

MEC_SZ 14923

Tudományos tudásmegosztás határok
nélkül multidiszciplináris
megközelítésben – International
Society for Research in Education and
Science és az Óbudai Egyetem Keleti
Károly Gazdasági Karának közös
konferenciája



OBUDA UNIVERSITY
KELETI KÁROLY FACULTY OF BUSINESS
AND MANAGEMENT



NATIONAL RESEARCH, DEVELOPMENT
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HUNGARY

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SHARING SCIENTIFIC KNOWLEDGE WITHOUT BORDERS IN A MULTIDISCIPLINARY APPROACH
TUDOMÁNYOS TUDÁSMEGOSZTÁS HATÁROK NÉLKÜL MULTIDISZCIPLINÁRIS
MEGKÖZELÍTÉSBEN

Joint conference of the International Society for Research in Education and Science and the
Keleti Károly Faculty of Business and Management of Obuda University
International Society for Research in Education and Science és az Óbudai Egyetem Keleti Károly
Gazdasági Karának közös konferenciája

7th International Conference on Management Economics and Business (IConMEB)
was held between 28th and 31st August 2025 at Obuda University, Budapest/Hungary

Obuda University
Keleti Károly Faculty of Business and Management
2025
Budapest
Hungary

2nd Edition

Editors

Dr. Seyit Ahmet Kiray
Prof. Dr. Ágnes Csiszárík-Kocsir

ISBN 978-963-449-401-0



NATIONAL RESEARCH, DEVELOPMENT
AND INNOVATION OFFICE
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THE RELATIONSHIP BETWEEN E-COMMERCE AND BLOCKCHAIN TECHNOLOGY

Abstract: E-commerce is gaining more ground these days. It is almost impossible to remain on the market without selling on the Internet. Small, medium, and large companies are also represented in E-commerce. The application of blockchain technology in this field is a novelty, since very few people are aware of the possibilities inherent in blockchain. The aim of the research is to create and present a blockchain solution that could be successfully applied in the field of E-commerce in the future. By applying this method, commercial processes can be made secure and transparent. The research will create such a blockchain and present the structure of its operation. It can be stated that blockchain can be created and applied in everyday life. The relationship between commerce and blockchain will certainly become closer in the future, and its possibilities should be assessed first. This solution allows both the seller and the buyer to manage purchases and various orders more securely and transparently.

Keywords: E-commerce, Blockchain technology, Data storage solution

Introduction

With the rise and widespread use of the Internet, new commercial solutions have emerged. In recent years, with the maturity of the development of network information technology and the deepening integration of traditional business models, e-commerce, as a product of the combination of network information technology and e-commerce, has become an important trend of economic development in the new era (Ma & Gu, 2024). The rise of Internet information and mobile technology has led to the rapid development of e-commerce in recent years. Many e-commerce platforms, such as Amazon, eBay, and JD, have entered the e-commerce market. These platforms and their suppliers constitute most e-commerce platform supply chains (Zhang et al., 2024). The behavior of market participants has also changed, which poses new challenges for the entire economic market. Some socially relevant actors are already using blockchain technology. It is known that changing the model for a multinational company is a complicated and complex process, but they nevertheless take on the new challenges and risks. From the point of view of customers, this is a beneficial solution when shopping, as they can shop when they have time, every day and at any time, they do not have to be physically present in stores, so they have more time to select products and compare features and prices of different online stores at the same time, and finally, they have unlimited choice and a higher degree of personalization (Zennaro et al., 2022).

In today's fast-paced world, we have had to learn that uncertainty is constant and that we must face it in unexpected situations. Applying blockchain technology in E-Commerce was an unimaginable solution a few years ago (Csiszárík-Kocsir, 2023). By implementing blockchain technology, the purchasing process becomes more transparent, and orders can be tracked more easily. However, security is also a key factor these days, so blockchain can be an excellent choice from this perspective. It is known that the blockchain is made up of blocks, so it is very difficult to modify them illegally. so, is because the blocks are closely linked to each other, so in case of unauthorized modification, all the blocks in the blockchain would have to be modified retrospectively.

For larger purchases or orders, this could certainly be an additional service that will be in demand in the future. All businesses would need to do is use blockchain. Its operation would not incur additional costs compared to the usual centralized data storage.

The research presents the creation of a blockchain that can be operated on a low budget, while ensuring the highest possible level of security. The following research questions were formulated:

Research Question 1:

- Is it possible to create a blockchain that can be used in the field of E-commerce?

Research Question 2:

- Does blockchain provide adequate security for E-commerce?

The research is structured around the following topics:

- Blockchain technology solutions,
- Creation of E-commerce blockchain,
- E-commerce blockchain security solutions.

Blockchain Technology Solutions

The real-world use cases of blockchain technology, such as faster cross-border payments, identity management, smart contracts, cryptocurrencies, and supply chain blockchain technology, are here to stay and have become the next innovation, just like the Internet (Habib et al., 2022). Blockchain is also a tamper-proof distributed ledger technology. Its distributed yet secure nature makes it widely adapted, like Internet technology. Blockchain technology has emerged as a transformative innovation with the potential to revolutionize various industries such as E-commerce (Dong et al., 2023). The e-commerce sector is continually developing, as new technology and methods of purchasing and selling services and items are developed. The traditional e-commerce system is plagued with problems, such as payment disputes, chargebacks, fraud, and a lack of transparency; however, blockchain can transform e-commerce by making transactions more efficient and safer. Blockchain can be used to build a decentralized network that allows people to securely store and share digital assets (Taherdoost & Madanchian, 2023). Blockchain technology as decentralized data storage ensures broad and secure access to consumer and logistics data. With a distributed ledger technology, blockchain allows information to be stored in shared databases and protects information from removal. Blockchain also operates with fully shared and unchangeable information in a decentralized system with the same level of certainty. In other words, a blockchain is a distributed database that is structured as a list of systematic blocks where the committed blocks are immutable (Bálint, 2025). The blockchain used in E-Commerce is built according to the following blockchain structure, which is shown in Figure 1 below.

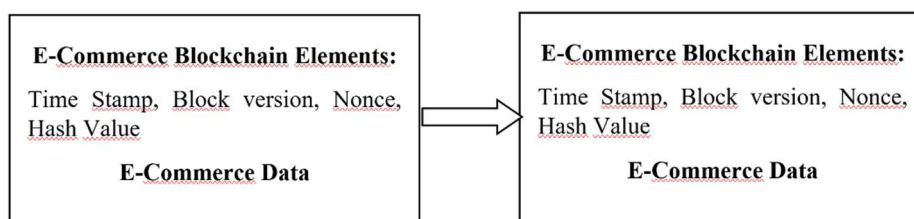


Figure 1. E-Commerce Blockchain Elements

The information in the blockchain is transmitted anonymously and super-encrypted and can be traced back to the production and transportation process of goods, logistics, and supply chain information. Adopting blockchain technology in e-commerce can bring about a safer, more

efficient, and cheaper trading environment. Therefore, an opportunity is provided for diverse stakeholders, including companies and consumers, to contemplate the factors of intention for using blockchain technology (Esfahbodi et al., 2022).

In the figure above, it can be observed that the blockchain used in E-commerce operates on a similar principle and structure as the “traditional” blockchain. Like all blockchains, this one must contain a block header and a block body. The actual trade-related data is saved in the block body. This data can be:

- Personal customer data,
- Transaction data,
- Shipping details,
- Company data,
- Product related data,
- Service-related data.

In the case of blockchain, it is important to determine the exact block size. This must be done before the Genesis block is created. This is important because data will be stored in blocks. In practice, however, this size is very difficult to determine, as if the block is too large, it will result in slower blockchain operation, and if the block is too small, it will be unable to store much data. For this reason, it is necessary to assess the company's needs in each case, how much data they plan to work with per block, and based on this, the optimal block size must be determined.

Creation of E-Commerce Blockchain

When creating a blockchain, the Genesis block must be created. This step is one of the important features of blockchains. Since blocks in a blockchain will be closely linked to each other, creating the first block is a crucial step. In addition, the Genesis block's property will be inherited by the

other blocks, so the Genesis block's property will be the same as the other blocks. Fig. 2 shows the most important step in creating the Genesis block of the E-Commerce blockchain.

```
{
  "config": {
    "chainId": "E-Commerce 100",
    "homesteadBlock": 1,
    "ERC20Block": 1,
    "byzantiumBlock": 1
  },
  "difficulty": "200",
  "gasLimit": "50",
  "extraData": "0x00",
  "alloc": {
    "56c5kza8obv0097562220872534698hjdscyq94n": {
      "balance": "2"
    },
    "hol84dpmv82554kpcneqfwwjm00054867596knz": {
      "balance": "2"
    }
  }
}
```

Figure 2. Creation of E-Commerce Genesis block (Bálint, 2025)

When a blockchain is created, a new and up-to-date blockchain is created. The blocks will have both input and output data. This is presented in Fig. 3 below. The blocks must always contain the latest order data, and these blocks are linked to each other. As a first step, the customer's registration and purchase data are saved to the blockchain as input data. After these are processed, outgoing data appears, which the company has processed and informs the customer about the status of the order, delivery, and payment. This data is also part of the blockchain.

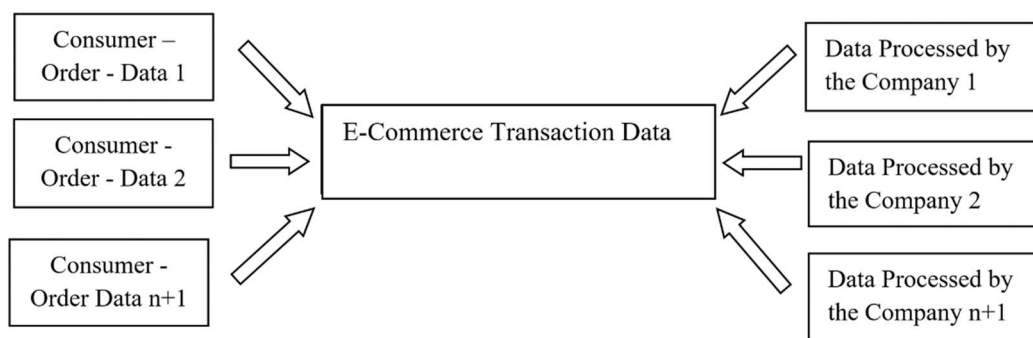


Figure 3. E-Commerce transaction data solution

When creating a new blockchain, the latest customer and consumer needs must of course be considered. However, as the years pass, new needs may arise. In this case, there are two options available:

- Hard-Fork and the
- Soft-Fork solution.

If an upgrade in the blockchain process is non-backward compatible with the existing blockchain implementation, it is termed a hard fork. It can result from a rule change such that the client software and virtual machines validating transactions and blocks according to the old rule will consider it invalid and redundant, hence requiring upgrades of all the nodes involved. One of the prime examples of this is the hard fork of Bitcoin and Bitcoin Cash. Imagine in a blockchain process, after the n th block, some rules in the node were changed, or an upgrade in the blockchain protocol was proposed. The miner nodes (peers on the peer-to-peer network) are required to vote on the adoption and incorporation of these changes. In case the incumbent process is elected, no changes would occur, but if the upgrade is elected and made, it could trigger a "Hard-Fork" in the chain. For instance, any block mined using old protocols would become invalid and could not be chained to the block with the new protocol as depicted in (Yiu, 2021).

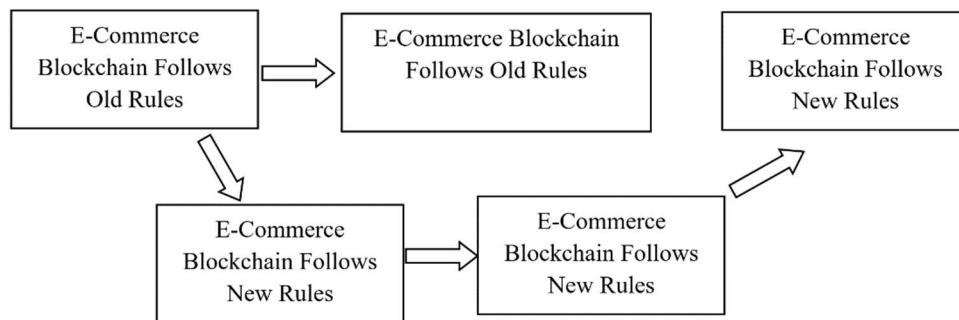


Figure 4. E-Commerce Blockchain Soft-Fork solution

Unlike the Hard-Fork, a Soft-Fork is backward-compatible upgrade, where the upgraded nodes can communicate with those non-upgraded nodes. This is possible only if the new and upgraded rule does not clash with the old one. Examples of this can be seen in both Bitcoin and Ethereum blockchains, where the published and incorporated upgrades are backward-compatible. This process also leads to deviation in the chain sometimes when any block mined using old rules is not processed by the upgraded nodes, but the non-upgraded nodes process it instead - leading to asynchronization without the users noticing it (Yiu, 2021).

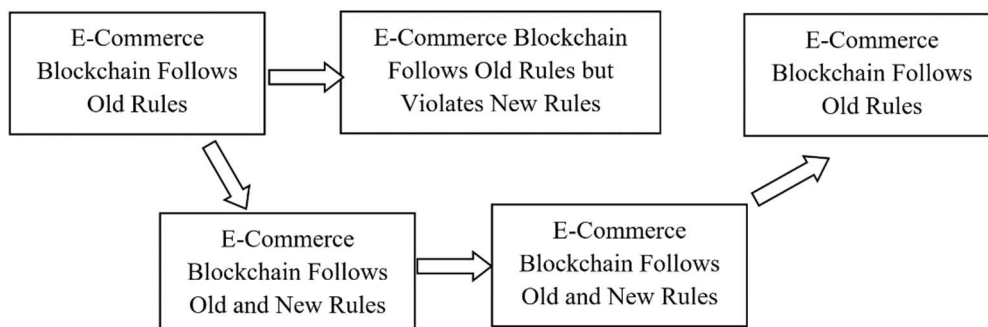


Figure 5. E-Commerce Blockchain Soft-Fork solution

At this point of research, it is difficult to decide whether Soft-Fork or Hard-Fork will be implemented on an E-Commerce blockchain in the future. The consumer market is dynamic and

constantly changing. The analysis of consumer patterns, preferences, and attitudes, and the monitoring of changes in consumer decisions are of key importance for all professionals with a market-oriented approach (Garai-Fodor, 2023). Competitiveness can be analysed in relation to all economic actors, whether national, regional, industrial, corporate, or individual (Fekete et al., 2024). For companies, this step is preceded by serious and complex research and assessment of market needs. They will certainly choose the option that suits them best. In everyday life, after a new blockchain is created, it usually operates without modification for a few years, as these blocks are created together with the Genesis block to meet both current and future needs.

