4 presents the planned areas for the utilization of mineral resources in Varaždin County—geothermal waters for therapeutic, tourism, recreational, and other purposes.

No.	Location	Municipality	Coverage
1.	**VARAŽDINSKE TOPLICE**	Grad Varaždinske Toplice	-
2.	**TOPLIČICA**	Grad Novi Marof	-
3.	**PODEVČEVO**	Grad Novi Marof	-
4.	**BELEC**	Grad Ivanec	-

Table 4: Mineral Resources - Geothermal Waters for Therapeutic, Tourism, Recreational, and Other Purposes
(Source: Spatial Plan of Varaždin County (2000). "Official Gazette of Varaždin County," no. 08/00, 29/06, 16/09, and 96/21.)

Varaždin County possesses a diverse potential for the utilization of geothermal waters for various purposes. While areas such as "Lunjkovec - Kutnjak" and "Mali Bukovec" offer opportunities for energy exploitation, locations like Varaždinske Toplice and Topličica provide resources for therapeutic, tourism, and recreational uses. By combining these applications, geothermal waters can contribute to energy self-sufficiency, sustainable development, and the tourism appeal of the county.

6. CONCLUSION

The spatial and ecological analysis of geothermal resource exploitation in Varaždin County, within the framework of the green transition, highlights the significant potential of this area to contribute to Croatia's energy independence. Geothermal energy, though underutilized thus far, offers considerable economic and environmental benefits, including the reduction of greenhouse gas emissions and decreased reliance on fossil fuels. With favorable geological conditions, high temperature gradients, and estimated geothermal capacities, Varaždin County emerges as a critical location for the development of renewable energy sources. Although

strategic frameworks have been established at the national level, the implementation of geothermal activities must adhere to the Spatial Plan of Varaždin County. This ensures that the development of essential infrastructure can enable sustainable geothermal energy use, environmental protection, and secure energy development over the long term. The geothermal energy potential in Varaždin County represents a crucial step toward Croatia's sustainable energy transition. Its full utilization could significantly contribute to the decarbonization of energy consumption and the mitigation of adverse climate change effects. Achieving a balance between sustainability, security, and accessibility in the energy sector is paramount for building a resilient and robust energy system. The geothermal resources of Varaždin County provide concrete opportunities for investments in energy projects that could shape Croatia's successful and sustainable energy future. Proper consideration of all factors, such as supply security, sustainability, and accessibility, will be critical to designing a stable energy infrastructure that supports economic growth and preserves quality of life. The development of geothermal energy as a renewable energy source, aligned with green transition objectives, not only reduces greenhouse gas emissions but also contributes to environmental preservation. This approach ensures a balance between energy availability, ecological impact, and economic viability, paving the way for a stable energy future aligned with the goals of sustainability, societal progress, and climate change mitigation.

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TEACHING AND LEARNING HUMAN-COMPUTER INTERACTION (HCI): CURRENT AND EMERGING PRACTICES

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ABSTRACT

Against the backdrop of the information age, new technologies are constantly affecting all aspects of people's lives, especially in the field of education. Through the impact of informatization on education in places further away from city centers, in smaller communities, classes on more remote islands, it has been determined that there is still a large gap between the basic construction of inaccessible informatization teaching and the teaching of teachers, professors in cities. This paper analyzes the challenges faced by remote classrooms against the backdrop of the information age by combining cases of informatization from practice and thus provides appropriate suggestions. So that everyone has equal opportunities in education and easier access to information, both gifted students and those with disabilities. When creating applicable computer programs for distance learning, it is important to know certain design principles when constructing and adapting the graphical interface to the user. By changing the graphical display of the screen, we directly encounter stylized transitions, or animations, and we achieve a certain attractiveness when selecting the offered content. Thus, dynamic navigation serves spatial orientation within virtual reality.

Keywords: *Distance learning, Teachers, Digital Teaching, Educational Informatization, User Interface (UI), Graphical interface*

1. INTRODUTION

The paper investigates three core dimensions of their engagement with AI: general attitudes towards AI in education, the influence of AI tools on decision-making processes and factors affecting AI acceptance and use. Additionally, it examines their overall perceptions of AI in education. Innovate the use of methods to improve the level of digital teaching in the education of teachers, lecturers, professors in remote schools. The development of digitalization of education is intuitively reflected in the activities of classroom teaching in schools on remote islands, underdeveloped regions of counties. Teachers only prepare lessons through classrooms or using digital source media, which to a certain extent narrows the scope of digitalization of education. The digital development of county education in the future should move towards unknown educational scenarios, break the dependence on existing classroom teaching paths and additionally open broad horizons to students. Specifically, the construction of synchronous classrooms and smart classrooms at the city or county level will coordinate and integrate high-quality educational resources in the county and deeply integrate digital technology into the educational development of the city and county. It is recommended to develop a comprehensive

digital literacy plan for teachers of remote schools based on the national digital strategic policy and the specific needs of county education. The plan should include establishing special digital literacy courses and combining these courses with the actual teaching needs of county schools to achieve a teaching effect that integrates knowledge and action.

Education, upbringing

Education and upbringing are integral components of the culture of a people. Cultus, Colere, in the broadest sense of these words, education and upbringing, are universal human phenomena, mutually and inseparably connected and active. Anthropology, however, generally speaking, is a holistic science about man, about his nature and culture, so its approach and insights are always current and indispensable both in the scientific, pedagogical treatment of education and upbringing and in its application. So, *naobrazma* (Greek: morfé, haraktér, trópos), means, namely, the founding, composition, creation, shaping - of man. Education is the process of spiritual formation of man, his person, the cultivation of his self-awareness and social consciousness (Valcic, Herceg, 2023). That is why we say that teaching is a complex, but unique educational process. Education and upbringing (paodeia) as a system, in a philosophical and humanistic (not ideological) sense, means that they are and should be a kind of causa sui, i.e. A whole conditioned by man and people, by the measure of man and his sociality, conceived by a philosophical concept, since man is by his essence and nature a social and spiritual being (zoon politikon, ehon logon), a being of free development, progress (anth), creativity and transcendence of his natural and merely empirical givenness (ana-tras-ops). Pedagogy, which claims to deal with all of the above as a science, is directed towards anthropology as the science of the whole man, or rather towards the philosophical discourse on man as a totality and towards its understandings and assumptions about the nature, essence and meaning of man's being and survival. Humanistic and holistic anthropology should, beyond any ideologisation, thoroughly theoretically and empirically examine all forms of human natural, spiritual and social, economic, political and cultural activities and achievements. All these givennesses, activities and achievements, of course, do not exist outside the cultural-historical-social framework, but neither outside man. They are in the possession of man, in the possession of the Croatian man as the sum and continuity of all his positive human achievements, so true values and goods transcend their time and space and are at the same time beacons and signposts for future generations in their human and civilized endeavors and aspirations. This is both the general and basic meaning of culture in the broadest sense of the word as a universal human phenomenon. Culture is by definition a historical, social category that changes with changes in social conditions, which it itself influences. Therefore, definitions and theories of culture must encompass, in addition to the relatively constant elements of culture, dynamic cultural processes (acculturation, enculturation, innovation), or their mutual conditioning and interpenetration. Therefore, we are forced to constantly reexamine the graphical user interface, analyze the interactions between the user and the computer, functional design, element architecture, and design structures, with special emphasis on navigation and flow. We should get a representation of movement through the computer user interface with and without micro-animations, thanks to which the importance of feedback that creates a logical link between the actions performed is indicated.

2. WHAT DOES IT MEANS TO TEACH HCI?

Human–computer interaction (HCI) is the academic discipline dedicated to understanding how humans interact with technology. Since technologies play such a prominent role in our daily lives, ensuring that they are designed to reflect the full spectrum of human abilities, skills, and

experiences is more important than ever. Between higher education HCI courses and degrees and practitioner-oriented UX training programs, there are more opportunities than ever to teach and learn HCI, but HCI can be taught from various disciplinary perspectives at different academic levels, in different modalities, and in different institutional contexts. Therefore, for educators, what does it mean to teach HCI? For students, what are the most impactful and effective ways to learn HCI?

3. NEW USER INTERFACE SOFTWARE

With the development of mobile devices, graphical user interfaces for mobile devices have also evolved, as have the mobile operating system interfaces used on smartphones today. From the first smartphone in 1992 (developed at IBM, called the Simon Personal Communicator) to Apple's iPhone (2007), the user interface has gone through several phases. These include the use of a stylus to interact with the interface, a sliding keyboard under the screen, multitasking capabilities, and a fully customizable home screen. Simplicity, usability, and visual appeal have become standards in the design of modern Web application user interfaces. Before the 1960s, the concept of the "user interface" was completely unarticulated. This is why early visions of personal, desktop access to vast information stores (Bush 1945), graphical and gestural user interfaces (Sutherland 1963), and synchronous collaboration through direct pointing and shared windows (Engelbart and English 1968) are historically so significant. During the 1970s, advancements in workstations and bitmap displays enabled the consolidation of these early visions. A notable example is the work at the Xerox Palo Alto Research Center (PARC) with the Alto computer and the Smalltalk-72 environment. User Interface (UI) Design User interface (UI) design is the process used to create product interfaces with a focus on appearance or style. These interfaces are designed according to the principles of user experience design and as such must be simple and pleasant to use. A user interface refers to the access point through which users interact with the design, and these interfaces can be of three types: graphical (GUI), voice (VUI), and gesture-based. Graphical user interfaces (GUI) include all interfaces where users interact with visual displays on digital control surfaces. The best example of a GUI is the computer desktop. VUI, or voice-controlled interfaces (VUI), are interfaces where communication between the user and the system takes place via voice. This group includes Siri, Alexa, Google etc. The last type of interface is gesture-based interfaces where users engage in 3D spaces and communicate with the interface through body movements. These are the most modern interfaces and the best example is VR, i.e. virtual reality. By applying the previously defined factors and rules of user experience design, a correct user interface can be designed. Just as with experience, users evaluate the appearance of the interface and at the same time care about usability and appeal. Design is not as important as the simplicity of performing the desired tasks. Therefore, design should be "invisible" in the sense that it should not be in focus, but the focus should be on the context and flow of the tasks to be performed, and the look of the interface is adjusted accordingly. The user interface should be pleasant and anticipate the needs of users so that they can enjoy personalized and impressive experiences. In addition to appearance, they play an important role and emotions that users associate with the product.

3.1. User Interface Software and Tools

User interface software and tools deal with user interface concepts and metaphors, display and interaction techniques, and software development methods. This is probably the most visible and successful area of HCI. The user interfaces that more or less everyone encounters—the desktop metaphor and window management, screen widgets such as scroll bars, menus, and dialog boxes—are derived from work on improving.

A consistent thread of research in this area is architectures for user interface software. The goal was to separate the user interface and application functionality into distinct layers. This approach modularized the user interface in user interface management systems, encouraging iterative redesign (for example, Tanner and Buxton 1985). However, layering limited the granularity of user interface interactions. It also proved to be an obstacle to incremental development methods, as it assumed a top-down decomposition of what the user interface was and what the application functionality was. Current approaches favor the user in developing interfaces and functionality in the same language, either in new languages invented for the purpose, such as Visual Basic, or through extensions of standard languages to implement functionality, such as libraries and tools for C++ or Java.

3.2. COMPUTER ICONS

An iconic interface is a user interface composed of iconic images. Each icon represents what task will be performed when the image is clicked. This interface can be used with a computer operating system, computer games, software that controls hardware, etc.

Figure 1. Iconic interface

A formal methodology for guiding designers in the production of iconic user interfaces is presented. One of the main issues of the proposed methodology is the possibility of separating the overall design of the interface from the design of individual presentations on the screen, keeping both within a single framework. Another methodological issue concerns the choice of the level of abstraction that allows the designer to concentrate on the main aspects of the interface, deferring implementation details. The presented approach is based on state transition diagrams that provide a solid theoretical basis for the methodology. The characteristics of iconic interfaces are illustrated. The methodology of designing an iconic interface is presented. An application to knowledge-based system interface design is given. The effectiveness of the presented approach is shown. Graphical user interfaces as we use them today allow the user to communicate with the computer using symbols, visual elements, and pointing devices. This form of interface has replaced complicated text-based interfaces and is more user-friendly, natural, and intuitive. The historical details of the evolution of computers and human-computer interaction and user interface design can be divided into several phases. The first implementations of user interface design methods date back to the early 1970s, to the era of cumbersome character. This was an era of applications that did not have development process methods, while they were still to be developed.