E-commerce Blockchain Security Solutions

In the case of the blockchain, data is constantly available, as the blockchain is made up of nodes. These nodes provide the highest security solution for E-commerce, as data is stored evenly distributed across nodes. Blockchain does not use a centralized solution, as it represents a completely different structure from centralized data storage.

Choosing the right consensus mechanism is also an important step. There are several mechanisms available, such as:

- Proof-of-Work (PoW),
- Proof-of-Stake (PoS),
- Delegated Proof-of-Stake (DPoS),
- Practical Byzantine Fault Tolerance (pBFT),
- Ripple Consensus Algorithm (RCA),
- Proof of Authority (PoA).

Among the many consensus solutions, the most important to consider is the PoW solution as a first step. This is necessary because it was the very first such mechanism that provided adequate

security for the blockchain. It has been used for a very long time and is still used daily today. It can be stated that this solution forms the "foundation" of blockchains.

In PoW-based protocols, the mining nodes must complete and solve an unknown complex mathematical challenge and obtain a result less than the target value before adding a new block to the network. This computationally intensive approach is the core safety mechanism in this protocol. As PoW is a computationally intensive approach, it slows down the TPS (transactions per second) of the network and the time lag in accepting the new block may lead another miner to find the optimum solution as a proof of work thus creating a fork in the network which increases the time taken to reach on a consensus (Joshi, 2021).

The E-commerce blockchain uses the PoA (Proof-of-Authority) consensus mechanism. To accept new blocks, Clique implementation is used inside the PoA algorithm. This algorithm leverages the value of identities, which means that block validators are not staking coins; rather, they are staking their reputation. The process of becoming a validator requires scrutiny and rigour, and, therefore, it is a difficult task to try to compromise the network as a validator's reputation and identity are at stake and can be prosecuted. PoA blockchains are secured by the validating nodes that are arbitrarily selected as trustworthy entities (Chikezie et al., 2021). The main advantages of using PoA consensus mechanism:

- High-risk tolerance, except in cases where 51% of the validators are acting maliciously,
- Predictable block generation time, in the case of PoW or PoS the generation time varies,
- High transaction rate,
- No need to waste resources on processing, like in the case of PoW (Manolache et al., 2022).

For database security and optimal energy consumption, the POA mechanism may be the best choice for E-commerce blockchains. It provides a high level of security with low power consumption.

Multinational organizations usually interact with thousands of customers daily. While some customers are physically served, others are served by automated systems, such as online carts that are synced with check out systems. Essentially, the sale or purchase of a commodity by an organization result in a specific form of contract, which may or may not be enforceable under certain circumstances, each sale or purchase by the organization can, therefore, be treated as a contract. In the case of a business organization, the purchase of any service package by the customer or the purchase of the products by the organization can, as a contract. Such contracts can be digitalized and executed as digital tokenized assets (Nzuva, 2019).

The use of smart contracts provides many new opportunities in the field of E-Commerce. Contracts are fundamentally a legally binding agreement between two or more parties, with each party committed to fulfilling its commitments. Importantly, the agreement must be enforceable by law, often via a centralized legal body (organization). Nevertheless, smart contracts replace trusted third parties or mediators between contracting parties. They make use of this with the assistance of code execution that is automatically disseminated and checked by network nodes in a decentralized blockchain (Taherdoost, 2023). Security is of paramount importance. Blockchain provides sufficient security, however, inappropriate or incorrect use of blockchain can be a serious risk factor that should be avoided. Larger companies often employ IT specialists. An experienced IT professional can avoid many threats lurking on the Internet and can also prevent many malicious attacks. The research aims to develop a security solution that can be implemented even without serious IT knowledge. For this purpose, it is advisable to write a smart contract. This is necessary because the smart contract automatically executes the instructions without making any mistakes. Fig. 6 below shows the main steps in creating a smart contract.

```
pragma solidity ^0.8.0;

contract name E-Commerce Smart Contract {
    // Storage
    string firstName_E;
    string lastName_Commerce;
    constructor(string memory _firstName, string memory _lastName) {
        mapping (address => company address) balances;
    }
    function fullname (E-Commerce) private view returns (string memory) {
        return string(abi.encodePacked(lastName_E;  firstName_Commerce));
    }
}

functions send EC data (E-Commerce blockchain address)
}
```

By using a smart contract, data is automatically saved to the blockchain and is not compromised. Every E-Commerce step is therefore carried out automatically without the help of IT specialists. The orders are recorded in the blockchain by the smart contract, and the smart contract is directly connected to it, thus avoiding human errors.

Conclusion

During the research, it was determined that blockchain technology can indeed be applied in the field of E-Commerce. However, this also requires sufficient dedication for companies to store their data on the blockchain instead of centralized data storage. Like any innovation, such a serious data storage change is certainly not an easy task, which presumably requires properly prepared statistical research.

If blockchain technology were to be chosen, it can be stated that it can be created and applied in this area. When creating it, the Genesis block must be created, after which additional blocks that can store E-Commerce data are automatically created. I would like to propose the most optimal consensus mechanism possible. In this case, the POA solution was used. It is advisable to choose this because it consumes less power than the POW solution while providing adequate security.

For easy use of the E-Commerce blockchain, it is advisable to write a smart contract. This means that E-Commerce blockchain-based data storage tasks are performed in a fully automated manner. Using a smart contract does not require a specially trained IT specialist, as every task recorded in the contract is executed automatically, which is why it is called a smart solution. For efficient operation and increased security, it is recommended to use blockchain in conjunction with smart contracts. Answering the second research question, it can be stated that it is possible to create a secure blockchain that can meet the needs of E-Commerce.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

Funding

* Project no. MEC_SZ 149231 has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the MEC_24 funding scheme.



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Conflict of Interest

* The authors declare that they have no conflicts of interest

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Management Economics and Business (www.iconmeb.net) held in Budapest/Hungary on August 28-31, 2025

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EXAMINING PROJECT SUCCESS FACTORS AND SUCCESS CRITERIA IN A COMPANY FROM THE PERSPECTIVE OF PROJECT LEADERS

Abstract: Within the project management literature, there is a decades-long history of interpreting and investigating the success of projects, and of uncovering the details behind the success of projects. The present project success research study covered the project leaders of a pharmaceutical development and manufacturing company in the corporate sector in Hungary. The aim of the study was to identify and evaluate the success factors and success criteria of projects with the help of using the results of the relevant project management literature and the relevant project success research. A questionnaire survey was used as a quantitative research method to assess project leaders' perceptions of success factors and success criteria. The questionnaire survey investigated what success factors project leaders consider important in achieving project success and what success criteria they use to judge the success of projects. The study shows that the understanding of project success often goes beyond the classic project triangle (time, cost, quality) and the human factors, including stakeholder satisfaction, play an important role. The results of this research can contribute to a deeper understanding of project management practices and can also support the development of a project culture at organizational level.

Keywords: Pharmaceutical industry; Project success; Success factors; Success criteria, Project leader

Introduction

The research included the identification of project success factors and project success criteria defined in the domestic and international literature, and their importance within a given company. According to prominent representatives of the project management discipline, project success should no longer be examined and defined within the framework of the classic project triangle (time, cost, quality/specification). The assumption made within the research was that, in addition to the basic elements of the classic project triangle, other success factors and success criteria also play a somewhat important role in the evaluation of the project leaders.

The project and project management

Dancsecz stated that the definitions found in the literature are not uniformed in terms of the concept of a project but listed some common features that are found in project definitions. These characteristics are the followings:

- a single, complex task
- a specific objective, goal (product/service/outcome)
- a specific start and end time
- a unique, complex and significant problem
- specialized knowledge and multiple resource needs
- short to mid-term, strategically important process
- change, create something new or special
- multifunctionality (Dancsecz, 2008).

Blaskovics states that the diversity of project definitions points to the fact that its interpretation goes beyond the earlier, otherwise essential project triangle [according to Olsen (1971), time, cost and quality] (Blaskovics, 2014; Olsen, 1971 in Blaskovics, 2014).

The professional standards for project management are:

- the process by which a project is scoped, planned, monitored, controlled and executed to achieve pre-defined outcomes (APM, 2008),
- the application of knowledge, skills, tools and methods for activities to meet project requirements (PMI, 2012); (AIPM, 2008).

According to definition of Görög, project management is "... a management function that focuses information, resources - especially the project team staff as the temporary project organization implementing the project - and project management tools to achieve a specific project outcome within a given schedule and budget" (Görög, 2013).

According to the authors Varga and Csiszárík-Kocsir, the importance of project management can be demonstrated in many areas and is more than just a set of methodologies. Project management is a dynamic discipline in which complex tasks can be carried out along well-designed processes, thus reducing potential

risks and directing and focusing the available resources and activities towards a specific goal (Varga, Csiszárík-Kocsir, 2024).

The review of the stages of development of project management also provided an interesting insight. In her doctoral thesis, Horváth provides a visual summary of the overview of the different project management trends, schools and their development over time, as previously formulated by Turner (2013) and his colleagues (Horváth, 2018).

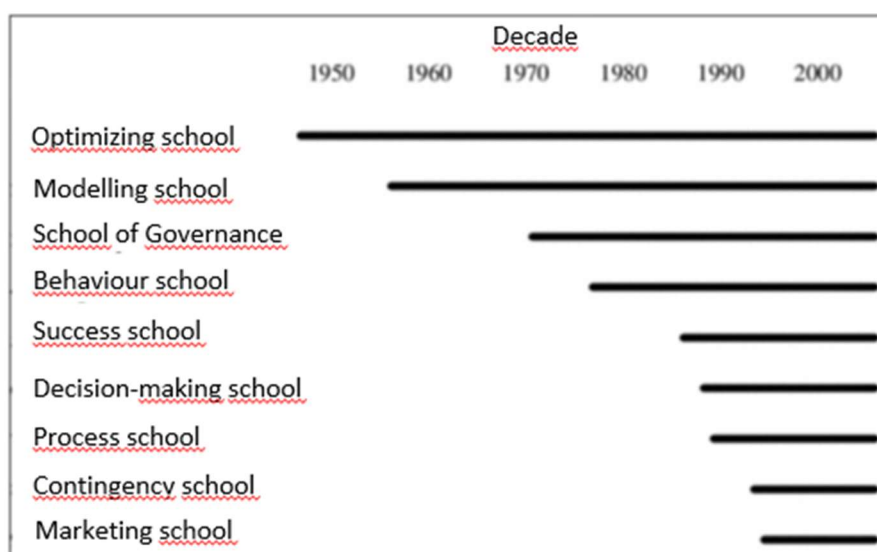


Figure 1. The nine schools of project management (Horváth, 2018)

In terms of research direction, the success school is highlighted, which examines the relationship between project objectives and business, strategic goals. Two main areas of research are project success factors (which may contribute to some extent to the achievement of success) and project success criteria (which allow the measurement of project success) (Turner et al., 2013).

Project success

The topic of the research was success research in the field of project success research, so of course, the literature review also covered the concept of project success in the following.

The most cited researchers in defining project success are Baker, Murphy and Fischer, who argue that project success cannot be defined in its entirety/exhaustively as achieving quality/specification within a timeframe and budget. Perceived project success was defined as the achievement of the defined quality/specification with a high level of satisfaction of the parent organization, client/customer, user and project team. It can be observed that the authors were the first in the literature to mention the importance of customer satisfaction (Baker et al., 1983).

Görög formulated the following definition of project success: "a project is considered successful if the project outcome contributes to the achievement of the underlying strategic goal in the initiating organization and both the project delivery process and the resulting project outcome are acceptable to the stakeholders involved" (Görög, 2013).

According to Horváth, like the project, clearly defining project success is a challenging task. "Defining the success of a project is difficult in itself, and understanding it is greatly aided by defining two related concepts, the success factor and the success criterion, and distinguishing between the two" (Horváth, 2018).

In Blaskovics' formulation, success factors focus on the parameters that contribute to success, thus they deal with the input factors of success, while success criteria allow the measurement of the project success achieved, i.e. they concern the output of success (Blaskovics, 2014).

In the following, the possible success factors and success criteria for projects are showed, based on the literature.

Success factors

The Pinto-Slevin team has identified 10 success factors that depend on the internal organization as a result of their collection-aggregation work:

- project objective, goal
- support of senior management
- project schedule
- consultation with stakeholders, identification of requirements

- team members
- technical performance
- acceptance of the project result by the client
- information flow (monitoring, feedback, control)
- communications
- troubleshooting, problem solving (Pinto-Slevin, 1988).

According to Verzuh, regardless of the industry, all successful projects can have certain characteristics that are constant, so five success factors were summarized for projects:

- clearly defined objectives, agreed by all participants,
- an appropriate project plan (task plan, schedule, budget),
- constant and effective communication between stakeholders,
- a well-defined and regulated scope,
- support of senior management (Vezuh, 2006).

Carden and Egan reviewed the literature from the 1970s, 1980s and 1990s and found that the following success factors were highlighted: project management competencies of management, communication and negotiation skills, project organization structure, and collaboration between business units and senior management (Carden and Egan, 2008).

In their research, El Khatib and his colleagues highlight the importance of emotional intelligence. They state that the key to project success is a project manager with high emotional intelligence, i.e. with appropriate social skills, motivation, empathy, self-awareness and relationship orientation. If the project manager is able to perceive, understand and effectively manage the feelings and emotions of the project team, it can have a positive influence on the project team's performance and thus on the outcome of the project also (El Khatib et al., 2023).

An important moment in the history of the discipline is that the literature has identified success factors within the set of success factors that are of particular importance and weight. These are the critical success factors (CSF).

According to Earl, the method of critical success factors is to identify a small number of factors (preferably 3-7) during the project planning process, the achievement of these factors alone can ensure the success of the project (Earl, 1989).

Rockart also states that while success factors may contribute to some extent to success, critical success factors contribute to a large extent (or the greatest extent for the project, in extreme cases up to 100%) to project success (Rockart, 2002).

Similar findings are made by Fortune and White, who describe critical success factors (key success factors) as those that contribute to a large or outstanding extent to the evolvement of project success as defined by one of the criteria (Fortune and White, 2006).

Cooper's complex, comprehensive, multi-industrial study during the Covid-19 pandemic suggests that the key to success lies in accelerating development and innovation processes, which can also ensure companies' survival.

The author highlighted the importance of the project success factors identified in the literature that could have contributed significantly to maintaining or improving the performance of companies during the pandemic:

- an appropriate and realistic schedule plan
- adequate resource plan
- known and appropriate processes
- partner's satisfaction
- customer's satisfaction
- the satisfaction of colleagues
- stakeholders' satisfaction
- management's satisfaction
- owner's satisfaction
- satisfaction of the project leader
- the size of the project team
- composition of the project team

- the commitment and satisfaction of the project team
- communication within the project team
- change management competences of the project leader and project team
- problem-solving skills of the project leader and project team
- the commitment of management, the project leader and the project team
- continuous monitoring, evaluation and feedback on the status and scope of the project (Cooper, 2021).

The complex national Project Management Panorama survey, conducted in 2022, covering both the public and private sectors, highlights that the human factor is the most prominent and primary factor influencing project success. Personal, competence-related factors were clearly identified as the most important determinants (facilitators or inhibitors) of project success. The research concludes that project success is almost guaranteed if project managers - who are motivated, customer and user-oriented, have the right competences, the ability and willingness to work in partnership with stakeholders - work together with committed and motivated project teams with the right competences (Hungarian Project Management Association, 2022).

Success criteria

In her doctoral thesis, Dancsecz summarized the results of research on the criteria for judging project success and concluded that, in addition to the elements of the magic triangle, the contribution to the strategy and the satisfaction of the different stakeholders/interested parties are the main elements that appear more often in the different works studied (Dancsecz, 2008).

The 6th edition of the Project Management Body of Knowledge (PMBOK) published by the Project Management Institute has formulated the following success criteria:

- the compliance of the revenue/benefit plans,
- compliance with the financial indicators (net present value (NPV), return on investment (ROI), internal rate of return (IRR), payback period (PBP), and cost-benefit ratio (BCR)) of the pre-decision study that determines the business case,
- to meet the non-financial objectives of a pre-decision study to determine the business case,

- meeting the quality requirements of the outcome,
- integrating the project results into the organization's operational environment,
- fulfilment of the contractual conditions,
- meeting organizational strategy and objectives,
- meeting the objectives of organizational governance,
- achieve the desired positive changes in the organization,
- the satisfaction of the stakeholders concerned,
- customer's/end-user's satisfaction
- other criteria (PMI, 2017).

Horváth classified these criteria - in terms of their content - into the following four basic competence categories:

- business value-based criteria
- criteria for meeting the primary project objectives (time, resource and cost plans and quality requirements)
- satisfaction of the project owner organization and compliance with organizational objectives
- criteria addressing the satisfaction of the stakeholders concerned (Horváth, 2018).

Project success in the pharmaceutical industry

As the project success research was conducted in a pharmaceutical development and manufacturing company, it was important to include the relatively small amount of published success literature also that reported on previous pharmaceutical success research results.

According to Sara, the key to success is to involve management/leadership in the project from the start, providing moral, financial and business support (Sara, 2012).

According to Pattanaik, the critical success factors for a pharmaceutical project are the role of the project manager and stakeholders, team communication, and business processes (Pattanaik, 2014).

According to Koka and his co-authors, project management itself, as a success factor, is one of the most effective management tools to influence the full process (from clinical research through production to market logistics) of the entire spectrum of drug development and manufacturing (Koka et al., 2015).

Overall, the quality and quantity of the success factors and success criteria identified and highlighted in the literature clearly indicate that the elements considered in defining and evaluating project success are no longer limited to the elements of the project triangle. More than 4 decades of success research have led to the recognition and acknowledgement that, while the importance of the project triangle is undeniable, the number of elements contributing to project success has increased in proportion to the increase in complexity of projects.

Method

Following the literature review, questionnaire-based primary research was conducted to investigate which success factors and success criteria were considered important by the project leaders of the given company (study population) according to their experience.

The research methodology (questionnaire) is based on the books by Malhotra (2017) and Gyulavári et al (2017).

The success factors and success criteria listed in the questionnaire are external data from secondary research, publications, articles, studies, validated questionnaires, no pilot surveys were needed. The number of pharmaceutical industry-specific studies and literature was relatively small compared to the total literature processed, so the success factors and success criteria identified in the general multi-industrial literature, and the small number of pharmaceutical industry-specific literature were used together as a basis for the definition of the success factors and success criteria to be included in the questionnaire.

The success factors of the project under review were grouped into logically and substantively coherent clusters based on the study by Tsiga et al (2017). The success criteria of the project under review were sorted into logically and content-wise coherent groups based on the research of Horváth (2018).

The questionnaire was designed to allow the project leaders to rate anonymously, based on their own opinion, the success factors and success criteria listed in the questionnaire on a scale of 1 to 4, with 1 being the least important and 4 being very important. The scale categories were determined based on research by Bostock Marketing Group (2014) so that there were no neutral response options. Respondents were given a choice of two positive and two negative response options (forced choice). The questionnaire subjects were asked to choose which success factor/success criterion was most important to them in their work.

The questionnaire was a one-answer closed-ended questionnaire. The questionnaire also included free spaces to allow the respondents to specify some additional factors/criteria if they did not find them listed but were important to them.

The research sought to answer the following questions:

What are the success factors that can determine the success of projects in the given company from the perspective of project leaders?

What are the success criteria for assessing the success of projects in the given company from the perspective of project leaders?

Do the chosen success factors and success criteria differ from the elements of the classic project triangle?

Results and Discussion

More than 90% of the project leaders were willing to fill in the questionnaire, allowing for a representative survey. The evaluation was carried out according to the recommendation of Malhotra (2017) and using Microsoft Excel software, examining success factors and success criteria for each group separately.

Success factors

In the success factors section of the questionnaire, project leaders who completed the questionnaires were asked to rate which factors they felt and experienced contributed to the success of their projects.

The first set of success factors are external and internal challenges. In this group, respondents could rate the environmental factors surrounding the company and its employees. Of the success factors included in this group, the working environment and the technological environment were considered the most important in terms of their scores. The availability and provision of adequate working equipment and a suitable working environment have paramount importance to the company. The evaluation scores reflect the company's strong HSE (health, safety, environment and health and safety) policies and principles. For project leaders, the technological environment is an important factor, i.e. the facilities, equipment, technical staff, R&D, infrastructure, technical and technological standards, IT infrastructure.

The next group of factors is the knowledge and experience group. Factors in this group scored highly. Both knowledge management and realistic and achievable plans are important factors. Incorporating previous experience and lessons learned from similar projects into the new upcoming project can lead to efficiency and lower risk for project leaders.

Within the senior management support group, the most important factors in the group, according to the project leaders, are the support of the project by Management and the commitment of Management to the project. If Management commits and shows commitment to the project and supports the project as one person, then the designated project leader and the project team he/she manages can execute the project with greater efficiency and therefore greater success.

The next group of factors is the group of institutionalized factors. The factors in this group were found to be equally important for project leaders. In the pharmaceutical industry, quality and quality specifications have high importance, as their existence and assurance are essential throughout the life cycle of pharmaceutical products. Projects can be implemented faster and more efficiently by following known processes.

The project manager competence group is the next group of factors assessed. The project manager's competence in team organization and team leadership, his/her competence in planning and organization, his/her ability to manage conflict, and his/her ability to inspire and motivate were all given maximum scores by all respondents, making them critically important success factors to the project leaders who completed the questionnaire. These competences and skills are essential for project leaders to possess throughout the project life cycle, from planning to closure, in order to ensure successful project implementation. Failure to

take these assessed success factors into account may result the failure of the project. Problem solving and communication skills scored highly. The importance of these factors indicates that the 'soft' elements of the human aspect may also contribute more to project success.

According to the scores given to the factors in the project-based organization group, the existence and subsequent continued presence of a project team and a defined resource plan were rated as critical success factors for the project leaders who completed the questionnaire. The provision of the necessary resources for project planning and implementation, including human resources and a project team for the entire duration of the project, were considered by the evaluating project leaders to be critical for a successful project. High scores were given to the defined time and schedule plan, the defined scope and the defined budget plans.

Among the factors classified into a separate group based on contractual and partner aspects, the commitment of partners was rated as a critical success factor by the project leaders. The support, presence, cooperation and planning ability of partners (suppliers, service providers, partner companies entrusted with specific phases of development and production, other partner companies) were rated as a key success factor, and their potential contribution to the success of the project was rated the highest by the project leaders.

Among the elements of the project team competency factor group, the project team's commitment to the project and communication within the project team scored highly with project leaders. This group also contains factors that were identified as critical factors based on the scores. A committed project leader and a collaborative project team can be a solid indicator of project success.

The next and last group of factors assessed is the requirements management group. The project leaders who completed the questionnaire gave also the highest possible score to one factor in this group, namely the defined project objective. This factor was rated as a critical success factor, so for this factor it can also be concluded that planning and implementing projects without a goal can lead to the failure of the project. It is evident for the project leaders conducting the evaluation that knowledge of the project's goal has a great importance, as it is this goal that they communicate to the project team and stakeholders, and it is this goal that they and their project teams are working towards.

Success criteria

In case of success criteria, the project leaders who completed the questionnaires were asked to rate the criteria listed in the questionnaire according to which criteria they preferred when evaluating the projects executed.

The first set of success criteria is the set of business criteria. Within this group, profit growth and value creation both scored highly as success criteria, so project leaders place great emphasis on these criteria when evaluating projects. Business and economic profit was rated as a critical criterion by the project leaders, it became a critical criterion, so failure to meet this criterion could make the project unworthy to evaluate by the project leaders. The profit generated by the successful execution and implementation of a project is an important driving force for projects, which can make an integral contribution to the survival and development of the company. Profit can be a direct result of the projects and a direct performance indicator for the project team and the project leader.

When evaluating the criteria in the group of project ownership and organizational criteria, project leaders highlighted the project manager's skills, abilities, competences and goal performance criteria as important. These criteria became critical criteria based on the project leaders' ratings. For project leaders to evaluate a project as a successful project, the project manager's ability, skill, and competency performance throughout the project, as well as the project's goal performance, are also important evaluation criteria. It was observed that among the success factors discussed in the previous chapter, the project manager's ability, skills and competencies, as well as the defined project goal, were critical success factors. They are therefore critical elements of high importance, both from the input and output side.

Of the criteria in the group of stakeholder criteria, both the product/process sustainability and reliability criteria scored highly in the assessment of the project leaders who completed the questionnaire. For them, the satisfaction of stakeholders, the partner and the client/customer is also an important project evaluation criterion. The high scores for these criteria show that the pharmaceutical product and process development projects should not only last until the product and process are developed and improved. To secure survival, development and future of a company can be based on reliable and sustainable processes and products, and on the trust and cooperation of satisfied internal and external stakeholders.

Conclusion

In the assessment of success factors by project leaders, 10 factors were also rated as critical success factors. Because of their relatively high number, these priority factors deserve more attention. If they are applied throughout the project life cycle, they can make a very significant contribution to the successful execution and implementation of the project and to the achievement of project success. The more identified critical success factors are implemented into the projects, the greater the likelihood of a successful project life cycle. It is observed that several success factors that are not elements of the classic project triangle received high and maximum scores. It is noteworthy that several of these factors have a 'soft' human aspect.

During the evaluation of the success criteria by the project leaders, several success criteria received high scores, and 3 criteria were also evaluated as critical success criteria, CSC (like the name of the critical success factor), the achievement of these criteria can itself entail a significant positive assessment, evaluation and project success. The critical success criteria include a 'soft' criterion with a human aspect, not belonging to the classical project triangle (the project manager's skills, abilities and competences).

In case of several of the elements to be evaluated, it was observed that they were rated as critical elements with a maximum score both on the input side (i.e. as success factors) and on the output side (i.e. as success criteria). In other words, the inclusion of these elements, their fulfilment and compliance with them can in themselves ensure the success of projects, greatly increase the likelihood of successful project implementation in the given company, and their fulfilment can make a significant contribution to the sustainable development of both the company and its colleagues.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

Funding

* Project no. MEC_SZ 149231 has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the MEC_24 funding scheme.



PROJECT
FINANCED FROM
THE NRDI FUND

Conflict of Interest

* The authors declare that they have no conflicts of interest

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Management Economics and Business (www.iconmeb.net) held in Budapest/Hungary on August 28-31, 2025

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A BIBLIOMETRIC EXAMINATION OF ENTREPRENEURIAL TRAITS IN SCIENTIFIC LITERATURE

Abstract: Entrepreneurship research has increasingly recognized the role of individual traits in shaping entrepreneurial behavior and success. Despite the growing body of literature, systematic evaluations of how entrepreneurial traits are studied remain limited. This paper applies bibliometric analysis to map and synthesize scientific publications on entrepreneurial traits, identifying key research trends, influential authors, and thematic developments in the field. The study draws on data retrieved from the Dimensions.ai database, covering publications up to nowadays. Using bibliometric techniques, the analysis examines citation structures, co-authorship networks, keyword co-occurrence, and temporal trends. The results highlight the rapid growth of interest in entrepreneurial traits over the past two decades, with a concentration of research in journals focusing on entrepreneurship, management, and psychology. Among the most frequently studied traits are risk-taking, innovativeness, proactiveness, resilience, and self-efficacy, often linked to broader constructs such as entrepreneurial orientation and personality frameworks. Co-occurrence mapping further reveals clusters of research connecting traits to innovation, firm performance, and entrepreneurial intention. The findings show that the field has shifted from trait-based personality approaches toward more integrative perspectives that situate traits within social, cultural, and institutional contexts. Collaboration patterns indicate a global and interdisciplinary network, although research remains concentrated in Europe, North America, and parts of Asia. This study contributes by providing a structured overview of the evolution and current state of entrepreneurial trait research. By highlighting influential works and emerging themes, it helps scholars navigate the literature and identify underexplored areas, such as cross-cultural comparisons and the role of traits in digital and sustainable entrepreneurship. Bibliometric evidence also offers practical implications for educators and policymakers seeking to foster entrepreneurial capacities in diverse contexts.