Pictographic symbols are used to convey a wide range of meanings, especially in the design of human-machine communication interfaces, such as product labels, traffic signs, computer icons, etc. Icons are used extensively because:

(1) Icons can be easily recognized and remembered (Weidenbeck, 1999)
(2) Images have more universal recognition than text, since icon interfaces face fewer barriers than language (Lodding, 1983; Wickens, 1992)
(3) Icons offer a perception of accessibility, which can facilitate human-machine interaction in terms of ecological perception (Gaver, 1991; Lodding, 1983)
(4) Users prefer icons to text for performing tasks, although their performance may be neither better nor worse (Kacmar and Carey, 1991; Nielsen, 1990)

However, an improperly designed icon can diminish the above-mentioned advantages. Two common problematic issues regarding icon design are: first, icons often have language barriers that do not ensure immediate understanding across cultures, or even within them (Waterworth, 1993; Valčić, Herceg, 2023; Manes, 1985; Kolers, 1969; Karfhage and Karfhage, 1986; Dreyfuss, 1972); second, people cannot quickly locate the icons they need (Gittens, 1986; Wickens, 1992). Many principles, criteria, and guidelines for icons have been proposed to qualify icon design (Marcus, 1984; Tognazzini, 1992; The CD-I Design Handbook, 1992; Gittens, 1986; Preece et al., 1994; Foley, 1974). For example, Lin (1992) found that key design factors include: recognizable, meaningful, concise, associative, attractive, and symbolic factors. However, design experience can influence how people judge icons (Christle and Gardiner, 1991). Therefore, it can be difficult to obtain information about icon design criteria from subjects who are not experienced in icon design. Due to the current popularity of the Internet, more and more graphic designers are engaged in the design of computer icons for commercial homepages. Icons have become individual consumer products. The function of computer icons is no longer limited to communication (which mainly emphasizes being memorable and understandable); commercial requirements are expanding the role of computer icons beyond communication to suit user preferences. The most deserving of this is digital marketing and the great need for it by organizations and companies and even civil and political society. In short, most previous studies have used objective criteria such as meaningful, recognizable, concise, relatable, and memorable to assess the suitability of icon design. Subjective and aesthetic aspects of icon design are neglected. Along with the popularity of icons for commercial purposes, subjective preferences can play a key role in the success or failure of an icon design. Furthermore, people with design experience may use different criteria for evaluating icon design than those without design experience. Most of the existing icon design criteria and principles are based on research findings from studies where students with no experience in icon design were surveyed. These criteria and principles may not apply to experienced designers. The intent of this study was to investigate whether aesthetic and subjective preferences are important factors in icon design and whether design experience affects the relative importance of different icon design criteria.

3.3. Design language

Each operating system is visually distinct, has its own distinctive visual style and standardized usage patterns. Before embarking on the design and development process, it is necessary to understand the platform's idioms and behavior. This way, users will be able to easily understand and use the application on the platform they are used to, and the product will always be functional, clear, and good-looking, regardless of whether it is used on a mobile phone or tablet. For example, we can cite the Android user interface. It is based on material design. Material design is a new approach to cross-platform design that harmonizes the classic principles of good design with the innovations and capabilities of technology and science, and provides a unique experience on all screens and device sizes. The same style is used by Google.

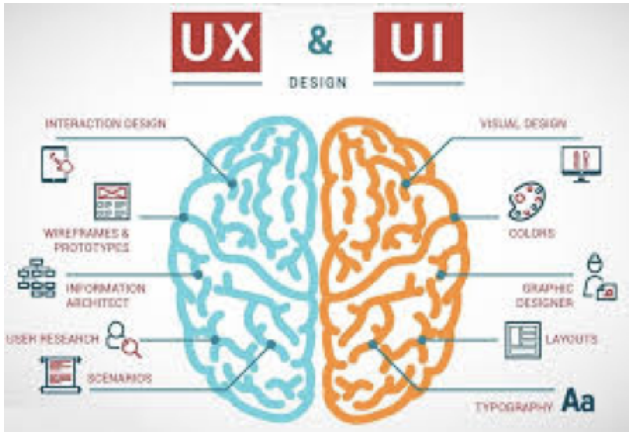
3.4. UX DIZAJN (User experience)

UX (User Experience) design is the process of designing a product (digital or physical) that is useful, easy to use, and pleasant to interact with. It is a discipline based on understanding the needs of users, what users value, their capabilities, and their limitations. The impact on the user experience is also related to the decisions made by the organization and how the developer performs a specific task. The UX designer's task is to determine how the consumer feels when using the product. When designing, there is no single solution to any problem, but rather multiple different solutions. The UX designer's responsibility is to ensure that the product transitions logically from one step to the next one.

3.5. UX DESIGN

UX (English User experience) design or user experience is the process of designing a product (digital or physical) that is useful, easy to use and enjoyable to interact with.
It is a discipline based on understanding the needs of the user, what the user does price, what are its possibilities, but also its limitations. Impact on the user experience is related to the decisions made by the organization and to how the developer performs a specific task. The task of the UX designer is to determine how the consumer feels when using product. When designing, there is no single solution to any problem, but several different solutions. The UX designer's responsibility is to ensure that the product logically transitions from one step to another.

Figure 2. UI & UX



Principles of Graphical User Interface Design:The components of a user interface design are:

- ✓ window navigation model – defines the windows and navigation options available to users to perform online functions
- ✓ window specifications – defines the windows in the interface
- ✓ help system specification – defines the help system that will be implemented to assist users in using the application.

However, more complex user interface windows will require a detailed prototype. The purpose of prototypes is to prove that the requirements are properly understood, not to create a working version of the system. User interface modeling is indeed essential in any application system

development, and should not be postponed until the final stage of system development – its implementation – allowing developers to "deal" with what is best possible; rather, it should be modeled and its development should be included in every stage of application system development (Strahonja, Picek,2005). The design of a graphical user interface should take into account the needs, experiences, and capabilities of users. In addition, it is necessary to be aware of the user's physical and psychological limitations (e.g., limited short-term memory), as well as the fact that people make mistakes when using the interface, that they are different and have different interaction priorities. Graphical user interface design parameters serve to improve the quality of the interface design and the design process. According to the book Wayfinding design guidelines, there are seven principles of universal design:

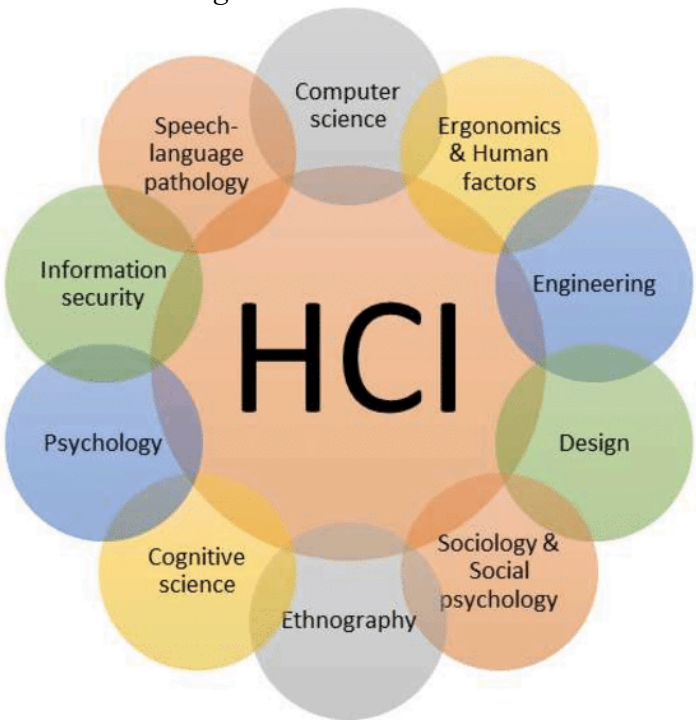
1) Uniform usability
   The design is useful and marketable to people with different abilities.
2) Flexibility in use
   The design encompasses a wide range of individual preferences and abilities.
3) Simple and intuitive use
   The use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current level of concentration.
4) Tangible information
   The design effectively communicates useful information to users, regardless of the user's environmental conditions or sensory abilities.
5) Tolerance for error

The design minimizes hazards and harmful consequences of accidental or unintended actions.
1) Low physical effort
The design can be used effectively and comfortably, with minimal fatigue.
2) Size and space for access and use

Adequate size and space are provided for access, reach, manipulation and use regardless of the user's body size, posture or mobility
Because of all of the above:

- ✓ ensure real-world consistency, consider experience, expectations, work conventions and cultural conventions
- ✓ ensure internal consistency, follow the same conventions and rules for all aspects of the graphical interface, application interface or website, including operational and navigation procedures, visual identity or theme and component
- ✓ organization
- ✓ presentation
- ✓ use
- ✓ location
- ✓ follow the same conventions and rules across all related interfaces
- ✓ deviate only when there is a clear benefit to the user.

Figure 3. Research areas



3.6. Wayfinding

By navigating a user interface, we are actually going through some kind of journey. In order to navigate towards a certain goal, people use available spatial information. Wayfinding (Lynch, 1960; Downs and Stea, 1973) can be translated as journey or orientation, but wayfinding in design has not yet received its own independent translation. It is a major component of Environmental Graphic Design (EGD). EGD can be defined as the graphic communication of information in the built environment. This discipline encompasses various design practices, including urban design, architecture, interior, product and graphic design. Despite its frequent use in EGD, the term wayfinding is considered a misspelling by various spellcheckers and does not appear in most dictionaries. Looking at the original words, it is possible to trace its meaning through four different time periods, which help to trace its contemporary usage:

1. The term wayfinding was introduced in the 16th century as "a journey or journey by road". Thus, a wayfarer is "a person who travels by road, especially on foot".
2. In 1960, urban planner Kevin A. Lynch coined the term wayfinding in his influential book Image of the City. He defined it as "the consistent use and organization of certain sensory cues from the external environment". His work is based on the concept of spatial orientation and its preconditioned, cognitive maps. The former refers to the ways in which a person's ability to determine their location in their environment, and the latter refers to the overall mental image or representation of the physical space and its appearance.
3. An important conceptual shift occurred in the early 1970s. Cognitivists argued that it is necessary to understand the underlying processes in order to interpret how people find their way. Therefore, the relevant concept was no longer based solely on spatial orientation, but on processes involving perception, cognition, and decision-making. This new concept gave rise to the concept of wayfinding. This idea reflects a different approach to the study of human movement and their relationship to physical space.

Cognitivists presented it as a spatial problem-solving method that linked three interrelated processes. First, decision-making is the development of a plan of action. Second, the execution of the decision translates this plan into appropriate behavior and actions. Finally, information processing is responsible for the database of two processes related to decision-making.

4. In 1984, in his book Wayfinding in Architecture, environmental psychologist Romedi Passini expanded the concept by linking it to architecture and signs. But why is the concept of wayfinding so important? Generally speaking, wayfinding involves four phases that have been implemented in user interface design over a period of time. They are:

   1) orientation - the current location in relation to nearby objects must be determined,
   space is broken into smaller parts and significant signs are noticed
   2) choosing the way to the destination - improved by reducing the number of navigation choices
   and by giving signs (generally speaking, people generally prefer shorter routes to longer ones
   paths, even if the shorter path is more complex), good mental representations of the space for
   navigation are very useful if the space is large, complex, poorly designed
   3) route tracking - tracking to determine that it leads to the appropriate destination.
   4) recognition of the destination - the destination must be easily recognizable.

4. WINDOWS 8.1. USER INTERFACE-Metro Language

The Metro UI interface is not just an interface, but also Microsoft's interface design language, and thus their vision of the future. The name came from where the inspiration came from – from the information tables of the underground railway company. In 2012, the name Microsoft Design Language was adapted. According to Microsoft, Metro was always a code name and nevermarked the final product. It first appeared with Windows Phone, which made a move away from the previously seenstandardized icons.

4.1. Understanding users and the way they perceive content

Designing a layout is actually understanding everything that shapes the behavior and actions of users. The first part of the cognitive cycle is the part where the user gets their data from the environment. Most of the information that the user uses to understand the layout comes through their eyes (what they see). Understanding the way users see, among which the most important is user scan – scanning, is a valuable input for the design process. Scrolling occurs when the layout that is designed and implemented is longer or wider than the space that is limited by the screen. This causes horizontal or vertical scrolling elements to appear and allows the user to switch to another screen. When switching to another screen, the overlap line is the point at which the screen ends and the movement through that screen begins. If you want to achieve intuitive scrolling, then it is necessary to divide the elements in such a way that certain parts are above and below the overlap line - the visible area, that is, that part of the content "sticks out" or comes out. This is applicable to both vertical and horizontal scrolling. Animation is subject to great and often impossible demands.

The Twelve Fundamental Principles of Disney Animation are a set of rules that define the realistic impression of movement with the basic laws of physics. In the early 1930s, Walt Disney and his company, in an effort to set a standard for their company, devised the movements that their characters must exhibit, and thus established the “12 principles of animation” that are still the standard for hand-drawn animation today. Each rule can be applied to animation and micro-animation in the design of graphical user interfaces.

I. Squash and stretch
The purpose of this principle is to give a sense of weight and flexibility to drawn objects. The most important aspect of this principle is the fact that an object has volume and that volume should not change when the object is flattened or stretched.

II. Anticipation of action
Used to prepare the audience for action, and makes the activity more realistic. The technique can also be used for smaller physical activities.

III. Staging
This principle imitates staging as it is known in theater and film. Its purpose is to direct the audience’s attention to a situation of great importance that is taking place on the scene. The essence of this principle is to keep the viewer's focus on what is relevant.

IV. Successive animation and from pose to pose (Straight Ahead and Pose to Pose)
"Successive animation" means animating the scene frame by frame from
from beginning to end, while with the principle "from pose to pose" several are made
keyframes, and then interframes are filled in later.

V. Follow through and overlapping action
These two principles are closely related, through their intertwined use
we get more realistic movements, character movements for which the laws of physics apply. Follow through and overlapping action

VI. Slow in and slow out
The movement of the human body, as well as most other objects, needs time to accelerate and slow down. For this reason, the animation looks more realistic if there are more drawings near the beginningand the end of the action, and less in the middle.

VII. Arcs
The idea behind this principle is that all movements are performed slowly in a circular arc. The exception to this rule is robots and mechanical devices. All human movements, from moving an arm to turning a head, describe a circular arc. That is why it is very important to include thisprinciple in the animation process.