Keywords: Entrepreneurial traits, Bibliometric analysis, Entrepreneurship research, Research trends

Introduction

The entrepreneurial traits, competences, attitudes, entrepreneurial motivations and behaviours, as well as entrepreneurial characteristics, are important determinants of who becomes a successful entrepreneur in the long term. It is clear that the existence of entrepreneurial success factors plays an important role, but it is also necessary to clarify in which combination and with which emphasis these entrepreneurial traits ensure that an individual becomes a successful entrepreneur. In recent years, academic research focusing on business management and the identification of related success factors has come to the fore both at national and international level. With the increasing number of studies in this field, there has been more emphasis on clarifying analyses that identify the entrepreneurial traits and individual characteristics that can be considered as the key to successful entrepreneurship.

The environment surrounding the entrepreneur (economic, social, political, legal, etc.) has sensibly changed in recent decades. Character traits and individual personality traits play a key role in how an entrepreneur reflects to these changes also under these changed conditions how he or she can successfully sustain his or her business in the long term. In addition, high entrepreneurship is a key driver of economic growth and job creation and can provide the entrepreneur with potential career opportunities (Mubarka et al., 2012).

The running and management of the business can be learned, according to Drucker (1985). With the emergence of entrepreneurship as an independent scientific field, the role of entrepreneurship education in higher education has increased, making higher education institutions that offer entrepreneurship majors or specializations play a key role in training socially and economically responsible professionals (Salamzadeh & Farjadin, 2014). Researchers have also focused more attention on this topic (Kusmintarti et al., 2016), as they have recognised the key role of entrepreneurial characteristics. In their study Hofmeister-Tóth et al. (2016) explicitly identified the exploration of entrepreneurial leadership characteristics as an interdisciplinary research topic.

This paper takes a novel approach regarding the emergence of entrepreneurial traits and characteristics in literature. The main objective is to identify which entrepreneurial traits have been identified by the most internationally cited authors who published on the subject and whether there appeared any traits that have

been identified as relevant by all researchers. A further objective of the research is to present results that provide an accurate picture of citation relationships in this field based on international literature.

To achieve the stated objectives, the authors of the paper first review the international literature related to entrepreneurial traits, with a particular focus on the entrepreneurial traits identified by eminent researchers in the field. This is followed by an analysis of publication relationships using bibliometrics, a subfield of scientific metrics. Bibliometrics is an excellent tool to explore the interrelationships between different literature publication databases (van Eck & Waltman, 2014), to identify the citation networks between authors and the countries that have a close publication collaboration in the resulting network of relationships.

Literature Review, Theoretical and Conceptual Framework

In terms of profit-generating business initiatives, we can distinguish the outstanding entrepreneurs of the first half of the twentieth century, such as Rockefeller, Ford, Alkaringi, and their entrepreneurial models, as well as the outstanding representatives of the second half of the century, such as Bill Gates, Berne, Larry Page, and David Filo (Abood et al., 2014). Even by today's standards, these entrepreneurial geniuses were major figures of their time. In their case, researchers have not been able to identify – one or a few – specific common traits that possibly could determine their success. Researchers have found that these outstanding individuals possessed a capacity for continuous learning, which significantly influenced the development of their entrepreneurial traits and skills (Dyer et al., 2011).

In the literature on the subject, there are several definitions of an entrepreneur. According to Chen et al. (2006), an entrepreneur is a person who takes the risks of starting and running a business, and in most cases does so using his or her own resources. Van Ness & Seifert (2016) claimed that entrepreneurs are individuals who risk their personal capital, time, and reputation to make their business venture a success.

The scientific study of entrepreneurship and entrepreneurial traits came to the fore following the reassessment of the role of small businesses in the 1980s and 1990s. Initially, the explanatory factors of entrepreneurship were only personal characteristics, later complemented by entrepreneurial skills, which are highly dependent on cultural and institutional conditions (Wennekers & Thurik, 1999). There is still a lot of

relevant international and national research on entrepreneurship. The authors of the multidisciplinary and therefore quite varied literature on the subject have sought to identify the personality traits of the successful entrepreneur, but there is still no consensus on the definition of fundamental characteristics (Gartner, 1989).

While some researchers have focused on the identification of innate and learned entrepreneurial traits (e.g. the need for control and achievement) that can be developed through education and training (McClelland, 1961), others have analyzed entrepreneurial traits in the longer or shorter term (Ajzen, 1991). Lucas, in a study published in 1978, concluded that individuals with a wider range of entrepreneurial traits are more likely to start their own firm in the future, ultimately maximizing both output and individual profits (Lucas, 1978).

In the literature on the monitoring of entrepreneurial traits, empirical studies of entrepreneurial characteristics and traits have been increasingly emphasized since the 1980s (Cooper et al., 1988). According to Hornaday (1982), the individual characteristics necessary for entrepreneurship are self-confidence, optimism, prudent risk-taking, positive response to challenges, adaptability, market knowledge, independent thinking, knowledge, persistence, a need for performance, initiative, dynamism, patience and, finally, a vision for the future. Peterson (1985) identified opportunity-seeking as the most important trait, while Gibb (1993) stressed the importance of risk-taking and entrepreneurship. Chen et al. (1998) focused on starting one's own business and identified entrepreneurial self-efficacy as a key personal entrepreneurial trait.

Studies on entrepreneurial behavior have identified different influencing factors, which can be social, environmental and individual characteristics as well (Gurol & Atsan, 2006). The social factors' model examined the importance of personal and family background, career, and early life experiences (Gibb, 1993). The environmental factors' model analyzed the value of wealth, tax benefits, indirect benefits, and the impact of market conditions (Alstete, 2002). The individual traits' model focused on the personality characteristics of entrepreneurs (Koh, 1996). The latter model assumed that entrepreneurs possess such unique traits, attitudes and values that provide a continuous charge and momentum throughout their entrepreneurial existence, in fact, these factors distinguish them from others (Thomas & Mueller, 2000). It can therefore be concluded that individual personality traits play a vital role in entrepreneurial activities, greatly influencing the performance and success of entrepreneurs at all stages of the entrepreneurial process (Brockner et al., 2004).

Based on Kiggundu's (2002) study, it can be concluded that the study of individual characteristics alone is not sufficient to fully explore the reasons behind entrepreneurial success or failure. Shane (1992) argued that different entrepreneurial characteristics can be identified in different countries, which have a bearing on success. Mueller et al. (2002) have shown through their research that individuals socialized in distinctly masculine cultures (USA, Canada, UK) are psychologically more prone to entrepreneurialism. Individuals with different entrepreneurial characteristics are strongly influenced by the social and societal characteristics of different countries, as well as by national culture (Tajeddini & Mueller, 2008). Mueller (2004) has reached a similar conclusion in his research. The emergence of entrepreneurial characteristics may therefore vary across countries and cultures, as supported by the research of Farrington et al. (2012).

Baum and Locke (2004) investigated the relationship between entrepreneurial traits (characteristics), skills and motivation in relation to future business growth. In a six-year longitudinal study, they collected data from sole proprietors, corporate managers and co-entrepreneurs in each industry. Their research revealed the importance of entrepreneurial traits such as passion, perseverance and the ability to manage new resources well, which were found to be indirectly related to business growth.

In their research, Ardichvili et al. (2003) assessed entrepreneurial personality traits in terms of their contribution to entrepreneurial success. Their work demonstrated that two specifically named personality traits are associated with the perception of the potential for success, namely optimism and creativity. In contrast, Rasheed and Rasheed (2004) identified several important psychological traits as indicators of entrepreneurial behaviour. However, the Kristiansen and Indarti (2004) author pair have been quite critical of attempts to study entrepreneurial behavior (attitudes), as their research has failed to identify specific personality traits that are key to successful entrepreneurship. These results were also previously concluded by Shaver and Scott (1991), who in their research experiments pointed out the serious shortcomings of the psychometric tests that were being used, stressing that they failed to distinguish between most of the traits. It is important to highlight, however, the landmark study written by Kristiansen & Indarti (2004), which highlighted the crucial role of individual attitudes in the identification and prediction of entrepreneurial traits and personality characteristics.

Schroeder and Rodermund (2006) concluded that family background, parental pattern and educational attainment can predict individual evolution towards entrepreneurship. They found that environmental and demographic factors have a significant impact on the development of entrepreneurial personality types.

Pillis & Reardon (2007) found that high achievement motivation and a positive self-image are the most important factors that make an entrepreneur successful. Zimmerer et al. (2008) also identified several entrepreneurial personality traits such as high willingness to take responsibility, need for immediate feedback, high energy level, future orientation, value of performance over money, commitment, flexibility, persistence, and preference for moderate risk. However, the latter is highly relative, as Shane's (2003) research has shown that individuals' attitudes towards risk are not the same. Entrepreneurship is inherently high risk, so risk tolerance in terms of individual characteristics plays a crucial role in entrepreneurial activities.

Cools and Broeck (2007) argued for the identification and assignment of groups of entrepreneurial traits in the first place, arguing that this method can be more useful for assessing the personality of the entrepreneur than focusing on a single salient trait. Karimi et al. (2011) also argued that identifying a larger group of traits is more important than determining a single entrepreneurial trait.

According to Chell (2008), the identification and exploitation of entrepreneurial potential depend on several factors, both for start-up, i.e. practical purposes, and for research purposes, i.e. theoretical purposes. The researcher emphasized the recognition of opportunities, independence, self-efficacy, social leadership, intuition and having a vision regarding the future (Chell, 2008). In their research, Duckworthe et al. (2007) examined the importance of courage as a non-cognitive trait. In addition to courage, other traits such as creativity, high emotional intelligence, charisma, self-confidence, emotional stability, and physical attractiveness were identified in their study of highly performing individuals.

Although the role of individual characteristics in unlocking entrepreneurial potential is considerable, studies over the past decade have shown that economic, financial, and socio-cultural factors play an equally decisive role (Vob & Muller 2009). Ali et al. (2010) argued in their study that entrepreneurship development, and within it the development of entrepreneurial characteristics, is the responsibility of higher education institutions. Related to this, Van Eeden et al. (2005) conducted research to report on the development of business (entrepreneurial) attributes and knowledge of university students and to investigate whether differences in the development of entrepreneurial attributes and skills could be identified across countries. Through their results, they demonstrated that the educational environment and the quality of entrepreneurship education in each country play a key role in the development of entrepreneurial qualities. Following their research, Salamzadeh & Farjadin (2014) proved that companies founded by alumni university students have a great impact on the socio-economic development of a given economy.

Akmaliah et al. (2012) defined entrepreneurial attributes as characteristics that motivate and enable an individual to embark on the challenging process of starting a business. Farrington and his co-authors (2012) argued that it is the different entrepreneurial traits, personality characteristics that really distinguish entrepreneurs from others. As a summary of the literature review section, the theoretical definitions presented by the researchers/authors are summarized in Table 1 in chronological order.

Table 1. Chronological overview of identified entrepreneurial characteristics

Name of author(s)	Year	Identified entrepreneurial characteristics
Chen et al.	1998	self-efficacy
Shane	2003	willingness to take risks
Ardichvili et al.	2007	optimism, creativity courage, creativity, high emotional intelligence,
Duckworth et al.	2007	charisma, self-confidence, emotional stability, physical attractiveness
Pillis and Reardon	2007	high achievement motivation, positive self-image willingness to take risks and responsibilities, need for immediate feedback, high energy level, future orientation,
Zimmerer et al.	2008	valuing performance over money, commitment, flexibility, perseverance recognising opportunities, independence,
Chell	2008	self-efficacy, social leadership, intuition, positive vision

A review of the academic research on this topic reveals how the emphasis on the key characteristics of the entrepreneur has shifted over time. While individual characteristics have emerged as key factors, we cannot overlook the individual's parental and family patterns, the quality of education, which may be a factor influencing the evolution of entrepreneurship. These sociological and demographic factors (characteristics) alone have a significant impact on the development of entrepreneurial personality types.

Methodology and Conceptualization

From the 21st century onwards, researchers have at their disposal a variety of software, electronic interfaces and platforms, as well as a wide range of well-qualified literature databases that provide a systematic repository of publications. These have contributed significantly to the explosion of disciplines dealing with the analysis of the processes of the scientific world, including bibliometrics and science metrics.

Table 2. Categorisation of bibliometric-based studies

Name of author(s)	Year	Purpose	The subject of the study	Database
Cancino et al.	2017	Identifying the most productive and influential universities in innovation research	Studies filtered by keyword "Innovation" (1989-2013)	Web of Science
Khalife et al.	2020	Analysis of the history of research on project management	Publications related to project management (1980-2019)	Web of Science
Hamidah et al.	2020	Analysis of the scope of COVID-19 research	3,513 studies (2019-2020)	Scopus
Yuetian et al.	2020	Analysis of literature on COVID-19	3,626 publications on COVID-19	Web of Science
Fan et al.	2020	Exploring the difference between COVID-19-related publications in English and Chinese medical/scientific journals	143 English and 721 Chinese articles	English and Chinese databases
Ullah and Saeed Ullah	2020	A Journal of Medical Sciences Peshawar's bibliometric analysis (2014-2018)	322 scientific papers	Journal's website and print copies

Sweileh	2020	Evaluation of research activities on climate change and health, with a special focus on communicable diseases	4,247 health-related and 1207 infection-related literature (1980-2019)	SciVerse Scopus
Fei et al.	2022	Analysing current state of research on delirium (cognitive impairment)	Top 100 most cited studies	Web of Science
Zuccolotto Pessin et al.	2022	Introduction to the theoretical framework (evolution) of scientific mapping and bibliometric analysis	Various visualization options (HistCite, CiteSpace, BibExcel, Vosviewer, SciMat, Proknow-C)	-
Abdullah et al.	2022	Assessing global TB research trends and performance	Literature related to TB research (2011-2020)	Web of Science
Atsiz et al.	2022	Analysis of the number of years spent in tourism	60 studies from the field of tourism	Web of Science

Bibliometrics is a scientific analytical method that uses a wide range of statistical tools to examine and analyse a set of publications, studies, books and other scientific writings (van Eck & Waltman, 2014). Two main areas of research and mapping on bibliometrics can be distinguished: the study of the impact of similarity measures and graphical representation. When constructing bibliometric maps, researchers investigate the effect of similarity measures and typically experiment with mapping techniques (van Eck & Waltmann, 2009). Graphical representation of bibliometric maps has received considerably less attention in academic work (van Eck & Waltman, 2010), although some researchers, such as Skupin (2004), have also exhaustively studied issues related to representation. The visualisation reveals the citation relationship between clusters.

Authors in the international literature on bibliometrics have made extensive use of this method for mapping network systems across a range of disciplines. The studies analysed are summarised in Table 2, according to which authors, in which year, with what central aim, what was analysed and based on which database, using the bibliometric method.

Based on the research summarised in Table 2, it can be concluded that mapping based on bibliometrics can be applied to a wide range of disciplines, such as medicine, social sciences, humanities and their various sub-disciplines. The present research aims to investigate entrepreneurial characteristics within the subfield of management and organization sciences using the bibliometric method. It analyses these characteristics from three different angles: institutions, countries and the number of citations of the authors of the publications. The aim of the study is therefore to assess the volume of research and trends in scientific publications closely related to this topic.

The research focused on the following two questions: Q1: Which country has the largest publication network of academic publications on entrepreneurial characteristics? Q2: Can common characteristics of entrepreneurial personality traits be identified in the studies of the most cited authors? The hypotheses related to the research questions formulated above are the following, and their validity will be tested in the analyses: H1: In terms of countries, the United States has the most extensive publication network. H2: In the studies of the most cited authors, common traits of entrepreneurial personality traits can be identified.

For the most cited studies, it was analyzed whether the authors with more than 1,000 citations identified the same entrepreneurial personality traits in their studies. Through the country-level analysis, the countries whose researchers published and cited the highest number of papers were prioritized. This also sheds light on the reasons leading to higher citation counts. The research search strategy was based on the Dimensions database (www.dimensions.ai), which is currently the world's largest interconnected research information database. The data set exported from the Dimensions database is uniquely suited to provide the bibliometric software used in the study with an input that can be imported in a processable state and in an orderly structure without modification. The exact process of searching the dimensions.ai database is illustrated in Figure 1.

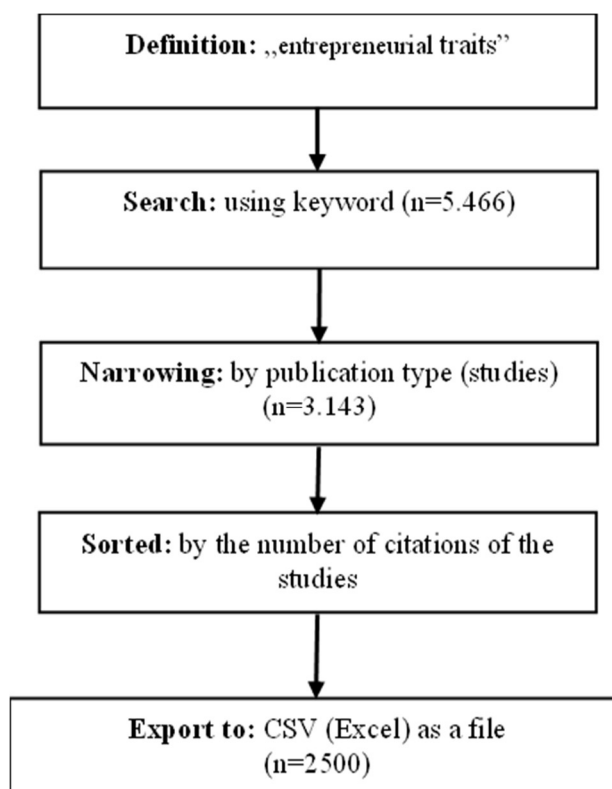


Figure 1. Flowchart for searching the www.dimensions.ai database

As can be seen in Figure 1, the limitation of this database is that it allows the export of the first 2500 studies by default, and the database thus produced is the basis of the research. After downloading the data table, the bibliometric analyses were carried out using the freely available bibliometric mapping software VOSviewer developed by Van Eck & Waltman. The program generates maps based on the co-occurrence matrix of the dataset obtained from the queries, thus allowing them to visualise the existing networks of relationships in different ways according to the aspects to be analysed (see for example institutions, countries, studies). The maps are produced using the VOS (visualisation of similarity) mapping technique, which can be seen as an alternative to multidimensional scaling (Van Eck & Waltman, 2007).

The research underlying the present study highlights the authors, institutions and countries with the most citations that can be grouped into clusters based on the same characteristics. The collaboration observed in these clusters is essential to improve scientific performance and to develop and deepen international relations. For this reason, the authors have researched the term "entrepreneurial traits" in international

literature. The focus of the research was on entrepreneurial traits, and therefore a bibliometric analysis was carried out exclusively on this vocabulary. Synonyms of this term and other substitute terms referring to the subject were not included in the present study. The exact flow of the analysis in VOSviewer is illustrated in Figure 2.

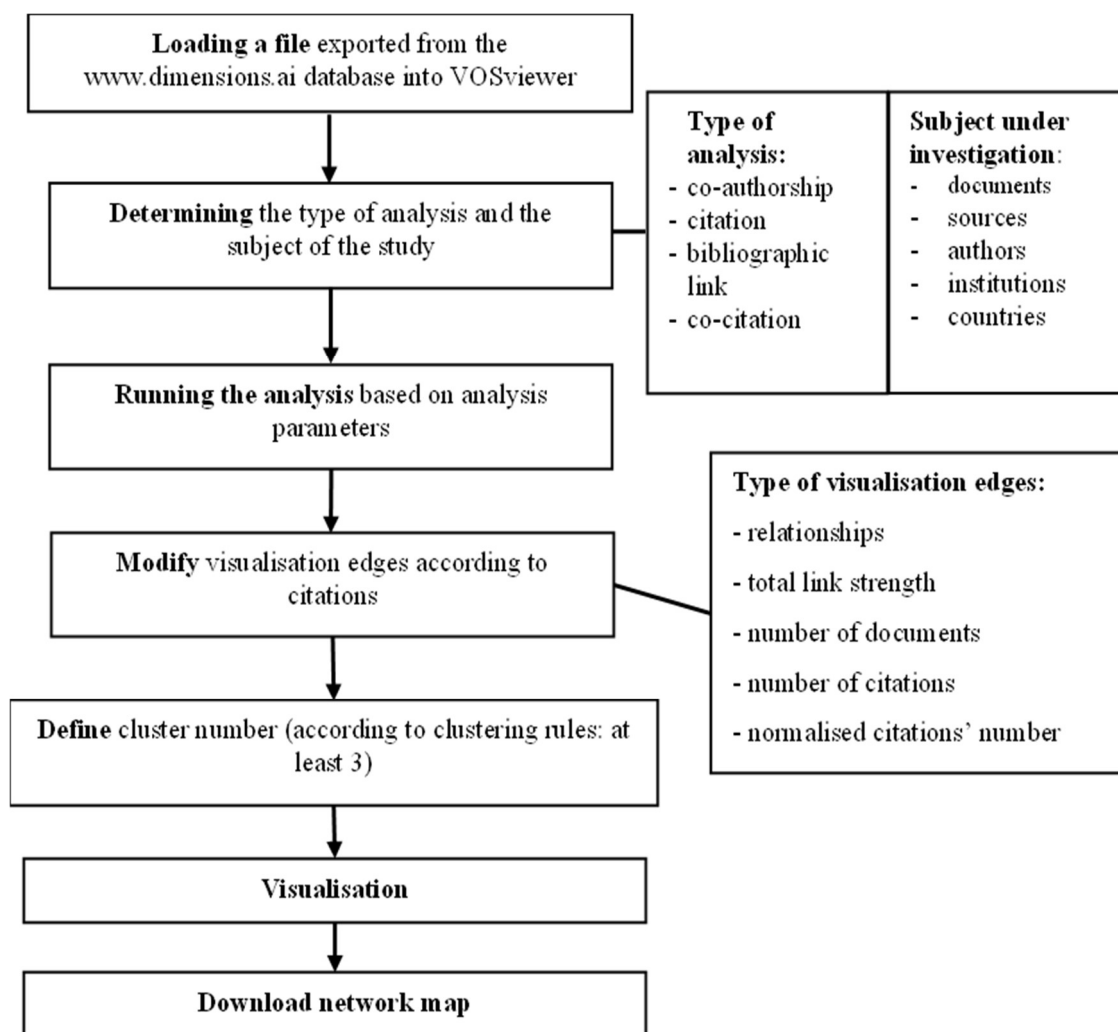


Figure 2. The VOSviewer's map creation flowchart

Anticipating the research findings, the analysis identified both cooperation and competition between countries.

Research Findings, Results

Before presenting the results of the bibliometric analysis, Table 3 illustrates the studies included in the sample in terms of the journals and disciplines in which they were published.

Table 3. Top 10 most active journals in the results list based on entrepreneurial characteristics

Ranking	Journal name	Scimago classification	Country	Number of publications	Field of expertise of the journal
1.	International Journal of Entrepreneurial Behaviour and Research	Q1	United Kingdom	80	Business, management and accounting
2.	Entrepreneurship Theory and Practice	Q1	United States	77	Business, management and accounting; economics, econometrics and finance
3.	Journal of Business Venturing	Q1	United States	68	Business, management and accounting
4.	Small Business Economics	Q1	Netherlands	57	Business, management and accounting; economics, econometrics and finance
5.	Education + Training	Q1	United Kingdom	51	Business, management and accounting; social sciences
6.	International Entrepreneurship and Management Journal	Q1	United States	47	Business, management and accounting
7.	Journal of Small Business & Entrepreneurship	Q2	United Kingdom	46	Business, management and accounting

8.	Journal of Small Business Management	Q1	United Kingdom	46	Business, management and accounting
9.	Journal of Small Business and Enterprise Development	Q1	United Kingdom	37	Business, management and accounting
10.	The Journal of Entrepreneurship	nem rangsorolt	United States	36	Several scientific disciplines

Table 3 shows that of the 10 most active journals identified, approximately one-fifth (545) of the 2500 publications included in the study were published in the identified journals. The remainder of the scientific publications (1955 publications) were distributed among a further 1091 journals. Within this total, 90 journals contained between 6 and 34 publications, while 1001 journals contained less than 5 publications for the term under study.

From a disciplinary point of view, the publications under review cover the fields of commerce, management, tourism, services, business, economics, psychology and cognitive sciences. The top ten most active journals in the hit list include six from Europe and four from the United States. Table 3 also shows the serialisation, i.e. the ranking of journals according to the Scimago Journal ranking. Unsurprisingly, the vast majority of the top 10 journals in each criterion have the highest ranking of Q1. This suggests that research into entrepreneurial characteristics is a focus of interest for both authors and journal editors.

The authors of the study during their bibliometric analysis first carried out a reference-based analysis of the institutions (universities, research centres). The results obtained showed that academic research on entrepreneurial characteristics is led by US-based higher education institutions, demonstrating the dominant academic role of US universities worldwide. However, the top ten universities with the most citations include two European universities (Erasmus University - Rotterdam, Netherlands; Jönköping University - Jönköping, Sweden), one Canadian university (University of Toronto) and one Australian university (University of Melbourne). Leading the way is the University of Pennsylvania (3248 citations), followed by Erasmus University (3109 citations) and Rensselaer Polytechnic Institute (2861 citations) in third place. The clustering of these research centres and universities is illustrated in Figure 3.

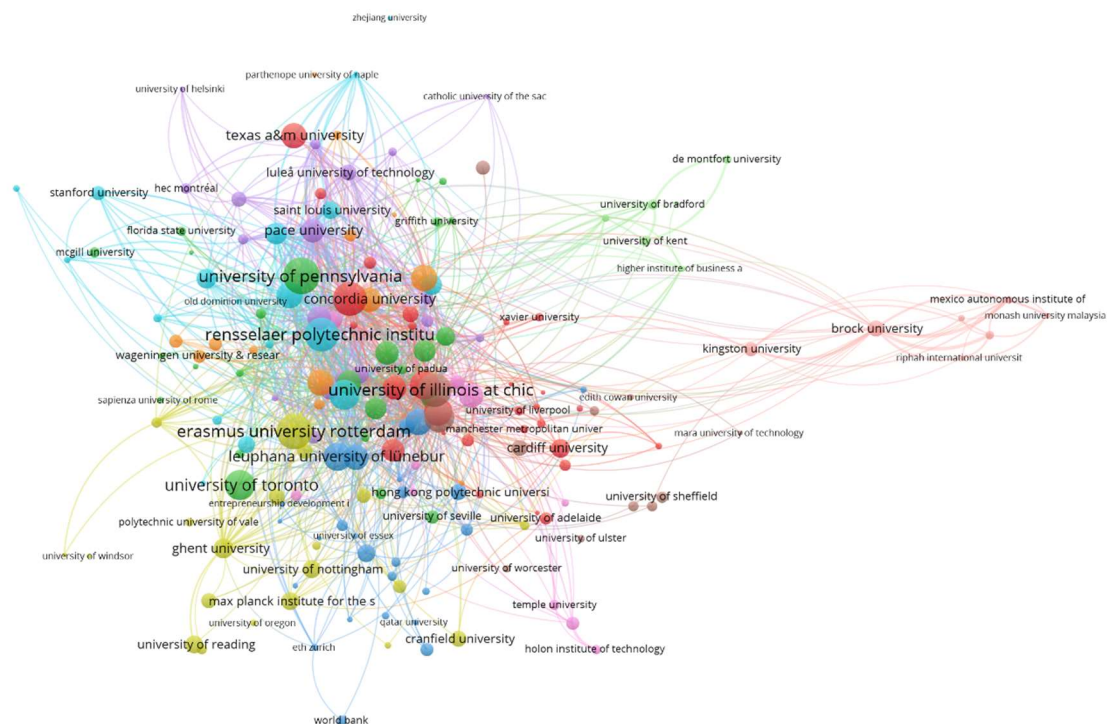


Figure 3. Location of universities and research centres in clusters on a database of publications on entrepreneurial characteristics

The clusters that emerge reveal an international network of collaborating universities and institutions that show a high level of cooperation in terms of publications. For the ten most cited authors (Table 4), it can be concluded that they tend to be active in universities, higher education institutions or research institutes with the most significant international publication links according to country classification.