VIII. Secondary action
Adding a secondary action to the main action gives the scene more life. The important thing about secondary actions is to emphasize them, not distract from the main action.

IX. Timing

Duration is one of the most difficult elements of animation to get right. It is the speed at which certain actions are executed. If one element is poorly timed there is a possibility that the entire scene will be unsuccessful no matter how well everything else is done. For this reason, there is no exact way for an animator to learn how to correctly determine the duration of an activity other than to sit down, work, and learn through trial and error.

X. Exaggeration

Exaggeration is particularly useful for animation, perfect imitation of reality can look static and boring. The degree of exaggeration depends on how much we want to emphasize movement. If a scene contains several elements, there should be a balance in which elements are exaggerated in relation to others to avoid viewer confusion Solid Drawing The principle of solid drawing takes into account the third dimension of the character. For an animation to look good, drawings must have weight, depth, balance and other elements that emphasize the three-dimensional space on the paper. Appeal A cartoon character must have what actors call charisma. Regardless of whether it is a good guy, a villain or a monster, the character must be attractive, it is important for the viewer to feel that the character is real.

5. CONCLUSION

The results of this study showed that qualified computer icons should include the following design criteria: style, message quality, meaningfulness, locablity, and metaphor for distance education services. These findings can be applied to the planning of training programs for computer icon designers. The paper deals with the integration of sustainability concepts into management curricula and identifies strategies that business leaders can apply to improve their professional skills using elements of distance learning. The paper delves deeper into the literature on sustainability education in management curricula, addressing the fundamentals, bringing significant changes and tactics to be applied at each stage of the curriculum. Interpretive thematic analysis revealed the following themes: infrastructure of governance institutions, aptitude for sustainability skill sets, labor market needs, new employment, anthropological and philosophical knowledge. The paper proposes that the implementation of educational strategies and activities aimed at the transformation of learning and the sustainability of knowledge should be coordinated with all levels of AI and ICT activities. A holistic environment that takes into account both the micro and macro aspects of sustainability needs to be provided and carefully managed, so that the students who will become the educators of tomorrow have the potential to become the leaders of the new education. Over the past two decades, these original focus areas have continued to expand and diversify, although their synergistic relationship remains the cornerstone of HCI. Other focus areas have also developed, such as group/cooperative activity and media/information. Methods and concepts of usability engineering achievements for the field of education, the early focus of usability engineering was evaluation: measuring the performance of implemented software and systems with respect to measurable criteria. It is modeled after the laboratory-oriented paradigm of human factors in telecommunications. However, the rise of prototyping and iterative software development and the ambition to engage cognitive science as a foundation for human-computer interaction pushed the focus of evaluation work upstream into the system development process. Prototyping and iterative development strongly favor formative, rather than summative, evaluation (Scriven 1967)—that is, evaluation that takes place within the development process. and this can lead to a usable, appropriate redesign, rather than just measuring the attributes of the design output.

Formative evaluation methods are often qualitative; a typical method involves people "thinking aloud" as they perform a task. Theory-based models and tools have taken an even more ambitious position, seeking to enable analytical evaluation of designs before they are implemented even as prototypes.

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FISCAL POLICY AND PUBLIC DEBT GROWTH IN KOSOVO POST-COVID-19 CRISIS: CHALLENGES AND PERSPECTIVES

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ABSTRACT

Fiscal policy and public debt are among the most critical topics of economic stability and sustainable development of a country. The COVID-19 pandemic has imposed a severe and widespread impact on the economies of numerous countries, resulting in serious complications for public finances and economic activity. The health crisis has pushed governments to take unprecedented measures to support their citizens and economies by increasing public spending and implementing stimulus policies. This unstable situation has increased concerns about the growth of public debt and has created uncertainty over the sustainability of state finances in both the short and long terms. This work aims at researching the interconnection between fiscal policy and the growth of public debt in Kosovo, explaining the impact of the fiscal policies up to now on the debt level and its sustainability. Although there have been ongoing efforts to stabilize the economy, Kosovo's public debt has followed a rising trend, and it represents one of the greatest challenges to the financial management and long-term development of Kosovo. The objective of this paper is to identify the determinants for the increase in debt, such as public expenditures, fiscal income and stimulus policies undertaken during times of economic crisis. Through a close review of information offered and a comparison of fiscal policy models, the paper will present recommendations for plausible action towards the management of public debt such that it is compatible with economic development and financial sustainability. The findings of this research will provide concrete recommendations to the Kosovo authorities, with a perspective of offering a sustainable fiscal trajectory and boosting investor and citizen confidence in the Kosovo financial system.

Keywords: *Fiscal Policy, Public Debt, Economic Growth, Covid – 19 Pandemic, Kosovo*

1. INTRODUCTION

Since the outbreak of the COVID-19 pandemic, the interaction between public debt and fiscal policy has become of extreme importance and is currently one of the main challenges for the majority of countries, including Kosovo. Following the devastating economic and health effects of the pandemic, the majority of countries were forced to resort to emergency measures in order to stabilize their economies and protect the health of their citizens. This action, such as increasing public spending and having stimulus policy, was intended to prevent the impact of the crisis but brought huge uncertainty and dilemma in sustaining public debt and state finance.Following the COVID-19 pandemic, the nexus between fiscal policy and public debt has been a central theme for the majority of countries, including Kosovo. Governments' choices to introduce emergency measures in an effort to ease their economies and to shield their citizens from the economic and health crisis implications led to an increase in public spending, like direct aid to citizens and for major sectors of the economy. COVID-19 post-fiscal policy was marked by the increase in government spending, both to give direct relief to citizens (emergency wages, social assistance, relief to enterprises) and to finance public health (vaccine procurement, hospital assistance, etc.). These were necessary to maintain social and economic stability during crisis conditions. Furthermore, most countries introduced economic stimuli that often included tax cuts, investment incentives and other measures that were intended to improve

the chances of economic recovery.However, these policies, though necessary to control the crisis, had a high cost to public finances. High state spending, combined with the possible decrease in tax revenues (due to the slowdown in economic activity), led to an increase in public debt. Debt, which had a sustainable level before the crisis, began to increase rapidly as a result of these stimulus policies and increased spending. Due to these expenditures, governments were forced to increase public debt, taking loans to cover deficits. For Kosovo, despite efforts to stabilize the economy, there has been a pattern in public debt that has raised questions about the sustainability of state finance. Fiscal policy, with increased public spending and economic stimulus, has put significant strain on public debt. Although these measures were necessary to maintain economic activity and protect public health, they have injected skepticism about the ability of the state to service debt in the long term. Moreover, in the post-COVID-19 period, the majority of countries have struggled to strike a balance between spurring economic growth and controlling public debt. The growth in debt has been hard to contain, as excessive debt undermines the ability of the state to finance other major development projects and negatively affects investor and citizen confidence in the financial system. This is the reason there is immense urgency to manage public debt and fiscal policy prudently, ensuring that the debt is maintained at sustainable levels and in line with Kosovo's economic growth in the long term. The increase in public debt since the crisis stemmed directly from the fiscal measures taken to support the economy in managing the adversity caused by the pandemic. As the governments of most nations, including Kosovo, needed to borrow funds to cover undue spending and economic stimuli, this fresh debt began to be a serious issue for managing the long-term public finances. This increase in debt has raised people's concerns about whether it is sustainable and whether they will be able to manage it in the future, especially when the debt is more than a level that makes countries have to resort to other restraint measures in order to balance the budget. To this extent, one critical concern has been the adequacy of fiscal action with the accumulation of the public debt. Although most states have been able to raise debt to fund the economy in times of crisis, debt must be carefully managed so that it does not load the burden unfairly on coming generations. Besides, most countries, including Kosovo, must seek balancing of expenditure on recovery with long-term public finance sustainability.This paper will explain the impact of fiscal policy undertaken post-COVID-19 pandemic on the increase in public debt in Kosovo, taking into account the factors that have led to its increase, such as public spending, fiscal revenues and stimulus policies. It will also provide recommendations for sustainable public debt management, so that Kosovo's economic growth and financial stability can be achieved in the future.Public debt management is crucial for maintaining healthy finances and long-term economic growth. The goal of this paper is to explore the impact of fiscal policies and public debt dynamics in Kosovo after the COVID-19 crisis.The pandemic had a significant global economic impact, causing great uncertainty in public finances.Governments worldwide implemented extraordinary measures to support their citizens and economies, increasing public spending and stimulus policies.

1.1. Research objectives

1. To investigate the link between fiscal policy and public debt growth in Kosovo post-COVID-19.
2. To assess the impact of fiscal policies on the level and sustainability of public debt.

1.2. Research questions

Rq1:What are the key determinants contributing to the increase in public debt post-crisis?

Rq2: How have public expenditures, fiscal income, and stimulus policies influenced public debt?
Rq3: What can be done to ensure that public debt is managed in a way that supports long-term development in Kosovo?

Understanding Kosovo's economic trajectory, particularly in terms of government expenditure, revenues, public debt, and GDP growth between 2009 and 2023, is crucial for assessing the fiscal health, sustainability, and potential for future growth of the nation. Understanding these associated factors of the economy is critical not only for policymakers and economists but also for investors, international organizations, and the general public. By observing the way the economy in Kosovo was managed during periods of stability, crisis, and recovery, we can make valuable observations regarding the planning that can determine economic futures. The study provides crucial information to assist in policy-making regarding fiscal policies, taxation, public expenditure, and public debt. The economic performance of Kosovo, especially after the COVID-19 pandemic, emphasizes the urgency of timely and efficient government intervention during economic downturn. Knowing how Kosovo readjusted its spending and revenues during the pandemic allows policymakers to evaluate the effectiveness of fiscal measures and determine the right response to a future crisis. As an example, studying how government spending went up in tandem with the pandemic provides valuable lessons for preparing for future crises, particularly for healthcare spending, social relief, and economic stimulus. In addition, the relationship between government revenues and debt is most critical in planning sustainable fiscal policy. The debt of Kosovo skyrocketed due to pandemic emergency spending, and thus future policies should find a balance between stimulating economic growth and managing debt so that it will not burden future generations.

2. LITERATURE REVIEW

The pandemic of COVID-19 took its toll greatly on the economies of countries all over the world, prompting governments to introduce fiscal and monetary policies that would contain its effects. The COVID-19 pandemic has significantly impacted global economies, leading to unprecedented levels of public debt. This situation has raised concerns about debt sustainability, economic recovery, and the long-term implications for fiscal policy and economic growth. However, the ability to impose these expansionary policies was hampered by several underlying economic situations before the pandemic. Pre-pandemic elevated inflation rates in most nations limited the extent to which the governments could relax fiscal policies since inflation rising acted as a restraint to their policy options. Wealthier nations, with stronger fiscal buffers and financing at hand, were in a better position to follow expansionary economic policies, thereby better riding the blow of the pandemic. In contrast, more extensive infections forced other governments to introduce more aggressive expansionary policies to support suffering citizens and sectors. Balkan nations, however, faced specific issues, where strict public health policies and higher infection rates prompted governments in the region to implement fewer expansionary policies in spite of higher economic support requirements. Balkan nation statistics reveal that the dynamic between pre-pandemic economic patterns, public health policy, and government action yielded mixed fiscal policy outcomes between regions. Higher pre-pandemic inflation rates limited fiscal expansion, wealthier nations were better equipped to implement expansionary policies, higher Covid-19 infection rates spurred more expansionary measures, and strict public health regulations caused Balkan governments to implement fewer expansionary policies, according to data from Balkan nations (Elgin & Elveren, 2025).

Otherwise, Avdiu (2025) show that while taxes seemed to have a role in lowering unemployment rates during the pandemic, higher unemployment was associated with increased consumption, government spending, and economic development. This study offers insightful information about the intricate relationships between unemployment and fiscal policy in the Western Balkans, with useful ramifications for central banks and policymakers in handling future crises. Through the use of macroeconomic instruments in the case of Kosovo, (such as the effect of budget deficits on GDP) and microeconomic tools (such as its impact on resource efficiency), fiscal policy can support human growth and development (Hamza & Milo, 2021). Tax system includes legal packages, guidelines, tax treaties, tax levels, tax types, assessment, collection, and controls for gaining public revenues within an area (Selimi et al., 2022).

Halilaj (2025) explores the impact of public debt on Kosovo's economic growth using quarterly data from 2013 to 2022. The data collected from the Ministry of Finance and Kosovo Statistical Agency include GDP per capita, Central Government Debt, and Government Spending in terms of Euro. The results confirm the long-run relationship between GDP and public debt and confirm the Keynesian hypothesis that public debt positively impacts economic growth. Rexha et al., (2021) prove that there exists a strong and positive correlation between government spending and economic growth. The pandemic has caused a significant surge in public debt since the governments of the world embraced fiscal policies to insulate their healthcare systems and economies. The increase is most evident in developed countries, where public debt has reached historic highs, with overall debt at $305 trillion at the beginning of 2023 (Angjeli et al., 2022); (Pak & Pekarski, 2024). In Europe, the pandemic increased debt issues, pushing some countries to unsustainable debt paths due to negative economic growth and unemployment (Briceño & Perote, 2020) ; (Mitsi, 2023). High public debt raises a number of concerns, such as the possibility of long-term high inflation and financial repression. Budget deficits have expanded as a result of pandemic fiscal stimulus measures, which calls into doubt the efficacy of inflation targeting regimes and the possibility of financial repression as a debt management strategy. High levels of public debt can also make it more difficult for a nation to invest in healthcare and other vital services, as is the case in European nations with higher COVID-19 mortality rates because of limited health system capabilities (Coccia & Benati, 2024). The argument is that high levels of public debt in countries create budget constraints that limit their ability to invest in health systems (e.g., health expenditure and investment), undermining the performance of health systems and causing systemic vulnerability and decreased preparedness during crises, such as the COVID-19 pandemic. The rise in public debt is one of the key sources of funding economic recovery in nations following the COVID-19 pandemic. However, the degree of uncertainty has risen significantly due to the COVID-19 pandemic and the strengthening of new trends in the evolution of the world economy. Consequently, nations with significant rises in public debt will have a far lower degree of macroeconomic stability (Prohorovs, 2020). Europe's post-COVID-19 public debt levels present difficulties, and policy suggestions include promoting international collaboration, fiscal consolidation, long-term debt management, and giving public investments top priority (Mitsi, 2023). The COVID-19 pandemic creates abrupt contractions in economic activity and abrupt expansions in public expenditure. These increase the riskiness of sovereign debts, especially in emerging economies. Furthermore the government decides distortionary labour taxation and whether to repay its earlier domestic and foreign debts. Foreign default is more likely after a negative productivity shock, while domestic default is more likely after a negative expenditure shock (Paczos & Shakhnov, 2020).

In order to support necessary public goods and services and to address emergencies, public debt has been vital to state development and economic expansion (Eichengreen et al., 2021). The Western Balkan nations are seen to demonstrate conditional convergence, suggesting a requirement for an increase in the steady state level (Fetai et al., 2017). The pandemic has produced a steep acceleration in public debt due to elevated fiscal spending, and the global public debt is at record levels. The ratio of U.S. debt-to-GDP will rise significantly, potentially to as high as 190% in 2050. This has generated fiscal concerns like debt sustainability, financial volatility, and lower macroeconomic stability. The acceleration in public debt can lead to financial repression and higher inflation. Low interest rates have provided some relief by moderating future debt build-up, but long-term projections remain sensitive to interest rate movements (Auerbach et al., 2021).

3. RESEARCH METHODOLOGY

The aim of this research is to analyze the relationship between fiscal policy and public debt growth in Kosovo after the COVID-19 crisis, founded on secondary data obtained from reliable and verifiable sources. The use of secondary data is common in this type of research, since it provides fertile and in-depth information without requiring the collection of new data, which can be time-consuming and financially demanding. For this purpose, the study relies on main sources: the Kosovo Agency of Statistics (KAS), the World Bank and International Monetary Fund. Research methodology employed in this study is focused on analyzing the economic performance of Kosovo between 2009 and 2023 with particular focus on government expenditure, government revenues, public debt, and GDP growth. The study aims to analyze the interrelations among these economic variables and assess their implications on fiscal policy, economic stability, and sustainable development in Kosovo. Quantitative analysis, comparative analysis, and analysis of historical data constitute the methodology employed.

3.1. Data Collection

The data in this research were gathered from official national data and reports submitted by Kosovo's Agency of Statistics, Ministry of Finance, International Monetary Fund and World Bank Indicators. These sources provide detailed and reliable data on government expenditure, revenue, public debt, and growth rates of Kosovo's GDP. Data were obtained for the period 2009-2023, covering both good economic years and the significant disorganization caused by the COVID-19 pandemic.

The key indicators of data analyzed are:

1) Government spending and receipts in annual and quarterly terms
2) Public debt levels in percentage terms of GDP
3) GDP growth rates at an annual rate
4) Fiscal actions during the period of study

Trend analysis is utilized in the study to examine the fluctuations of government expenditures and revenues of Kosovo over the years. By doing so, trends are determined, and an assessment can be established on how fiscal activities transformed over a series of years, specifically throughout pivotal occurrences such as the COVID-19 pandemic. The data for each year, which is broken down per quarter, are compared to determine seasonal or cyclical trends in government fiscal activity.

4. RESULTS AND DISCUSSION

The section fourth of this study presents the results obtained from the secondary data regarding the Public Debt as a percentage of GDP in case of Kosovo, the public revenues and expenditures in the case of Kosovo and GDP growth.

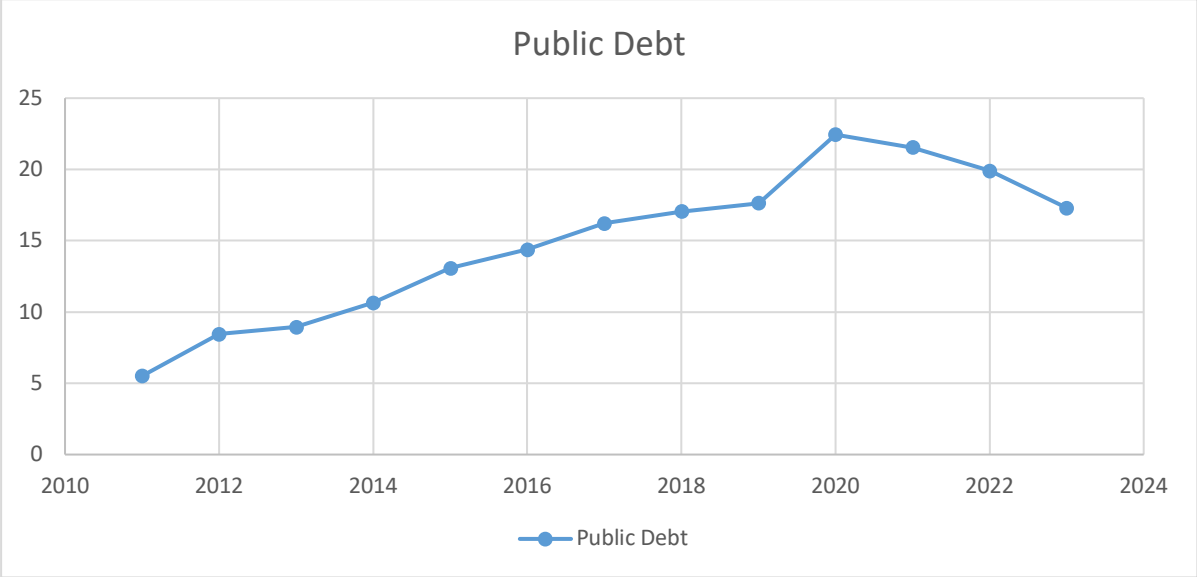

Figure 1: Public Debt as a percentage of GDP in the case of Kosovo (Source: CEIC data, Minsitry of Finance, https://www.ceicdata.com/en/indicator/kosovo/government-debt--of-nominal-gdp)

From 2011 to 2019, Kosovo recorded a consistent increase in public debt as a percentage of its GDP. The percentage of debt went up from 5.51% in 2011 to 17.63% in 2019. This increase is attributed to various factors including economic growth, government spending, and investment in services and infrastructure. However, Kosovo's debt remained relatively low when compared to the majority of countries, being below 20% over the years.In 2020, the pandemic of COVID-19 had a significant impact on the world economy, and Kosovo was no exception. In an attempt to meet economic and social consequences of the pandemic, Kosovo increased its public spending, particularly because of the health crisis and to support businesses and persons affected by lockdowns and other measures. As a result, Kosovo's public debt increased significantly to 22.44% of GDP in 2020, a record high in the data.This jump was mainly driven by government expenditure on pandemic relief, stimulus packages, and attempts to prop up the economy in the time of crisis. The increase in debt was a universal phenomenon for the majority of the world's countries as governments responded to the unprecedented crisis. After the peak year 2020, Kosovo's public debt relative to GDP began to decline. The debt stood at 21.53% as of 2021, having gradually decreased since the economy started recovering from the shocks of the pandemic. The debt had decreased further to 19.91% as of 2022, and to 17.3% as of 2023. The decrease shows that the economy of Kosovo was gradually returning to stability and that the government was likely aiming at slowing down its fiscal deficit and maintaining public debt within control as part of the recovery. Even if the post-COVID period reflected a downturn trend in debt, Kosovo and many other nations still found it hard to reconcile reduction in debt, investment, and recovery.

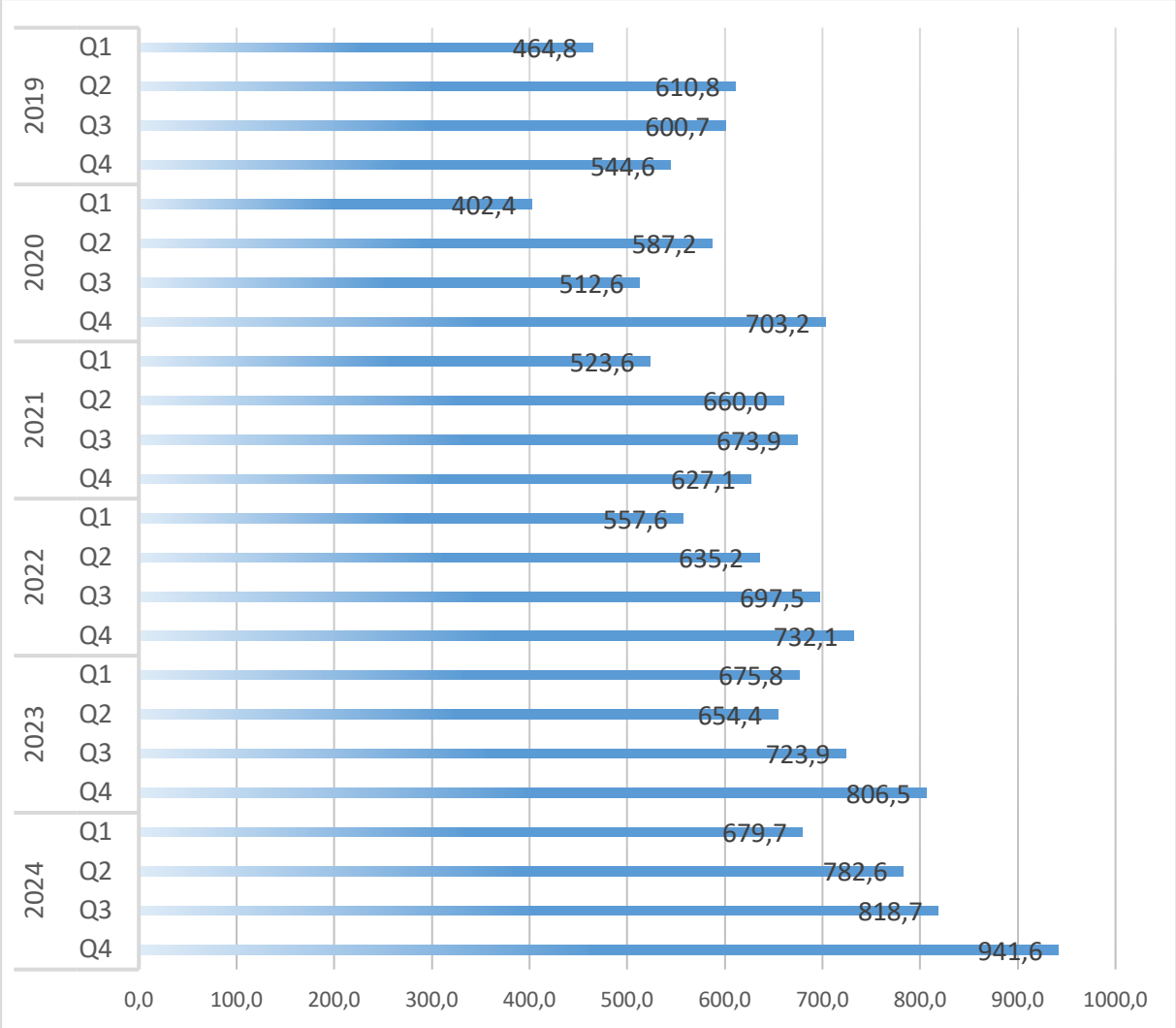

Figure 2: General Government Revenue based on ESA2010 by Variables, Year and Period (Source: Kosovo Agency of Statistics KAS, https://askdata.rks-gov.net/pxweb/sq/ASKdata/)

General Government Revenues structure, based on the ESA2010 methodology, provides a strict overview of government finances across various time periods and economic situations. The figures between 2019 and 2024 provide some fascinating observations about how the government performs financially, especially when compared between pre-and post-pandemic periods of the COVID-19 pandemic. These episodes capture abrupt changes in government revenues, capturing the impact of the world crisis on fiscal policy, and the recovery process thereafter. During the pre-pandemic era, the 2019 data also shows a fairly consistent pattern of government revenues. In the first quarter (TM1) in 2019, government spending was at its lowest quarterly amount for the year, at 464.8 million. Government spending subsequently rose throughout the year, with Q2 and Q3 showing 610.8 million and 600.7 million, respectively, demonstrating a fair increase in spending. Q4 of 2019 recorded the highest expenditure at 544.6 million, which is common because governments are usually more spending in the fourth quarter due to many end-year fiscal obligations, including tax refunds, public services, and social benefits programs. This was an era of typical fiscal policies, where there were recurring trends in government spending by quarters.

An increase in the revenues, particularly in the second and third quarters, signifies a stable economy, where the government was able to maintain typical public spending without substantial breaks. Growth in the economy in the earlier years up to 2019 likely helped to maintain a typical level of the government's revenue.The 2020 COVID-19 pandemic was a drastic government revenue paradigm shift. Government expenditure dropped to 402.4 million during the first quarter (TM1) of 2020, the lowest recorded value in the entire dataset. The sharp decline was likely due to economic lockdowns and measures that drastically restricted economic activity, reducing government income from social contributions and taxation. As the pandemic eased, government spending skyrocketed to address the public health crisis and the resultant economic downturn. Spending in Q2 was higher than in the first quarter, reaching 587.2 million but still far from last year. The government had to spend quite large on stimulus packages, health facilities, and social welfare programs, which points towards a shift towards emergency spending to stem the crisis.