Table 4. The ten most cited authors in the database of publications on entrepreneurial traits

Rank	Author's name	Number of Citations	Number of Contacts	Number of Studies	University
1.	Locke, Edwin	2503	238	5	R.H. Smith School of Business, University of Maryland (USA)
2.	Frese, Michael	2480	123	8	Asia School of Business, University of Lueneburg (GER)
3.	Baron, Robert	2131	144	13	Oklahoma State University (USA)
4.	Gartner, William	1771	58	7	Babson College (USA)
5.	Hmieleski, Keith	1705	102	9	Neeley School of Business, Texas Cristian University (USA)
6.	Shepherd, Dean,	1573	77	11	University of Notre Dame (USA)
7.	Cardon, Melissa	1327	145	9	University of Tennessee (USA)
8.	Audretsch, David	1212	52	8	Institute for Development Strategies, Indiana University (USA)
9.	Patzelt, Holger	1000	42	6	TUM School of Management, Technical University of Munich (GER)
10.	Obschonka, Martin	937	154	14	University of Amsterdam (NED)

No major outliers in the number of published papers can be identified, but there are some authors (including E. A. Locke) who have achieved a high number of citations with a relatively small number of papers in their field. In their case, therefore, it is not the high number of publications that leads to the highest number of citations, but the scientific value and significance of the results of their study. When exploring citation relationships between countries, international research cooperation can be detected between countries that are part of the same cluster, i.e. a homogeneous group. The authors have designed the clusters according to the rules of the clustering procedure, where at least 3-4 countries are included in a cluster for ease of interpretation. The map drawn from the data is illustrated in Figure 4.

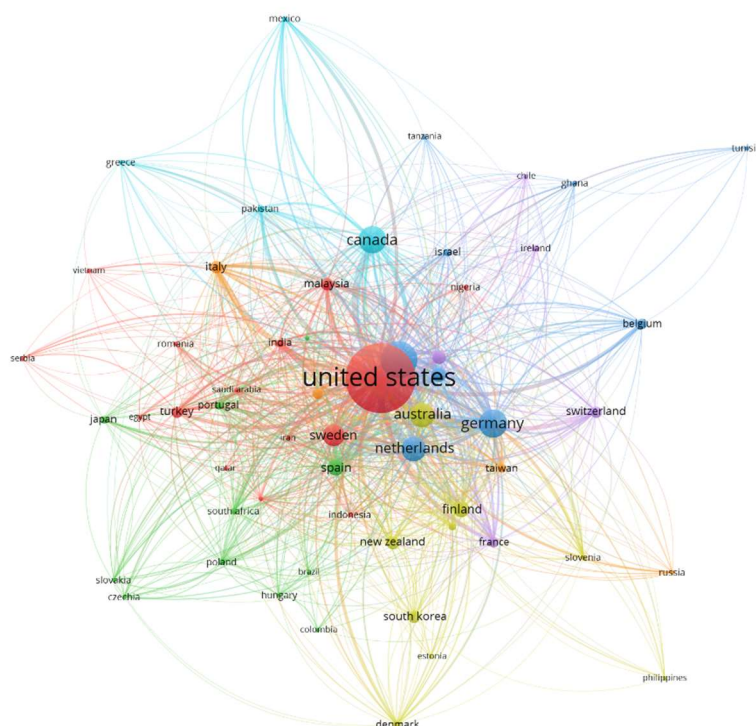


Figure 4. Cross-country citation trends in the database of publications on entrepreneurial characteristics

The map in Figure 4 focuses on the countries with the largest node size, such as the United States (49,190 citations), the United Kingdom (13,491 citations), Canada (7,363 citations), Australia (6,176 citations), Spain (2,773 citations), China (1,754 citations) and Italy (1,648 citations). Consequently, these countries have the most pronounced citation links, while the countries with the smaller node have the most modest international research cooperation in the field of research on entrepreneurial characteristics.

The clustering by country also shows the prominent scientific role of the United States. In terms of the number of elements in the clusters, the cluster with the US centre is the group that includes the most elements (countries). Among the countries in the cluster, for example, Nigeria, Vietnam and Egypt are much further away from the US in terms of citation links, indicating weak international research cooperation. On the other hand, Sweden, Iran, India and Malaysia are much closer to the cluster centre in an imaginary circle (the distance is therefore shorter, indicating the strength of the link). The map shows that these countries have stronger international research cooperation with the US that is at the centre of the cluster.

In terms of inter-country relations, Canada has weaker research cooperation with countries in the outer circle, such as Mexico and Greece, but stronger international relations with Pakistan in terms of the number of citations between them. The prominence and visualized centrality of the resulting cluster centres is confirmed by the Scimago Top 50 world ranking. The countries on which the research is based are all included in this authoritative ranking. The validity of the results obtained has been confirmed by other authors, such as Mester (2016), who also compared the countries with the most citations in the world with the Scimago world ranking.

The results so far have shown that in many cases organisations (universities, research centres) have very close international cooperation on entrepreneurial characteristics. It can also be noted that the number of citations between authors of the studies included in the study varies considerably. The bibliometric analysis from the authors' point of view, after creating and analysing the database and displaying the map, clearly showed that eight authors actively working on the topic had a citation count of 1,000 or more, while the other researchers had a more modest number of citations. In the studies examined, there can often be large differences in the number of visually formed edges, i.e. the number of identifiable links between the authors of the studies. This phenomenon can be discovered in Figure 5.

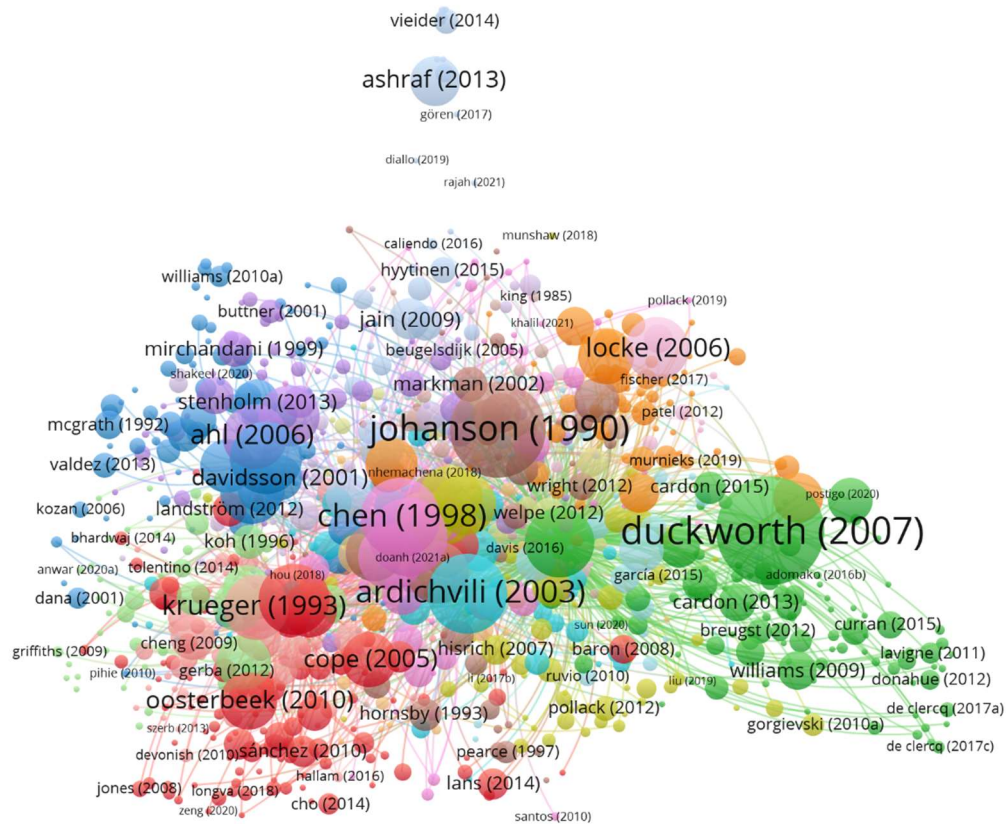


Figure 5. Cross-references between studies in the database of publications on entrepreneurial traits

The highlighted nodes in Figure 5 represent the authors of the most cited papers with significantly more citation links. The general conclusion is that authors who are located further apart have weaker citation links, while publication activity, i.e. citation links, between authors who are located closer are stronger. In this section of the analysis, the authors of the study draw conclusions on the publications of the clusters formed by the method described, which are ranked first in the number of citations. From a substantive point of view, the most cited studies can be divided into three main theoretical groups according to the prominence given to entrepreneurial characteristics. The publications in the first group were clearly aimed at exploring these characteristics. The studies in the second set focused on a fundamentally different topic but dealt to a lesser or greater extent with entrepreneurial characteristics. In the remaining articles, this word combination was only tangentially mentioned.

Research by Chen et al. (1998), Ardichvili et al. (2003), Duckworth et al. (2007), and Baum and Locke (2004) has clearly focused on identifying and examining entrepreneurial traits. Their publications mainly analyze these characteristics in relation to the creation of successful businesses. As highlighted in the theoretical bulk of this study, Duckworth et al. (2007) in their research demonstrated the importance of several relevant attributes that are essential for the creation and long-term operation of a successful business, such as courage, creativity, high emotional intelligence, charisma, self-confidence, emotional stability, and physical attractiveness.

Chen et al. (1998), – as already presented in the literature review – identified entrepreneurial self-efficacy as a defining personality trait, and also highlighted the general conclusion that entrepreneurship researchers have long been searching for individual characteristics of entrepreneurs, which they have examined in depth in relation to self-efficacy and have diverted attention away from the need for performance and control. This novel approach to the exam topic explains how the article by these authors has become one of the most cited studies.

In their study, Ardichvili et al. (2003) identified and rethought entrepreneurial opportunities, personality traits, social networks and prior knowledge of the entrepreneur based on existing theoretical and empirical research. Entrepreneurial personality traits/characteristics were assessed in terms of their contribution to entrepreneurial success. In the view of these authors, optimism and creativity have been shown to be related to the recognition of the potential for success, as highlighted in the literature review of this study.

The authors Baum and Locke (2004) used structural equation modelling techniques to uncover a network of relationships focusing on entrepreneurial characteristics. This network identified the determinants of entrepreneurial characteristics and the impact of these characteristics on firm growth. The traits identified in the theoretical summary, such as passion, perseverance and the ability to manage new resources well, are directly influenced by goals, self-efficacy and communicated vision, while the defined traits have an indirect influence on the future growth of the company. Baum and Locke found that communicated vision and self-efficacy are directly related to goals, and persistence to the ability to manage new resources well.

As a kind of transition, we can look at the studies of Shapero (1982), Krueger and Brazeal (1994), Wennekers & Thurik (1999), and Zhao et al. (2005), which did not focus specifically on entrepreneurial traits, but only tangentially addressed the topic. Krueger and Brazeal (1994) investigated the existence of

entrepreneurial traits prior to the revival of entrepreneurship, which had been little measured until then. Researchers have found that these traits can be linked to random profiles of several personality traits and demographic characteristics. Also related to personality is Shapero's (1982) conceptualisation of the propensity to act as a stable trait. The aim of the study by Zhao et al. (2005) was to investigate the role of self-efficacy in influencing students' intention to become entrepreneurs. In their work, structural equation modelling was applied to a sample of university students, and the results showed that self-efficacy plays a relevant role among entrepreneurial traits, like the results obtained by Chen et al. (1998). The third group of publications with the most citations merely mentions entrepreneurial characteristics. An example is the study by Johanson and Vahlne (1990), in which the authors referred to entrepreneurial characteristics in the context of the internationalisation of firms.

Conclusion

The present study focused on the bibliometric analysis of the entrepreneurial trait's vocabulary in international academic journals. In exploring the publication linkage in the given subject area, the authors of the study sought to find out whether the most cited authors share common characteristics of entrepreneurial personality traits in their studies, and which countries have the largest publication linkage network in terms of academic publications on entrepreneurial characteristics. The analyses were carried out in terms of institutions, countries and the number of citations of the authors of the publications.

Based on the Dimensions database, a bibliometric literature search of the vocabulary of entrepreneurial traits reveals a number of findings. The publications in the research sample ($n=2,500$) were published in academic journals with different disciplinary interests. In terms of the Scimago Journal ranking, these journals are ranked in the highest academic category (Q1) with two exceptions - Journal of Small Business & Entrepreneurship and The Journal of Entrepreneurship. This rating of journals may also indicate a strong preference for research investigating entrepreneurial characteristics, not only among authors but also among journal editors.

In their bibliometric analysis, the authors first carried out a reference-based analysis of institutions (universities, research centres). This confirmed that the top ranking for research on entrepreneurial characteristics is led by higher education institutions in the United States of America, while Erasmus

University in Rotterdam and Jönköping University in Sweden also made it into the top ten. In addition, the ten most cited authors are typically from American universities and research institutions. On this basis, a parallel can be drawn between the institutions with the most citations and the authors with the highest number of citations. An unforeseen but noteworthy result of the present study is that among the authors of the studies examined, one researcher (Edwin A. Locke) achieved a high number of citations with a relatively small number of papers that included significant, novel research in the subject area.