But by the fourth quarter (TM4) of 2020, expenditure had risen to 703.2 million, a sharp increase from the initial half of the year. This surge most likely resulted from continued government measures to support the economy and stimulate recovery. The pandemic led governments around the world to shift priorities, increasing expenditure in health care, unemployment benefits, and direct monetary aid to businesses. In the post-pandemic period, since 2021, government expenditure began to normalize, albeit remaining higher than during the pre-pandemic period. The data in 2021 reflect continuous recovery, with expenditure beginning at 523.6 million during Q1 and rising to 673.9 million by Q3. Growth in government expenditure throughout 2021 reflects continuous efforts towards reviving the economy, investment in public health, and support for unemployment recovery programs.Government expenditures had a steadier upward slope by 2022. TM1 of 2022 reported 557.6 million, which rose to 732.1 million for the fourth quarter. This trajectory in government expenditures is in alignment with the rise in fiscal stimulus programs and economic recovery programs in general. Governments were forced to balance the sustainability of social services and economic recovery measures with long-term impacts from the pandemic.There was another increase in expenditure in 2023, and it remained at 806.5 million in the fourth quarter, which was the second highest in the dataset. The steady increase in government revenue proves that by then, the majority of countries were engaged in economic recovery measures like investing in infrastructure, employment generation, and support to businesses most hit by the pandemic.Government expenditures in 2024 were the highest, totaling 941.6 million for Q4. This may show both a return to normal of economic conditions pre-pandemic and the sustained efforts of the economic recovery steps that had become necessary to continue supporting global economies.The structure of General Government Revenues before, during, and after the COVID-19 pandemic illustrates how heavily the global crisis impacted the pattern of government expenditures. The pandemic generated a steep decline in revenues and an even steeper increase in expenditures, particularly in 2020, as governments ramped up spending to cushion the economic blow of the crisis. The post-pandemic period illustrates a slow recovery, as expenditures gradually returned to above-trend levels, reflecting both recovery and structural fiscal reforms.Once the world crosses the short-term crisis of COVID-19, trends in data suggest that the government expenditure will remain high for a few years as most nations are still focused on econom ic recovery, public health, and sustainability in the long term. The policy shift amid and post-pandemic is poised to continue influencing the structure of government revenues in subsequent years.

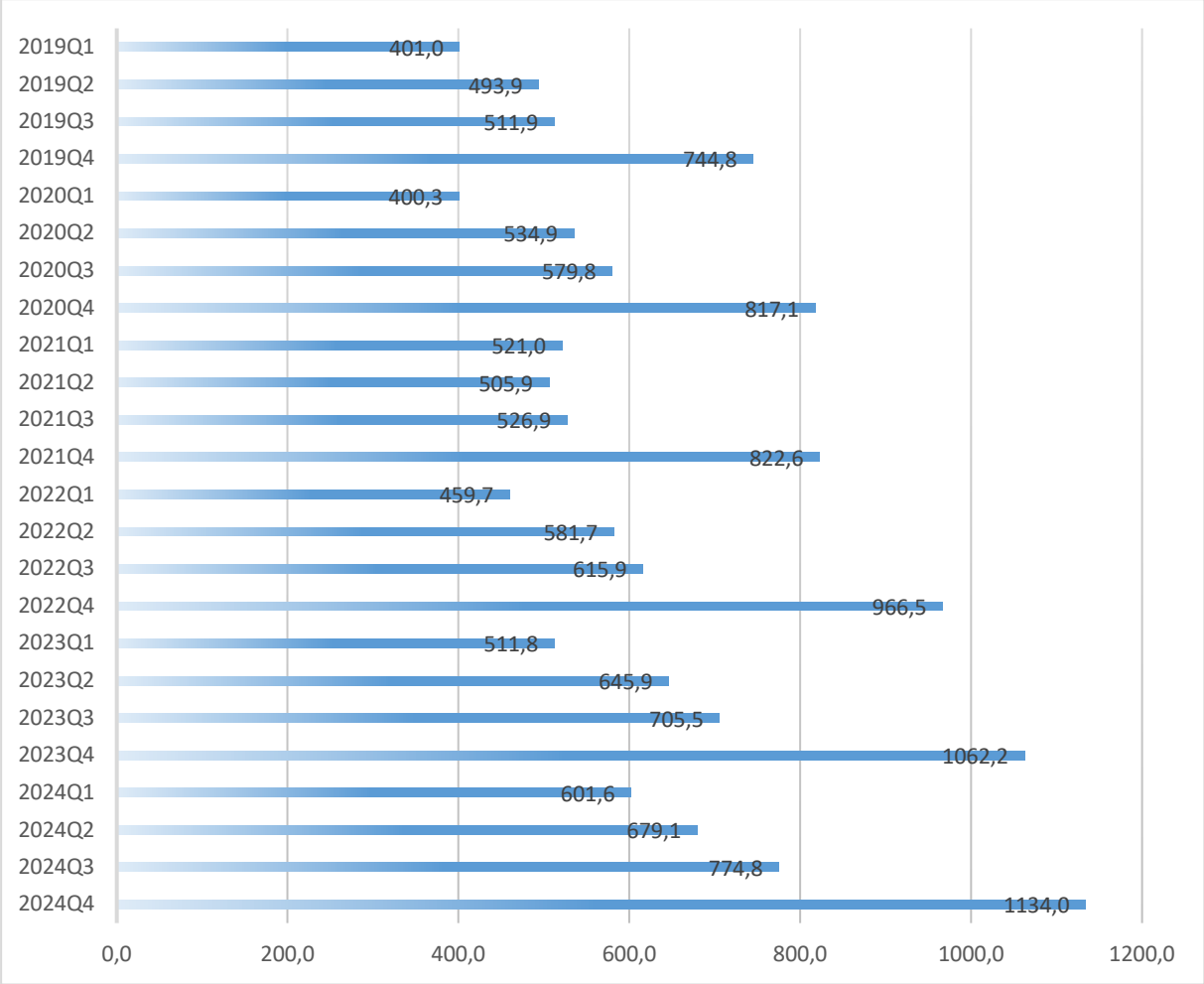

Figure 3: General Government Expenditures based on ESA2010 by ESA2010 (Source: Kosovo Agency of Statistics KAS, https://askdata.rks-gov.net/pxweb/sq/ASKdata/)

The period between 2019-2020 was marked with extreme fluctuations in government expenditure caused primarily by the COVID-19 pandemic. Government expenditure ranged between 401.0 million in Q1 to 744.8 million in Q4 of 2019, indicating a relatively stable economic position before the pandemic. This is typical government activity including development of infrastructure, public services, and social protection programs.

However, 2020 experienced a dramatic decline in Q1, and expenditure fell to 400.3 million, the lowest in the period under study. The decline is attributed to the initial impacts of the COVID-19 pandemic that resulted in economic lockdowns, reduced tax collections, and generally brought about the slowdown of the majority of government activity. The drastic decline in Q1 spending was a direct effect of the crisis's initial phase, when governments were forced to re-prioritize their budgetary allocations. Government expenditures picked up the pace in Q2, Q3, and Q4 of 2020, despite the initial decline. These increases are most likely attributable to the pandemic-fighting emergency measures taken in the form of healthcare spending, social welfare, and economic stimulus packages.

Governments worldwide applied fiscal interventions to support industries, provide unemployment benefits, and ensure the functioning of the vital services amidst the crisis. Government spending increased at the close of 2020 to help stabilize the economy and curb the effects of the pandemic. After the first recession in 2020, government expenditure saw a positive growth trend in 2021. In the fourth quarter (Q4), government spending had reached 822.6 million, which is considerably higher than a year ago. The growth points to the sustained economic recovery drive that was instituted to transform the economy from the impact of the pandemic. Fiscal measures continued to play a crucial role, with government spending aimed at restoring public confidence, boosting employment, and revitalizing industries affected by the pandemic. In 2022, government expenditures began stabilizing, the year of sustained recovery. In the fourth quarter (Q4), there was a peak expenditure of 966.5 million, indicating that the government maintained its support to the recovery initiatives. This stabilization in 2022 shows that governments were shifting to more sustainable recovery initiatives and long-term growth strategies, equalizing the fiscal support while planning for economic stability. These expenditures were investments in areas like infrastructure, public health, and social programs to obtain broad-based recovery and growth in industries. As we moved into 2023, government expenditure continued increasing, reaching Q4 at 1062.2 million. This increase suggests that the recovery not only held on but was deepening since the government went on implementing fiscal stimulus measures to enhance economic growth, public health, and jobs. By this time, the government had a critical role to stabilize the economy and deal with the lingering impact of the pandemic, such as supply chain problems and the need for continued welfare interventions. In 2024, the expenditure is also anticipated to increase further, with Q4 being estimated at 1134.0 million, supporting the trend of consistent fiscal support. This means that while the immediate impacts of the pandemic are waning, governments are actively involved in stimulating economic growth, addressing emerging economic challenges, and shielding vulnerable populations. The government will continue to pursue expansionary fiscal policy for economic revival, infrastructure development, and improving social safety nets. Government spending trends from 2019 to 2024 demonstrate the significant impact of the COVID-19 pandemic on economic activity. While government spending remained stable in 2019, the pandemic triggered a sharp decline early in 2020, followed by rising spending for responding to emergency requirements and recovery post-pandemic. Between the years 2021 and 2022, there was recovery as government spending increased as budgetary interventions aimed at stimulating the growth of the economy and bringing the economy back to life started yielding results. The trend lasted into 2023 and 2024, suggesting that government spending remains an important factor in keeping the recovery afloat and addressing long-term economic challenges. These trends reiterate the importance of fiscal policy in times of crisis and the continued need for government intervention to stabilize and stimulate post-pandemic economies.

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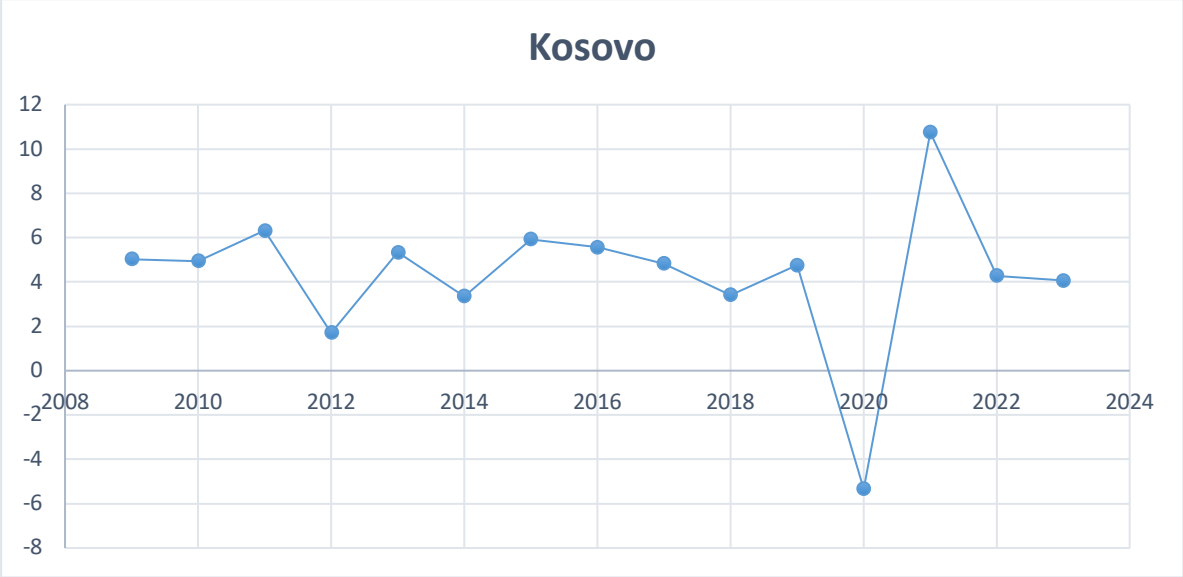

Figure 4: GDP growth in case of Kosovo
(Source: World Bank Indicators)

The 2009-2023 era of economic history of Kosovo is defined by rapid growth, economic troubles, and strong rebound from the pandemic of COVID-19. Analyzing the rate of growth in GDP and state expenditure between 2009-2023 enables us to derive significant data concerning the fiscal operations of the nation and its handling of stresses provided by international turmoil, that of the pandemic in this context. The 2020 pandemic recession triggered a steep economic contraction, yet post-pandemic economic growth in Kosovo has been stellar with a very rapid recovery in 2021. It requires understanding such tendencies to comprehend the overall economic scenario within which the authorities of Kosovo had to escalate fiscal support in order to accomplish growth, stability, and development in the long term. Before the occurrence of the COVID-19 pandemic, Kosovo's economy was exhibiting steady growth. From 2009 to 2019, Kosovo experienced GDP growth rates in positive terms that ranged from 3.35% in 2014 to 6.32% in 2011. These were relatively stable growth years that were supported by various factors, including infrastructure investments, foreign remittances, and exports. Government expenditure, as defined by the ESA2010 framework, indicated this economic growth because the government spent on public services, infrastructure investment, and social programs that spurred the developing economy.