The results of the research question on the cross-national network of scientific publications in the subject area under study showed that the United States, the United Kingdom, Canada, Australia, Spain, China and Italy are considered as countries with a central feature, thus demonstrating that these countries have a significant international publication network in the subject area. It is indisputable that most research – especially in business – is done in the United States of America, due to the large number and prestige of its higher education institutions. Consequently, the results of the analyses carried out for the countries clearly proved hypothesis H1 which states that the US plays a central role in scientific publications on entrepreneurial traits.

The map created with the help of the VOSviewer visualisation software shows most of the edges running out from these countries, representing the publication links that have been established. The prominent position of the cluster centres in the research and publication systems resulting from the analysis is confirmed by the Scimago Journal Ranking, which places these countries at the top of the ranking. Countries at the outer periphery of the clusters have a much looser international publication network, while scientific research cooperation is significantly stronger in countries at the centre of the clusters.

In terms of author citation counts for publications, the results of the analysis showed that the top eight authors actively working on the topic had a citation count of 1,000 or more, with the remaining researchers having lower citation counts. A review of the most cited studies shows that their authors identified different entrepreneurial characteristics. Consequently, the results obtained refute hypothesis H2, as no single common or named entrepreneurial trait can be defined based on the 10 most cited studies in the sample. Chen et al (1998) identified entrepreneurial self-efficacy as a key personal entrepreneurial trait. According to Ardichvili et al. (2003), two personality traits have been shown to be related to the recognition of the potential for success: optimism and creativity. In their research, Duckworth et al. (2007) investigated courage

as a non-cognitive trait in their study, such as creativity, high emotional intelligence, charisma, self-confidence, emotional stability, and physical attractiveness.

Overall, the results of the bibliometric analysis of the present study, the mapping of the networks of contacts, revealed the surprising fact that the reference system of the subject, which has been intensively researched for several decades on the national and international scene, is based on the studies of only eight authors. In addition to the achievement of the set objectives, the study will provide a literature basis for future research on the topic, as the results will contribute greatly to the mapping of publication-authorship relations in the field.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

Conflict of Interest

* The authors declare that they have no conflicts of interest.

Funding

* Project no. MEC_SZ 149231 has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the MEC_24 funding scheme.



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Conflict of Interest

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Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Management Economics and Business (www.iconmeb.net) held in Budapest/Hungary on August 28-31, 2025

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MATCHING LEADERSHIP STYLE TO PROJECT CONTEXT: EXPLORING CONTEXTUAL FACTORS AFFECTING PROJECT MANAGERS' LEADERSHIP STYLE

Abstract: Achieving project success is of vital importance for project owner organizations in implementing strategic objectives and supporting overall company development. The project managers' leadership style is a critical factor in project success. Several previous studies (Müller & Turner, 2007; Yang et al., 2013; Tabassi et al., 2016; Bhatti et al., 2021) have analyzed the relationship between project managers' leadership styles and project performance. Most of these studies have reinforced the general view that an appropriate leadership style facilitates successful project completion (Muller & Turner, 2007; Yang et al., 2013; Tabassi et al., 2016). However, there is no single best leadership behavior, as the effectiveness of a project manager's leadership style depends on the characteristics of the project and its organizational context. Bearing this in mind, several researchers (Müller & Turner, 2010; Raziq et al., 2018; Kabore, Sane & Abo, 2021; Nauman et al., 2022) have analyzed the relationship between leadership style and project success in a more context-related manner, taking into account various project and organizational attributes. Nevertheless, these studies often differ significantly in the range of attributes they analyze and in how they conceptualize these contextual factors, leading to notable limitations. To identify the appropriate leadership style for project managers in different project contexts, there is a need to establish a comprehensive framework that includes the fundamental characteristics of both the project and its organizational context. This study provides a systematic review of project management literature, focusing on the relationship between project managers' leadership styles, attributes of project context, and project success. Our findings reveal a lack of comprehensive, context-related studies in this field. Therefore, further research is needed to highlight key project and organizational characteristics that affect the identification of appropriate leadership styles by means of deductive reasoning.

Keywords: Project manager, Leadership style, Project characteristics, Organizational features, Project success

Introduction

Most organizations operate in rapidly changing environments and therefore formulate strategic goals in order to ensure successful adaptation. Projects are temporary forms of organizing and based on this, differ from permanent organizational structures and processes in several ways. Because of the inherent characteristics of projects as temporary structures – such as novelty, uniqueness, uncertainty, complexity, and low opportunity for standardization – leadership style, in addition to the project manager's skills and competencies, has a considerable impact on project success.

Several studies (Prabhakar, 2005; Muller & Turner, 2007; Yang et al., 2013; Tabassi et al., 2016; Bhatti et al., 2021) have examined the relationship between the project manager's leadership style and project performance. These studies have concluded that the leadership style adopted by the project manager significantly impacts the successful delivery of projects (Muller & Turner, 2010). However, there is no single best leadership behavior that can be optimally applied in all situations. The most appropriate leadership style is influenced by the inherent characteristics of the project and features of the organizational context (Muller & Turner, 2007; Larsson et al., 2015). Nevertheless, previous studies (Agarwal & Gupta, 2021; Blaskovics, 2016; Kabore et al., 2021; Raziq et al., 2018) have addressed this issue but have not provided an established and detailed analysis of project characteristics and organizational factors. Thus, there remains a significant lack of comprehensive studies that specifically focus on analyzing project managers' leadership styles in a context-related manner.

In this paper, we aim to reveal the interactions between the project managers' leadership styles and the contextual factors of the project, to identify the most appropriate leadership style for a given context. To fulfil this aim we conducted a content analysis of relevant project management papers to highlight previous findings on the relationships between contextual factors (e.g. project characteristics and organizational features), and the most appropriate leadership style of project managers. Based on the results, we can conduct further research to identify the most suitable leadership style for a given context and develop a framework that facilitates the alignment of project managers' leadership styles with the specific characteristics of projects and the organizational environment. This framework is constructed by means of a deductive approach and has significant practical implications. It has the potential to support both project managers and human resource professionals in understanding the interdependencies between leadership styles and contextual factors. By enabling the appropriate selection and development of project managers,

the framework may contribute to improving project success rates. Furthermore, it can serve as a foundation for tailored development programs and future research aimed at enhancing leadership effectiveness in various project contexts.

The structure of the paper is as follows: The next chapter provides a comprehensive literature review that presents the theoretical background of the research, with particular emphasis on the interpretation of project success, leadership styles, and the role of project characteristics and environmental factors. Special attention is given to situational (contingency) theories, which argue that leadership effectiveness largely depends on contextual circumstances. The next section presents the methodology of the systematic literature review is presented, followed by the results of the analysis of selected scientific publications. The findings are analyzed within three main categories: characteristics of the project, characteristics of the organizational environment, and characteristics of the project team. This approach enables the synthesis of extant research findings and facilitates the exploration and interpretation of the relationships among them and the project managers' leadership styles. The study concludes with a summary and conclusions.

Literature Review

Project Success

It is widely accepted that project success is a multifaceted concept that can be analyzed from various perspectives and assessed both qualitatively and quantitatively. Success criteria are the requirements or benchmarks against which the project's outcome is evaluated (Han et al., 2012). Although traditional project management literature defines success in quantitative terms, several studies propose a more project-specific approach to addressing the issue. Project success is most commonly assessed using the project management triangle, which focus on compliance with time, budget, and quality (Ellis et al., 2007). These are often referred to as the “*time/cost/quality triangle*”, the “*iron triangle*,” or the “*golden triangle*”. The criteria used to evaluate project success have evolved in accordance with the development of project management approaches. As stakeholders may prioritize different aspects when evaluating success, it can be interpreted from various perspectives (Turner & Zolin, 2012). Based on research in this area, Cooke-Davies (2004) identified three levels of project success: success of the project management activity, project success, and conscious project success (Table 1).

Table 1. Three levels of project success summarized

Success "level"	Typical criteria for success
Level 1: Project management success	time, cost, quality, technical performance, scope, safety
Level 2: Project success	benefits realized, stakeholder satisfaction
Level 3: Consistent project success	overall success of all projects undertaken, overall level of project management success, productivity of key corporate resources, effectiveness in implementing business strategy

Source: Own compilation based on Cooke-Davies (2004)

The first level is project management success, which refers to the effective implementation of project management processes. The criteria for success go beyond the traditional criteria of time, cost, and quality. In addition, technical performance, adherence to the project's scope, and the fulfilment of safety requirements are also considered integral components. The second level is project success, which extends beyond the technical implementation of project management and necessitates close collaboration between the project team, sponsor, customer(s) and/or user(s), in addition to other organizational units. A project can only be considered truly successful if it meets stakeholder expectations and if operational management is actively involved in realizing the intended benefits. The third level is sustained project success, which goes beyond the success of individual projects or project management performance. At this level the focus is on whether the organization consistently selects and executes the right projects over time. Success criteria at this level are typically evaluated by multiple stakeholder groups and are closely linked to the organization's market position and strategic objectives.

Another significant contribution to the understanding of project success is the work of Shenhar et al. (2001), who proposed a multidimensional framework for its assessment. Their study identified four key dimensions for evaluating success: project efficiency, impact on the customer, business success, and preparation for the future. The relative importance of these dimensions may vary over time and depends on the level of technological uncertainty. Moreover, the study highlights that different stakeholders continue to interpret success in varying ways. Table 2 summarizes the four dimensions and their corresponding measures.

Table 2. Four dimensions of project success summarized

Success dimension	Measures
Project efficiency	meeting schedule goal, meeting budget goals
Impact on customer	meeting functional performance, meeting technical specifications, fulfilling customer needs, solving customer problems, costumer product usage, customer satisfaction
Business success	commercial success, creating a large market share
Preparing for the future	creating a new market, creating a new product line, developing a new technology

Source: Own compilation based on Shenhar et al. (2001)

According to Gorog's formulation (2016), a project is considered successful if its outcome contributes to achieving the strategic goal that underpins the existence of the initiating (project owner) organization, and if both the project implementation process and the resulting project outcome are accepted by the relevant stakeholders.

However, the importance of the criteria varies depending on the context (Radujković et al., 2021). Koops et al. (2017) highlight that project managers in the public sector hold differing views on how project success can be measured, i.e. what the appropriate success criteria are. The authors compiled a list of 19 success criteria for evaluating the success of public sector projects based on extensive literature review and several exploratory interviews. The researchers applied Q methodology to identify four distinct approaches to assessing project success among public project managers in various countries: the conventional project manager, the product-driven manager, the parent-oriented manager, and the manager with a focus on stakeholders. Each perspective is associated with a unique set of success criteria, which influences how criteria are prioritized or considered less significant. The study concludes that the assessment of a project's success largely depends on the perspective from which it is examined. Table 3 illustrates the five most important success criteria for each of the four identified approaches, derived from a comprehensive list of 19 criteria.

Table 3. Four perspectives of project success summarized

Perspectives	The most important success criteria
The conventional project manager	fit for purpose, within budget, project specific political or social factors, satisfies needs of users, satisfied needs of shareholders
The product-driven manager	project specific political or social factors, delivered on time, safety, effect on the professional image of client organization, satisfies needs of users
The parent-oriented manager	project specific political or social factors, delivered on time, safety, effect on the professional image of client organization, satisfies needs of users
Manager with a focus on stakeholders	delivered on time, satisfies needs of stakeholders, within budget, satisfies needs of shareholders, safety

Source: Own compilation based on Koops et. al. (2017)

While studies on success criteria have identified largely similar requirements, the spectrum of explored success factors – the conditions, facts, and circumstances that influence a project's outcome and thus contribute to its success (Han et al., 2012) – is extremely broad and complex. Nevertheless, it is crucial to adopt a systems perspective that considers the interaction between the success criteria and the factors that influence them (Silva et al., 2016). Critical success factors are those through which project managers can enhance the likelihood of project success (Ika, 2009). It can therefore be concluded that success factors influence the effective implementation of a project, and that by shaping these factors, the project manager can affect the fulfilment of the success criteria.

Although different authors often emphasize various factors as critical to project success, the role of human factors has gained increasing prominence over the years. Numerous studies highlight human factors as key elements of successful project implementation (Cooke-Davies et al., 2007; Jha & Iyer, 2007; Turner, 2007; Ramos et al., 2016; Raziq et al., 2018). This suggests that one of the primary drivers of project success is consideration of human factors, including the leadership style and competencies of the project manager, as well as the readiness and capabilities of team members.

The Project Excellence Model provides a systematic framework for understanding the factors that influence project success. It clearly distinguishes between success criteria ("what"), i.e. the results to be achieved, and success factors ("how"), i.e. how those results are attained. The model posits that the

leadership style of the project manager and the professionalism of project management play a pivotal role in the successful implementation of projects. The factors contributing to project success are interdependent and must be aligned with the type of project, its objectives, and the external environment. A key lesson of the model is that success depends not only on the achievement of results (e.g. time, cost, quality), but also on the manner in which said results are delivered: specifically, through effective leadership, teamwork, stakeholder relations, and adherence to professional standards of project implementation (Westerveld, 2003).

Over time, the model has been continuously refined and expanded to incorporate new perspectives, supporting a deeper understanding of increasing project complexity and the rapidly evolving project environment. In recent years, sustainability and environmental considerations have become increasingly important in project evaluation. As a respond to these developments, IPMA (International Project Management Association) revised the model and introduced an extended framework, the Project Excellence Baseline (IPMA PEB), which was officially adopted as an IPMA standard in 2016. The assessment framework identifies three primary domains: People & Purpose, Processes & Resources, and Project Results. Achieving alignment across these three domains is critical for realizing excellence. The model not only focuses on the outcomes achieved, but also on the conscious leadership and management processes that contribute to them (Table 4).