In 2019, the GDP growth rate in Kosovo was 4.76%, showing stable prosperity in the pre-pandemic era. Government expenditures in 2019 were quite stable, reflecting the trends in economic growth. Increased expenditure on infrastructure and social welfare sustained the momentum of growth. However, the world economy was already beginning to weaken, and the outbreak of COVID-19 would shortly derail this stability, as it did for world economies.The 2020 COVID-19 pandemic affected the world economy severely, and Kosovo was no exception. The country's GDP growth rate for 2020 was a whopping -5.34%, reflecting the slowdown in economic activity due to lockdowns, reduced business activity, and reduced consumer spending. Government expenditure in 2020 also underwent similar adjustments, as fiscal policy had to be rapidly altered to counter the economic effect. Kosovo's government had to increase spending on healthcare, crisis relief, and economic stimulus in a bid to maintain employment and protect firms suffering in the crisis.

The fall in government revenue from the pandemic caused a temporary boost in expenditure as the government provided emergency financial support. These shocks were needed in stabilizing the economy, smoothing unemployment, and making the health system capable of coping with the pandemic. The rise in government expenditure in 2020 is thus in line with the need for fiscal intervention to prevent additional economic downturn in the crisis. 2021 was a dramatic shift from the effects of the pandemic, as Kosovo's GDP growth surged to an amazing 10.75%. The growth was fueled by the revival of economic activity, government stimulus programs, and global recovery programs. Government expenditures also expanded during this period to help recover, like additional funding in healthcare, employment, and economic stabilization. The high rise in government spending in 2021 came in response to the expansion of GDP, as Kosovo sought to revive its economy, increase public services, and support enterprises affected by the crisis. The recovery phase required targeted investment in infrastructure and social welfare so that economic growth benefits would filter through to every segment of society.

In 2022, the economy of Kosovo continued to expand at 4.28%, a more restrained but still robust rate, indicating that the economy was settling back into sustainable growth following the post-pandemic surge. Government expenditure during the period continued to drive growth but began to normalize, reflecting a shift from emergency expenditure to more strategic investment in long-term development sectors such as infrastructure, education, and public services. The year 2023 had a growth rate of 4.07%, which showed that Kosovo was in a post-pandemic stabilization period. While the high growth rate of 2021 was slowed down, the economy remained healthy, with moderate growth and ongoing fiscal stimulus to ensure stability. Government expenditure remained the driving force for sustaining this growth, as it financed public healthcare, as well as investing in the future growth of the nation.The fiscal policies of the government, while somewhat lower in intensity in 2021, remained directed towards long-term sustainability and post-pandemic world challenges preparation. Kosovo in 2024 will sustain a steady growth trajectory, with an expenditure likely to continue supporting the recovery efforts, infrastructure construction, and social welfare programs.The economic growth patterns in the period between 2009 and 2023 show Kosovo's resilience against both pre-pandemic stability and the shocks of the world caused by COVID-19. Public expenditure has been the driving force in the years concerned, responding to such adjustments in the economic landscape. From keeping expenditure on investment in infrastructure and social services before the pandemic to the increased outlays necessary to offset the effects of the COVID-19 crisis, the government's fiscal policy has been at the heart of Kosovo's recovery. The unexpected contraction of 2020 was then supplemented by a resounding recovery in 2021, highlighting the importance of swift government intervention. In the post-pandemic era of Kosovo, the focus is shifting to sustainable growth and stabilization, where government expenditure continues to underpin growth and stability. These developments need to be comprehended for being able to predict future economic conditions and ongoing government intervention to foster a strong and growing economy.

5. CONCLUSION

The economic trajectory of Kosovo from 2009 to 2023 has been shaped by seminal events that influenced government expenditures, revenues, GDP growth, and public debt management. The data on GDP growth rates, government revenues, and expenditure illustrate how the economy of Kosovo navigated periods of consistent growth, the shock of the COVID-19 pandemic, and strong rebound, while struggling with public debt pressures. Between 2009 and 2019, Kosovo experienced stable economic growth, with GDP growth rates between 4% and 6%, except for

a temporary dip in 2012 (1.71%). Throughout these years, government expenditure kept up with growth, enabling investments in public infrastructure, social services, and economic development. Government revenues also recorded steady growth, primarily driven by taxation, remittances, and foreign direct investments. But the country's public debt continued to be a concern in the years, since Kosovo, as all developing economies, was borrowing some of its development and building up its debt. The government expenditure was relatively stable in 2019, following economic growth, while debt management was about reconciling fiscal expansion requirements with debt sustainability. The stable economic situation allowed Kosovo to sustain development without serious fiscal imbalances, even though debt was an issue of policy concern. The COVID-19 pandemic caused a sudden economic decline of -5.34% in GDP in 2020 as the economy saw an enormous decline in economic activity. During this period, government revenues declined significantly due to economic slowdowns and decreased tax revenues, while expenditure jumped to cover emergency relief, healthcare, and economic stimulus packages. Public debt would have risen as Kosovo borrowed more to cover the increasing fiscal gap, thereby adding more pressure to debt levels. Government expenditures in 2020 rose as fiscal measures went towards crisis management, e.g., health spending, social support, and economic aid. But with a massive fall in government revenues, the government had to rely heavily on borrowing to finance these crisis support schemes. The result was raised public debt in line with the level of expenditure at the height of the pandemic. In 2021, Kosovo experienced a robust economic recovery, with a 10.75% growth in GDP, the highest in the period of observation. This post-pandemic recovery was fueled by easing restrictions, reopening of the economy, and stimulus by the government. The government expenditure continued to grow with this recovery, as the government invested in infrastructure, public health, and labor generation to stabilize the economy. Public revenues also began to improve as the economy recovered, but debt remained an issue since borrowing to cover recovery was still being undertaken. GDP growth slowed to 4.28% in 2022, and government expenditure began stabilizing. Kosovo's economy was nearly back to normal from the shock of the pandemic in the first phase, but it continued to grapple with the fiscal effects of rising public debt, which remained higher due to the fiscal stimulus interventions implemented to manage the crisis. As Kosovo went into 2023, the economy continued to expand moderately by a rate of 4.07%. It was a time of consolidation, in which government expenditure, although still increasing to address ongoing growth and recovery, was more focused on longer-term development than emergency measures. Kosovo had by then moved out of the first post-pandemic rebound into a more stable phase of growth. The fiscal conditions in 2023 and ahead will require careful management of public debt. While the post-pandemic GDP growth rates are welcome, Kosovo's public debt remains an issue, particularly as the spending continues to rise in areas such as infrastructure development, social services, and health. The government will need to ensure that it can maintain economic growth while keeping debt under control to avoid chronic fiscal imbalances. During 2009-2023, the economy of Kosovo was characterized by resilience and growth, with episodes of economic development marred by the crisis shocks of the COVID-19 pandemic. During the pre-pandemic years, the government recorded a balancing of revenues and spending, spurring steady economic growth. The pandemic, however, triggered a sharp decline in GDP, and increased government expenditure toward crisis management that caused public debt hikes. The strong bounce in 2021 was driven by government expenditure being raised to boost the economy, though the higher government spending also drove rising debt. As Kosovo heads into 2023 and beyond, efforts will focus on sustaining solid growth, with balanced government expenditure and good management of debt so that fiscal policy can support long-term development without damaging the country's financial stability. Kosovo's

economic performance, as seen through GDP growth, government revenues and expenditures, shows an economy in transition—recovering from the impacts of the pandemic, riding out the problem of public debt, and seeking to record steady, balanced growth. The challenge in the future will be how to maintain fiscal discipline while continuously investing in economic growth and public services so that the burden of debt is not made intolerable as the nation presses on towards a better future.

ACKNOWLEDGEMENT: *A special thanks to my PhD mentor, Prof. Dr. Petraç Milo, Faculty of Business and Economics, University of Tirana, Albania, for his invaluable guidance, support, and encouragement throughout my research.*

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SYSTEM EFFICIENCY IN MANAGING LARGE DATA FLOW RESOURCES

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ABSTRACT
In analyzing large volumes of data (commonly referred to as Big Data), particular attention should be given to the flow of these vast datasets and their impact on systems, computing infrastructures, and networks. Modern data ecosystems must handle unprecedented levels of throughput and complexity, demanding innovative approaches to data storage and retrieval. Consequently, both traditional relational database management systems (SQL) and non-relational (NoSQL) databases have emerged as critical tools. While SQL databases excel at handling structured data with well-defined schemas, NoSQL solutions are better suited for large-scale, unstructured, or semi-structured datasets that require high scalability and flexible schemas. The Web environment plays a central role in driving this continual influx of information, generating data at a global scale from an ever-increasing number of sources. Web applications, social media platforms, and interconnected devices contribute to the creation of complex data streams, which, when properly collected and analyzed, can inform strategic decision-making. As these flows of Big Data continue to evolve, organizations need robust, scalable architectures and interdisciplinary expertise to fully harness the potential of these data-rich environments for innovation and growth.
Keywords: *Big Data, data analytics, data storage, decision-making, large volumes of data, NoSQL, scalability, unstructured data*

1. INTRODUCTION

Unlike the predominantly structured data collected some twenty years ago, Big Data today involves large volumes of partially structured, unstructured, or combined data types. Databases that support and are designed for collecting, storing, and processing such data are referred to as NoSQL databases, which differ fundamentally from the traditional relational databases (SQL) that once prevailed (and were almost the sole model). Their widespread adoption has become particularly prominent over the past decade, propelled by the development of Web 2.0 and driven by the needs of pioneering companies in data-model innovation and technological solutions (such as Google, Amazon, and Facebook). Big Data has found extensive application in countless fields and is poised for continued strong growth due to vast data-storage capacities and advanced analytical capabilities. This paper will outline the fundamental characteristics, areas of application, and both the advantages and potential drawbacks of utilizing Big Data from organizational, technical, and technological perspectives. By examining current and emerging trends, this work also aims to provide insights into how Big Data solutions can be effectively deployed, managed, and scaled.

Increasingly, the flow of data is so substantial that organizations seek to tap into it for more informed decision-making, innovative product development, and better customer engagement. Governments and public institutions also use Big Data to optimize resource allocation, improve healthcare outcomes, and enhance transparency and public safety. The convergence of these phenomena underscores Big Data's significance and its transition from a buzzword to a cornerstone of modern information systems. This document is structured to provide a comprehensive view of Big Data concepts, from its historical context and technological foundations to practical applications, ethical considerations, and likely future trajectories. While the focus is on NoSQL and the significance of large, often unstructured datasets, the paper maintains a balanced discussion of SQL, demonstrating how relational databases still hold value when approached with a nuanced understanding of their strengths and limitations.

2. A HOLISTIC EXPLORATION OF BIG DATA

Big data can be defined as a set of information so extensive and complex that it cannot be processed using traditional databases or conventional data-processing applications. Social networks and other companies collect this data over the internet, then analyze it to glean various insights into their users' behaviors, preferences, and demographics. This process enables them to refine their services, personalize recommendations, and deliver targeted content that aligns more closely with user needs and interests. In this context, the network itself plays a crucial role in transmitting data between different nodes, acting as an interconnected system arranged according to a specific topology. Each node within this system can represent a device, server, or any endpoint that sends or receives information. By defining how nodes link to one another, the topology directly influences the reliability, efficiency, and speed of data transfer. As organizations increasingly rely on large data sets for analytics, well-designed networks become ever more essential to ensure seamless data flow from source to destination. (Singaravelan, Joy and Murugan, 2017)

Data science encompasses the application of both qualitative and quantitative methods to address relevant challenges and predict outcomes. By integrating statistical analysis, machine learning techniques, and domain-specific knowledge, data science practitioners can uncover meaningful patterns, make informed decisions, and drive innovation across various industries. (Waller and Fawcett, 2013)

NoSQL databases are increasingly employed for storing large volumes of data (commonly referred to as Big Data) in real-time web applications, as well as in cloud computing environments. The term "Big Data" denotes datasets so vast or complex that they cannot be efficiently processed using traditional application software. Addressing these datasets presents multiple challenges, including data collection, storage, analysis, preservation, search, sharing, transfer, visualization, querying, updating, and ensuring data privacy particularly within the healthcare and public sectors.

The phrase "Big Data" is often used to point to predictive analytics or user behavior analytics, along with other advanced analytical methods designed to uncover value judgments from data. By overcoming the limitations of conventional relational databases, NoSQL solutions offer the scalability and flexibility needed to handle these extensive and rapidly evolving data demands, thus allowing organizations to extract meaningful insights and drive informed decision-making across various domains.

Analyses of large datasets can uncover new correlations that may reveal business trends, aid in disease prevention, or support crime-fighting efforts. The McKinsey Global Institute, for instance, highlights five key areas where Big Data finds significant application: healthcare, the public sector, sales, manufacturing, and personal location (GPS). As mentioned earlier, the primary focus is on extracting value judgments from the substantial amounts of data we collect. Recent developments in information technology particularly in research methods, data collection and analysis, as well as data storage and retrieval have significantly improved the quality and precision of reporting. This progress, alongside enhanced access to information, enables more sophisticated and accurate analyses. Nonetheless, the effectiveness of any analysis still depends on data quality, and professionals such as scientists, managers, healthcare providers, public officials, and marketing experts frequently encounter challenges when drawing conclusions from large datasets. (Dmitrović, Dušak and Dobša, 2016)

Data sets are growing at an extraordinary pace, partly due to the proliferation of sensors associated with the Internet of Things (IoT), including mobile devices, home and surveillance cameras, microphones, wireless networks, and smart home systems. In healthcare, for example, electronic medical records may include X-ray and ultrasound documentation, adding entirely new dimensions to traditional patient histories.

The numbers illustrating this data explosion are striking. Comparisons to the U.S. Library of Congress often deemed a vast repository appear minuscule when set against the ocean of digital information now being generated. Indeed, estimates suggest that 2.5 exabytes (2.5×10^{18} bytes) of data are produced every single day, highlighting both the sheer volume of data and the immense challenges and opportunities it creates.

In 2012, Gartner defined Big Data as "high-volume, high-velocity, and/or high-variety information assets that demand cost-effective, innovative forms of information processing for enhanced insight and decision making." This widely used definition introduces what are known as the 3 Vs Volume, Velocity, and Variety which necessitate specialized technologies and analytical methods to transform raw data into actionable value. (Madden, 2012)

For instance, business intelligence employs descriptive statistics on data with high information density to measure various factors and detect trends. In contrast, Big Data approaches utilize inductive statistics and concepts from nonlinear system identification to extract governing principles (e.g., regression models, nonlinear relationships) from vast datasets characterized by lower information density. This enables the discovery of hidden correlations or dependencies and facilitates predictions of future outcomes and behaviors.

Big Data can be characterized by the following attributes:

- Volume: The amount of data generated and stored.
- Variety: The type and nature of the data.
- Velocity: The speed at which data is generated and processed.
- Variability: Inconsistent datasets can complicate data processing and management.
- Veracity: The quality of the collected data may vary, affecting the accuracy of analysis.

Factory-based and cyber-physical systems can employ a "6C" approach:

- Connection – Sensors and networks
- Cloud – On-demand computing and data

- Cyber – Modeling and storage
- Content/Context – Meaning and correlation
- Community – Sharing and collaboration
- Customization – Personalization and added value

Data must be processed using advanced tools analytics and algorithms to yield meaningful information. For instance, managing a factory requires taking into account both visible and invisible components. The algorithm responsible for generating actionable insights must detect otherwise hidden elements, such as machine malfunctions or unforeseen events, ensuring that decision-making is both comprehensive and proactive.

3. TRANSFORMING DATA STORAGE AND THE EVOLUTION OF BIG DATA WAREHOUSES

Big Data warehouses exist in a variety of forms, most commonly designed to meet the specific needs of individual companies. Since the 1980s, commercial enterprises have promoted systems based on parallel processing to address growing computational demands. In the early years, many companies relied on conventional database systems; however, as data volumes increased and the variety of data expanded, these systems began to show limitations. The evolution of Big Data warehouses has been driven by significant technological breakthroughs, enabling more efficient processing of large datasets. Innovations such as cloud storage solutions (e.g., Amazon S3, Google Cloud Storage), NoSQL databases (e.g., Cassandra, MongoDB), and real-time processing frameworks (e.g., Apache Kafka) have laid the foundation for modern business intelligence systems. Several pioneering companies and their groundbreaking technologies have played a crucial role in shaping the trajectory of Big Data advancements:

- Teradata (Pre-2008) – Initially specialized in structured databases but later integrated support for unstructured formats like XML, JSON, and Avro, enhancing flexibility and analytical capabilities.
- LexisNexis (2000) – Developed a distributed storage framework in C++ capable of handling structured, semi-structured, and unstructured data, offering scalable solutions for intensive data applications.
- Google MapReduce (2004) – Revolutionized parallel processing by dividing tasks into smaller sub-tasks (mapping), executing them across multiple nodes, and aggregating results (reducing), enabling efficient handling of massive datasets. Its success influenced various distributed processing frameworks, including Apache Hadoop.

Advancements in distributed systems are essential for addressing the challenges of real-time processing of vast data volumes. Modern architectures focus on scalability, flexibility, and faster query performance through parallel processing. Additionally, their diverse applications across industries highlight their role in driving innovation and supporting data-driven decision-making. Key priorities include:

- Scalability & Flexibility – Horizontal scaling, enabled by technologies like Kubernetes and containerization, supports diverse data types, including real-time IoT-generated data.
- Performance Enhancement – Parallel processing frameworks, such as Apache Spark, accelerate query execution and real-time analytics.
- Industry Applications – Finance (real-time fraud detection using machine learning), healthcare (patient record analysis for improved outcomes with predictive analytics), and manufacturing (efficiency optimization through predictive maintenance) benefit significantly from Big Data technologies.

Impact and Future Trends The shift from monolithic to distributed architectures has allowed organizations to efficiently manage increasing data volume, variety, and velocity. Integration with machine learning, data mining, and predictive analytics continues to drive innovation, providing deeper business insights and real-time decision-making. Emerging technologies such as edge computing, federated learning, and privacy-preserving AI models are gaining traction. Despite advancements, challenges like data privacy regulations (e.g., GDPR) and cybersecurity risks remain prominent. As data-driven applications expand, adopting advanced architectures will be crucial for sustaining high performance, scalability, and operational efficienc

4. LEVERAGING TENSOR REPRESENTATIONS AND DISTRIBUTED TECHNOLOGIES FOR ADVANCED BIG DATA ANALYTICS

In the 2011 report by the McKinsey Global Institute, the primary components and ecosystem of Big Data are characterized as follows:

- Data analysis techniques: These include methods such as A/B testing, machine learning, and natural language processing.
- Big Data technologies: This encompasses tools like business intelligence systems and various database solutions.
- Visualization: This refers to the use of charts, tables, and other graphical representations to present data effectively.

Multidimensional Big Data can be represented as tensors, which serve as a powerful and natural framework for modeling complex, high-dimensional datasets. Unlike traditional two-dimensional matrices, tensors extend to three or more dimensions, allowing data to be organized in a manner that preserves its inherent structure and interrelationships. This multidimensional representation is especially beneficial when dealing with data that arises from multiple sources or is characterized by several attributes, as is common in modern data-intensive applications.

Tensors are essentially multi-way arrays that generalize scalars, vectors, and matrices into higher dimensions. This flexibility enables them to capture relationships and interactions across several dimensions simultaneously. For example, in a social media analytics context, a tensor might represent user interactions with content over time across various platforms, where each dimension corresponds to a different aspect of the data users, content types, timestamps, and even geolocations. By employing tensor representations, analysts can uncover hidden patterns and correlations that might be lost or obscured when using traditional data models.

To efficiently process these tensor-structured data, tensor calculus provides the necessary mathematical framework. Tensor operations such as tensor decompositions, contractions, and factorizations enable the extraction of meaningful features and the reduction of dimensionality without sacrificing critical information. These operations are pivotal in applications like deep learning, where neural network architectures (e.g., convolutional neural networks) inherently exploit tensor computations to process images, videos, and other multidimensional signals. The efficiency gained through tensor-based processing often translates into faster computation times and improved accuracy in predictive modeling and pattern recognition tasks.

Complementing tensor computations, a range of additional technologies can be applied to manage and analyze Big Data. One such technology is massively parallel processing (MPP) of databases, which allows large datasets to be distributed across multiple servers and processed concurrently.

By harnessing the collective power of numerous processing nodes, MPP systems can significantly reduce the time required to perform complex queries and analytics on massive data volumes. This parallelism is crucial for real-time analytics and other time-sensitive applications. Another key technology is the use of specialized search applications. These applications are designed to efficiently index and retrieve information from vast data repositories. With the increasing volume and diversity of data, traditional search methods may fall short, making advanced search algorithms indispensable for quick data access and analysis. Such systems are optimized to handle the high speed and scale of data generated in today's interconnected world. Data mining, or knowledge discovery from data, is yet another essential technology in the Big Data ecosystem. By applying statistical models, machine learning algorithms, and pattern recognition techniques, data mining enables the extraction of valuable insights from complex and heterogeneous datasets. Whether it is identifying consumer trends, detecting fraudulent transactions, or forecasting system failures, data mining transforms raw data into actionable intelligence that can drive strategic decision-making. Distributed file systems and distributed databases further enhance the management of Big Data. Distributed file systems, such as Hadoop Distributed File System (HDFS), store data across multiple machines, ensuring scalability, fault tolerance, and efficient data retrieval. Similarly, distributed databases allow for the partitioning of data across different nodes or geographic locations, which not only improves system resilience but also enables faster query responses. These distributed architectures are integral to the infrastructure of modern data centers, where data must be both securely stored and readily accessible. Cloud infrastructure and the ubiquitous presence of the Internet also play a vital role in supporting Big Data initiatives. Cloud computing platforms provide scalable, on-demand resources that allow organizations to dynamically allocate computing power and storage as needed. This flexibility is particularly important when dealing with unpredictable data loads or when scaling operations to meet rising demand. Meanwhile, the Internet facilitates rapid data exchange and connectivity between distributed systems, enabling seamless integration of diverse data sources and ensuring that insights can be generated from a truly global pool of information.

Representing multidimensional Big Data as tensors and processing them using tensor calculus significantly enhances the efficiency and depth of data analysis. When combined with additional technologies such as massively parallel processing, advanced search applications, data mining techniques, distributed file systems, distributed databases, and robust cloud infrastructures, organizations are equipped to tackle the complexities of Big Data. This integrated technological ecosystem not only improves performance and scalability but also lays the groundwork for advanced analytics, enabling more informed decision-making and fostering innovation across various domains.

5. LAMBDA ARCHITECTURE INTEGRATING BATCH AND REAL-TIME DATA PROCESSING FOR BIG DATA APPLICATIONS

Lambda architecture is a robust data processing paradigm designed to manage enormous volumes of data by combining the strengths of batch processing and real-time streaming. Batch processing a technique that dates back to the era of MS-DOS when executable files with a .bat extension were prevalent refers to the execution of a series of prearranged tasks without operator intervention. This method efficiently handles historical data, enabling the systematic processing of large datasets to uncover trends and patterns over time. Conversely, streaming processing addresses data in real time. Instead of treating data as static tables or files, this approach handles data as a continuous, unbounded flow originating from various sources.

The primary benefits of streaming include immediate data accessibility before it is permanently stored, the capacity to integrate historical records with new incoming data to establish dynamic context, and the rapid processing of high data volumes with minimal latency. This real-time responsiveness is critical for applications that require prompt analysis and swift decision-making. By integrating batch and streaming processing, lambda architecture achieves a well-balanced system that optimizes latency, throughput, and fault tolerance. The dual approach allows for comprehensive historical analysis while simultaneously providing immediate insights into current data. This equilibrium is crucial for applications where both long-term trend analysis and instant data reactions are necessary.

The growing adoption of lambda architecture is closely linked to the surge in Big Data and real-time analytics demands. The underlying data model serving as both the source and repository supports this architecture, which is generally structured into three distinct layers. The first is the batch processing layer, responsible for large-scale, periodic computations that consolidate historical data. The second is the speed or real-time processing layer, which rapidly analyzes incoming data streams to deliver immediate insights. Finally, the serving layer merges outputs from both previous layers to facilitate efficient and accurate query responses.

Each layer is integral to the architecture's performance. The batch layer ensures the thorough processing of historical datasets, the speed layer maintains the immediacy of new data, and the serving layer provides a coherent, unified view for end-user queries. Together, these layers empower organizations to harness both the depth of historical data and the agility of real-time processing, thereby enhancing overall operational performance and decision-making capabilities.

Lambda architecture exemplifies an innovative solution to the challenges of Big Data processing. Its combined approach not only maximizes system efficiency and reliability but also enables businesses to achieve a balance between comprehensive data analysis and rapid responsiveness, ensuring that critical insights are both accurate and timely.

5.1.The three layers of Lambda architecture

The batch layer is responsible for precomputing results using a distributed processing system capable of handling extremely large datasets. This layer prioritizes accuracy and completeness by processing all available data when generating views. Since it has access to the full dataset, it can correct any errors by recalculating results based on complete data and then updating the existing views accordingly. The computed outputs from this layer are typically stored in a read-only database, where updates completely replace previous precomputed views. A prime example of batch processing technology is Apache Hadoop, which has become the industry standard for large-scale batch processing.

The speed layer processes real-time data streams without requiring the completeness of the entire dataset. Its main role is to bridge the gap created by the inherent latency of the batch layer, ensuring that real-time views are available based on the most recent incoming data. While the views generated by this layer may not be as precise or complete as those from the batch layer, they are available almost instantly after data is received and can be replaced when more accurate batch layer results become available. Popular stream-processing technologies used in this layer include Apache Storm, SQLstream, and Apache Spark, with output data typically stored in high-speed NoSQL databases optimized for rapid querying.

The serving layer stores output data from both the batch and speed layers, providing immediate responses to queries by retrieving precomputed views or dynamically generating views from processed data. Technologies used in this layer ensure fast and efficient access to aggregated results from both processing layers. One notable example is Druid, which manages a cluster for handling and querying output data from both the batch and speed layers. Dedicated storage solutions commonly employed in the serving layer include Apache Cassandra or Apache HBase for speed layer outputs, while ElephantDB or Cloudera Impala are typically used for storing batch layer results.

By integrating these three layers, lambda architecture effectively balances latency, throughput, and fault tolerance, ensuring that both real-time and historical data analytics can be performed efficiently. This structure enables organizations to leverage Big Data for instant insights while maintaining long-term accuracy and reliability.

6. BIG DATA IN GOVERNMENT AND PUBLIC SECTOR

The McKinsey Global Institute report highlights various governments and their public sectors as highly effective users of Big Data. Predictably, the most developed countries lead in this area, with the United States at the forefront, given its dominance in technological innovation and IT product development. Big Data is utilized across multiple governmental functions, including presidential and local elections, digital healthcare systems, law enforcement, national security, governmental agencies, social trend analysis, and financial oversight at both local and national levels.

To illustrate its impact, consider a few key examples:

United States: In 2012, the Obama administration launched the Big Data Research and Development Initiative, emphasizing its role in scientific discovery, national security, and healthcare. Big Data analytics played a crucial role in Barack Obama's reelection campaign, enabling targeted voter outreach and data-driven decision-making. The National Security Agency (NSA) established a data center in Utah designed to process vast amounts of internet data for national security. While the official storage and analytical capacities remain undisclosed, experts suggest that the agency manages global-scale data surveillance beyond domestic threats. The U.S. leads in supercomputer infrastructure, with many systems dedicated to defense, national security, and governmental research.
India: In 2014, Big Data analytics was used in the national elections to assess voter sentiment, improve campaign strategies, and enhance political outreach.

United Kingdom: In the public healthcare sector, Big Data is used to analyze prescribed medications, their distribution, and patient usage patterns. These insights support research aimed at improving healthcare systems, monitoring national health trends, and identifying regional variations in drug consumption.

These examples demonstrate how governments worldwide utilize Big Data to enhance policy-making, security, healthcare, and electoral processes, reinforcing its role as a critical tool for modern governance.

7. RECENT DEVELOPMENTS IN BIG DATA APPLICATIONS (2019–2024)

In the past five years, Big Data has continued to evolve, significantly impacting various industries, including government, healthcare, finance, artificial intelligence, and climate science. Below are some of the most notable advancements in Big Data applications from 2019 to 2024.

In 2019, law enforcement agencies in countries like the United States, the United Kingdom, and China began expanding their use of AI-powered predictive policing to forecast crime patterns based on real-time data. By 2020, the COVID-19 pandemic accelerated the global adoption of Big Data analytics for public health, including contact tracing, mobility tracking, and vaccine distribution planning. In 2021, governments worldwide increased their investment in cybersecurity and real-time intelligence systems to combat growing cyber threats. By 2022, agencies such as the NSA (U.S.) and GCHQ (U.K.) had enhanced their AI-driven surveillance programs, using real-time Big Data processing to detect potential national security risks. In 2023, Big Data analytics played a crucial role in monitoring social and economic trends, helping policymakers predict inflation and economic downturns. By 2024, automated decision-making systems became widely used in public administration, improving the efficiency of government services and resource allocation.

The healthcare sector saw a dramatic shift in 2020, when Big Data analytics became essential in tracking COVID-19 cases, managing hospital resources, and predicting pandemic waves. In 2021, AI-based diagnostic tools were developed using large datasets, improving early detection of diseases such as cancer. By 2022, genomic medicine had advanced significantly, with Big Data being used to analyze DNA sequences and develop personalized treatments. In 2023, wearable health devices became more widely integrated with real-time health monitoring systems, allowing for early intervention in chronic disease management. By 2024, hospitals and research institutions had fully adopted AI-assisted diagnostics, reducing misdiagnosis rates and improving patient outcomes through real-time decision support systems.

During the 2020 U.S. Presidential Election, political campaigns made extensive use of Big Data analytics, employing real-time voter sentiment tracking, micro-targeted ads, and AI-driven outreach strategies. In 2021, new AI-powered misinformation detection systems were deployed to combat deepfake content and election fraud. By 2022, major political parties across Europe and Asia began implementing predictive analytics to forecast election outcomes with greater precision. In 2023, real-time data dashboards became essential tools in tracking voter behavior and identifying swing districts. By 2024, Big Data-driven election monitoring systems were widely used to detect voting anomalies and ensure the integrity of electoral processes worldwide.

In 2019, major retailers such as Amazon and Alibaba enhanced their recommendation systems using Big Data-driven AI models, improving personalized shopping experiences. By 2020, the global supply chain crisis exposed vulnerabilities in logistics networks, prompting companies to adopt predictive analytics for supply chain optimization. In 2021, financial institutions improved fraud detection systems using machine learning models trained on massive transaction datasets. By 2022, AI-powered real-time customer sentiment analysis became standard in marketing strategies, allowing businesses to adjust campaigns based on consumer reactions. In 2023, dynamic pricing algorithms became more sophisticated, adjusting product prices based on market trends and competitor analysis.

By 2024, companies had fully integrated AI-driven business intelligence platforms, streamlining decision-making processes and boosting operational efficiency. The release of GPT-3 in 2020 marked a turning point in Big Data-driven natural language processing, significantly improving AI chatbots, virtual assistants, and content creation tools. By 2021, AI-powered image generation models like DALL·E revolutionized digital design, using Big Data to train deep learning networks for creative applications. In 2022, companies such as Tesla and Waymo expanded the deployment of self-driving cars, using Big Data from millions of road miles to refine autonomous navigation. By 2023, AI-powered legal research tools were widely adopted in law firms, enabling faster case analysis and document drafting. In 2024, real-time AI personal assistants integrated with Big Data analytics became a standard feature in businesses, improving customer support and administrative efficiency.

In 2020, cities worldwide began using real-time traffic data and AI-powered analytics to improve public transportation efficiency. By 2021, smart energy grids that optimized power distribution based on consumption data were widely adopted in developed countries. In 2022, environmental monitoring systems leveraging Big Data helped urban planners track pollution levels and air quality. By 2023, public transportation networks started using AI-driven demand forecasting models, reducing delays and optimizing schedules. In 2024, smart buildings equipped with sensor-based power management systems became the norm, improving energy efficiency in urban environments.

Between 2019 and 2024, Big Data transformed industries, revolutionizing government operations, healthcare, business intelligence, and AI development. The integration of real-time analytics, machine learning, and cloud computing has enabled organizations to process vast amounts of data more efficiently, improving decision-making, security, and innovation. As computational power continues to grow, Big Data will remain a fundamental driver of technological progress, shaping the future of digital transformation and automation.

8. BIG DATA IN THE EU PUBLIC SECTOR, BUSINESS, AND MANUFACTURING

The European Union's public sector is considered one of the most advanced in the world regarding Big Data analytics, second only to the United States. Many EU member states have undergone extensive digital transformation, integrating their citizens into e-societies where public services are fully digitalized. Countries like Estonia have even implemented electronic voting systems, demonstrating a commitment to leveraging technology for public governance. One of the most significant applications of Big Data in the EU public sector is found in healthcare analytics. The UK’s National Health Service (NHS), for example, does not merely use digital tools to streamline prescription management but also tracks national health trends and medication usage. This allows for better forecasting of future healthcare expenditures and more effective allocation of resources. (Manyika, 2011)

The EU's long-term digital strategy envisions the creation of a shared information infrastructure, with national public administrations expected to integrate into a larger European network. Already, cross-border data exchanges exist, such as tax and transportation records sharing between EU nations. Furthermore, supranational Big Data repositories, such as Europol’s law enforcement databases, allow for enhanced security cooperation. Additionally, the EU Business Register enables real-time verification of company records across member states.

In Croatia, the e-Citizen (e-Građani) platform and e-signature have been established to streamline governmental services, allowing citizens to access a broad range of public administration tools digitally. While the use of Big Data in national security and intelligence services is not openly disclosed, reports indicate that the EU has one of the most advanced data infrastructures in the world, second only to the U.S. In the private sector, Big Data analytics plays a key role in understanding consumer behavior. Companies develop advanced applications to analyze customer habits and optimize marketing strategies. One of the best-known examples is Amazon's personalized marketing algorithm. When a registered Amazon customer browses or purchases products, their shopping behavior is stored in a massive database. This database records previous searches, clicks, and transactions, allowing Amazon to generate highly targeted recommendations. For example, if a user recently searched for rare rose seeds and purchased a Japanese language textbook, Amazon's Big Data algorithms will tailor future advertisements to gardening supplies, Japanese culture, and language books. Manufacturing is a highly complex process that integrates multiple activities requiring precise coordination to maximize productivity. Effective Big Data analytics allows companies to gather, process, and interpret large volumes of data in real time, transforming raw information into actionable business intelligence. A well-implemented Big Data system provides insights into a company's financial health, material inventory, and operational efficiency. It also offers simulation tools for production processes, enabling managers to assess the impact of workflow changes. Determining warehouse stock levels can be done with a simple query, but optimizing the production process requires far more data. A comprehensive analysis might involve:

- Tracking how long raw materials remain in storage and their impact on operational efficiency.
- Assessing how supply chain delays affect overall productivity.
- Analyzing whether production is financed through loans or self-investment and evaluating cash flow risks.

Identifying the best target markets for faster inventory turnover. In small businesses, a skilled analyst might be able to manage these processes manually, but in medium and large enterprises, dedicated Big Data tools are essential for processing and interpreting massive daily data streams. The more complex a company, the greater the data segmentation, requiring specialized analytics to derive meaningful insights. With effective data analytics, manufacturing companies can achieve up to a 7% reduction in working capital expenses, a significant cost-saving factor that highlights the value of real-time data-driven decision-making.

9. ANALYSIS OF BIG DATA APPLICATIONS IN THE EU PUBLIC SECTOR AND MANUFACTURING

The European Union (EU) has been at the forefront of integrating Big Data analytics into both its public sector and manufacturing industries. This integration aims to enhance efficiency, transparency, and innovation. Below is an analysis of key applications and initiatives in these sectors:

- **EU Public Sector**

The EU has implemented several directives and infrastructures to promote the use of Big Data within public administrations:

Initiative	Description	Impact
Open Data Directive (EU) 2019/1024	Adopted on 20 June 2019, this directive enhances access to and re-use of public sector information by making datasets available in machine-readable formats and through APIs.	Facilitates the creation of value-added services and applications, promoting transparency and innovation.
Big Data Test Infrastructure (BDTI)	Launched by the European Commission in 2019, BDTI is a free, ready-to-use analytics cloud stack for public administrations to experiment with open-source tools and foster the re-use of public sector data.	Supports data-informed decision-making and encourages the adoption of Big Data solutions across EU member states.

- **Manufacturing Sector**

Big Data analytics has significantly transformed manufacturing processes within the EU:

Application	Description	Impact
Predictive Maintenance	By analyzing equipment performance data, manufacturers can predict when machines are likely to fail and perform maintenance before costly breakdowns occur.	Reduces downtime and maintenance costs, enhancing operational efficiency.
Quality Control	Real-time data collection from sensors allows manufacturers to monitor and analyze processes to identify anomalies or defects that could compromise product quality.	Ensures products meet high standards, leading to increased customer satisfaction.
Process Optimization	Big Data analytics helps in understanding and analyzing factors that contribute to production quality by evaluating decades of data present in a company.	Enables manufacturers to optimize production processes, increasing efficiency and reducing waste.

The EU's commitment to leveraging Big Data in both the public and manufacturing sectors underscores its dedication to fostering innovation, improving efficiency, and maintaining competitiveness in the global market.

10. CONCLUSION

From the insights presented in this study and the reviewed literature, it is evident that Big Data is becoming an indispensable tool in analytics across all industries, including healthcare, finance, administration, commerce, and manufacturing. The ability to extract meaningful insights from vast datasets is redefining decision-making processes and enabling businesses and governments to operate more efficiently. Technological advancements, particularly the evolution of Web 2.0 and the Internet of Things (IoT), have led to an exponential increase in data generation. As the volume of collected data continues to grow each year, new methods for data collection, processing, and analysis are emerging, enabling more refined and accurate analytics. The rise of NoSQL and hybrid databases has introduced more efficient and scalable solutions for handling massive data volumes, allowing real-time or near-real-time data processing. Companies such as Google, Amazon, and Facebook have pioneered new Big Data processing techniques, including parallel processing and MapReduce, both for commercial and scientific applications. Despite its advantages, the expansion of Big Data analytics still faces significant challenges. One major concern is the high demand for skilled professionals. According to McKinsey Global Institute, the demand for qualified data analysts is projected to

exceed the available workforce by approximately 200,000 experts in the coming years. This shortage of technical expertise remains a barrier to the widespread adoption of Big Data technologies, especially in countries with limited digital infrastructure. Currently, wealthier nations such as the United States, the European Union, and China dominate the Big Data landscape, largely due to their investments in advanced AI, cloud computing, and mobile technologies. The growing adoption of Big Data in business intelligence and corporate strategy further highlights its importance. According to a Transforming Data with Intelligence study, 70% of surveyed businesses recognized Big Data analytics as a competitive advantage, while 30% identified technical difficulties in managing it as a challenge. These concerns primarily stem from the complexity of data management, security risks, and the scarcity of skilled professionals. However, companies that successfully integrate Big Data into their operations experience improved efficiency, cost reduction, and data-driven decision-making, which are essential for long-term success in competitive markets. Looking ahead, Big Data applications will continue to expand into new sectors, driven by the increasing availability of advanced technologies and solutions. The ongoing evolution of hardware, software, and data analytics techniques will further accelerate Big Data adoption, making it more accessible and valuable across industries. The integration of AI, machine learning, and automated decision-making systems will enhance data processing capabilities, enabling real-time analytics and more precise forecasting models. As governments and organizations work toward greater digital transformation, new regulatory frameworks will emerge to ensure responsible data usage and security. The EU's leadership in digital governance, including GDPR and AI regulations, sets an important precedent for balancing innovation with ethical considerations. The rapid advancement of Big Data analytics, coupled with the increasing need for real-time insights, will drive significant growth in data processing and analysis. The continuous development of new methodologies, optimization of existing frameworks, and expansion of global data infrastructures will shape the next generation of data-driven decision-making, reinforcing the importance of Big Data in the modern world.

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