Table 4. Summary of the IPMA Project Excellence Model (PEM)

Main areas of the model	Focus	Criteria
People & Purpose	Project excellence is founded on leaders, including sponsors, who embody the requisite values and consciously apply an effective leadership style. The presence of capable individuals in leadership roles, a shared vision among team members, and effective leadership are all crucial factors in achieving success.	A1. Leadership & values A2. Objectives & strategy A3. Project team, partner & supplier
Processes & Resources	The management of key processes and resources that ensure successful project implementation. Active handling of complexity is essential. Project management-related processes receive special attention within the model.	B1. Project management processes & resources B2. Management of other key processes & resources

Project Results	Balancing stakeholder expectations and applying effective leadership processes lead to sustainable, outstanding results that are valuable and meaningful for all key stakeholders.	C1. Customer satisfaction C2. Project team satisfaction C3. Other stakeholder satisfaction C4. Project results
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Source: Own compilation based on (IPMA, 2016)

The project environment also significantly impacts performance and results. External influences may include socio-economic, geographical, political, regulatory, technological, and ecological factors, while internal influences may include organizational strategy, technological maturity, project management maturity, resource availability, and organizational culture and structure. Project complexity tends to increase with the number of internal and external influencing factors, thereby elevating the need for a sophisticated project management system. The model illustrates how various factors, competencies, processes, resources, leadership styles, and stakeholder engagement practices interact within the specific context of a project, providing a robust basis for evaluating the level of project excellence. Based on the literature, it can be concluded that numerous studies have confirmed that the project manager's leadership style significantly contributes to the successful completion of projects (Aga, et al., 2016). Nevertheless, it is important to note that different project types, assessed across various dimensions, involve distinct criteria and factors of varying importance, thereby requiring different leadership styles (Shenhar, et al., 2001).

Leadership Style

Over the years, researchers have offered various definitions of leadership. Northouse (2021, p. 6), for example, defines leadership as "a process by which an individual influences a group of individuals to achieve common goals". Nahavandi (2014, p. 25), on the other hand, defines a leader as "a person who influences individuals and groups within an organization, helps them set goals, and provides direction in achieving them, thereby enabling them to function effectively". Goleman (2019) emphasizes that effective leaders adapt to the emotional climate of their team and the challenges they face. Rather than adhering to their own temperament, they adapt their leadership style to suit the situation. According to Goleman, emotional intelligence is an indispensable skill for effective leadership (Goleman, 2005)

Leadership theories focus on different aspects and provide a framework for examining how leadership works and what constitutes effective leadership (Yukl, 2013). Classical leadership theories, which emerged in the 1930s and 1940s, focused on the leader's personality (Bakacsi, 2015). Trait theory assumes that leadership is an innate trait. According to this approach, leadership was defined as the ability to give effective instructions, with an emphasis placed on characteristics such as physical appearance, abilities, skills and personality (Müller & Turner, 2010). Initially, researchers examined the characteristics of famous historical leaders and drew general conclusions about leadership based on these characteristics. Later research also extended to analyzing personal characteristics and social background (Bakacsi, 2015). The main leadership traits include courage, openness, self-confidence, initiative, and decisiveness (Kirkpatrick & Locke, 1991; Stogdill, 1974). However, the main criticism of trait theory is that not all successful leaders possess these traits, nor does possessing them guarantee success (Nahavandi, 2014; Northouse, 2021). Another criticism is that the theory does not examine how leadership traits impact outcomes or explain their influence on group effectiveness in an organizational context. Nevertheless, trait theory provided an important foundation for subsequent behavioral and competency-based leadership models.

Subsequent research expanded to include the behavior of leaders (behavioral theory), focusing on their actions and the assumption that leadership skills can be learnt (Bakacsi, 2015; Muller & Turner, 2010; Northouse, 2021). Two of the most well-known behavioral theories emerged from studies conducted at Ohio State University (Stogdill & Coons, 1957; Fleishman, 1953) and the University of Michigan (Likert, 1961, 1967). These studies identified two basic leadership behaviors: task-oriented and relationship-oriented (Lussier & Achua, 2015). The main difference is that the latter researchers considered the two leadership styles to be mutually exclusive, whereas the former scholars argued that leaders can exhibit both styles simultaneously. Task-oriented leaders focus on meeting deadlines and achieving goals, while relationship-oriented leaders prioritize building trust, respect and a positive work environment (Henkel et al., 2019).

McGregor (1960) conducted a more nuanced study of leadership behavior, identifying two basic leadership attitudes: Theory X, which assumes that employees are passive and must be controlled by external means; and Theory Y, which assumes that people are responsible and capable of self-direction. Blake and Mouton (1964) depicted various combinations of task- and relationship-oriented behaviors in a managerial grid model, identifying five distinct points: Authority-Compliance Management; Country-Club Management, Impoverished Management, Middle-of-the-Road Management, Team Management. While trait theory and behavioral theory provide valuable insights into leadership, researchers have found that situational factors

must also be considered (Northouse, 2021). This led to the development of contingency theories. These theories suggest that there is no single leadership style that can be applied in every situation, but rather that leadership styles must be adapted to the situation (Chin, 2011).

Several models have been developed within the situational approach, the most prominent of which are Fiedler's contingency model and Hersey-Blanchard's approach. According to Fiedler's contingency model (1967, 1981), leaders can be either task- or relationship-oriented, and their effectiveness depends on the specifics of the situation. Fiedler examined how managers utilize available resources to enhance group efficiency. He argued that, since a leader's leadership style remains consistent, their effectiveness varies according to the situation (Fiedler, 1967). To lead effectively, leaders must first understand the environment and context in which they are operating. To identify potential leadership styles, Fiedler (Fiedler & Garcia, 1987) developed the Least Preferred Co-worker (LPC) measure. The model highlights three situational factors: the relationship between the leader and their subordinates, the structure of the task, and the leader's positional power (Fiedler, 1967, 1978). Leader-member relations (LMR) include the degree of trust, support, and group cohesion; task structure (TS) refers to the clarity of the task; and positional power (PP) refers to the leader's power derived from their position. Task-oriented leaders are most effective when situational control is either very high or very low. In high-control environments, where everything is running smoothly, they can focus on details and support team members in executing tasks. In such well-structured environments, they tend to be confident and efficient. By contrast, they perceive situations characterized by moderate control and uncertainty as stressful and threatening because they rely heavily on clear structures and explicit guidance. In these cases, they may become overly controlling, which can lead to poor performance. In low-control situations such as chaotic environments or crises where task structure is lacking, they often make autocratic decisions and pay little attention to their team members' needs. Nevertheless, they can still achieve results as they are driven by a strong commitment to completing tasks and do not give up easily (Nahavandi, 2014). Relationship-oriented leaders, on the other hand, are most effective in situations with a moderate level of situational control where team cohesion is weak and task structures are not clearly defined. In such contexts, they can apply their interpersonal and participative skills effectively. They can resolve conflicts, involve team members in decision-making, and foster collaboration, thereby improving performance in the long term. They are particularly valuable in environments where managing interpersonal dynamics and promoting group cohesion are critical for success (Nahavandi, 2014).

Hersey and Blanchard (1982) identified four leadership styles that depend on the maturity level of followers and the balance between relationship orientation and task orientation. Their Situational Leadership model enables leaders to adapt their leadership style to suit the situation and the maturity level of their team members. The four leadership styles are as follows:

- Telling: high task-orientation, low relationship-orientation. The leader gives instructions, assigns roles, and exercises close control.
- Selling: high task and high relationship-orientation. The leader directs, supports, and persuades.
- Participating: low task-orientation, high relationship-orientation. The leader involves and supports followers and engages in joint decision-making.
- Delegating: low task and low relationship-orientation. The leader shares responsibility and decision-making authority.

The original model was based on two variables: the follower's ability and willingness to perform tasks. However, a later and more refined version, the Situational Leadership II (SLII) model developed by Blanchard et al., (1985) redefined these dimensions as competence and commitment offering a more nuanced, context-based interpretation of follower development. The SLII model categorizes followers into four levels:

- D1 – Enthusiastic Beginner: high commitment, low competence
- D2 – Disillusioned Learner: low commitment, some competence
- D3 – Capable but Cautious Contributor: variable commitment, high competence
- D4 – Self-Reliant Achiever: high commitment, high competence

Corresponding to these development levels, the model identifies four leadership styles, which combine varying degrees of directive and supportive behavior.

- S1 – Directing: The leader focuses communication on achieving goals and provides minimal support. The leader gives specific instructions on what to do and how to do it, while closely supervising performance.

- S2 – Coaching: The leader focuses on both achieving goals and on meeting the socio-emotional needs of the followers. They provide encouragement and seek input from the followers but still make the final decisions themselves.
- S3 – Supporting: The leader adopts supportive behaviors, including active listening, giving praise, asking for input, and providing feedback.
- S4 – Delegating: The leader provides minimal direction and support, thereby reinforcing the employee's autonomy, confidence, and motivation.

The essence of the SLII model lies in aligning leadership behavior with the follower's development level. The model clearly matches each development level (D1–D4) with a corresponding leadership style (S1–S4). Each development level is therefore paired with a specific leadership style that facilitates the follower's growth and supports the successful completion of tasks (Blanchard et al., 1986).

Contingency models, which remain essential to leadership theory today. They offer different interpretations of leadership behavior and its aspects, thereby enhancing our understanding of leadership and our ability to develop it. Contingency theories reject the idea that a single leadership style can be applied effectively in all situations. Instead, they emphasize the need to adapt leadership styles to specific circumstances. Accordingly, different situations require different leadership styles.

Modern integrative leadership theories (Lussier & Achua, 2015) build on earlier approaches by considering the relationships between personality traits, leadership behavior, and situational factors. These theories aim to answer the question of which behaviors and characteristics facilitate effective leadership and which factors influence the relationship between leaders and their followers. A substantial scholar to this perspective is Bass (1990), who distinguishes between two key leadership styles: the transactional leadership, which is based on the exchange of rewards for the achievement of performance goals; and the transformational leadership, which emphasizes vision, charisma, trust, and the development of followers.

In recent years, researchers have increasingly turned to studying so-called 'soft' factors, resulting in a number of new approaches that highlight the role of emotional intelligence, empathy, charisma, and leadership competencies. The competency-based approach places emphasis on the skills and abilities that enable leaders to be effective. Dulewicz and Higgs (2005) in their competency-based approach identified three main domains of leadership competencies: intellectual (IQ), managerial (MQ) and emotional (EQ).

Based on their research, three distinct leadership styles were identified: goal-oriented, involving and engaging. Goal-oriented leaders set goals independently and motivate their team members to achieve them. Involving leaders adopt a less leader-centered approach involving team members in setting goals and selecting appropriate methods. Engaging leaders support team members in defining their own goals and the means to achieve them, with a strong focus on personal development.

The Inherent Characteristics of Projects

Sauser et al. (2009) emphasizes that, according to contingency theory, leadership style should be adapted to the internal characteristics of the project as well as to the organizational environment. This approach not only supports project success but also plays a crucial role in preventing failures. The importance of contextual factors is a recurring topic in project management literature, where the significance of project-specific and environmental characteristics is emphasized by numerous studies. Crawford et al. (2005) suggest that projects can be categorized using various attributes, including project size, level of complexity, geographical location, and technical discipline. Based on comprehensive literature review and focus group interviews, they identified a total of 37 attributes that can effectively support the classification of projects. These attributes represent the inherent, that is, internal and essential, characteristics of projects.

Tale 5 summarizes key studies that provide a theoretical foundation for the systematization of inherent project characteristics. While these frameworks vary in structure and emphasis, they often share common elements, such as the central role of uncertainty and complexity, which are frequently cited as fundamental attributes of projects. The identification of various dimensions of project complexity appears in numerous studies; however, the definition of complexity and the terminology used often differ. According to Baccarini (1966) complexity can be understood in relation to both the technical content of the project (including the implementation process and project outcomes) and its organizational context. Williams (1999) emphasizes that the complexity of a project increases as reciprocal interdependencies arise during execution - often due to the presence of uncertainty. Vidal and Marle (2008) interpret complexity as a source of risk, highlighting that projects characterized by a high number of risks tend to exhibit greater dynamics and more interactions, which in turn increase complexity. As Crawford (2013) points out, researchers distinguish between descriptive complexity, which is based on technology, structures, and organizations, and perceived (subjective) complexity, which individuals form based on their own experiences and interpretations of the specific situation.

Table 5. Inherent project characteristics identified in previous studies

Author(s)	Findings
Baccarini (1966)	• Complexity as interrelatedness ○ differentiation ○ interdependence
Williams (1999)	• Structural uncertainty • Uncertainty regarding goals and methods
Crawford and Pollack (2004)	• Goal/objective clarity • Goal/objective tangibility • Success measures • Project permeability • Number of solution options • Degree of participation and practitioner role • Stakeholder expectations
Xia and Lee (2005)	• Complexity ○ organizational/technical ○ structural/dynamic
Atkinson et al. (2006)	• Uncertainty ○ budget ○ stakeholders ○ the performance process
Jensen et al. (2006)	• Uncertainty (vertical; horizontal) • Interdependence (mutual dependence)
Shenhar and Dvir (2007)	• Novelty • Technology • Complexity • Pace
Geraldi and Adlbrecht (2007)	• Uncertainty: adequacy of available information for decision-making • Interdependence: interrelatedness and mutual dependencies between pieces of information
Perminova et al. (2008)	• Uncertainty • Risk
Mclain (2009);	• Uncertainty: the nature of relationships between project activities
Howell et al. (2010)	• Uncertainty • Complexity

Padalkar and Gopinath, (2016)	•	Project team empowerment
	•	Project importance
	•	Project urgency
	•	Uncertainty (structural, dynamic)
Florice et al. (2016)	•	Complexity
	•	Interdependence
	•	Complexity
	○	structural complexity
	○	dynamic complexity
	○	representational complexity

Source: Own compilation

Further studies provide additional classifications and conceptualizations of project complexity, emphasizing the importance of contextual studies in project management. Shenhar et al. (2007) developed a four-dimensional project classification model known as the Diamond Typology, which categorizes projects based on four dimensions: Novelty, Technology, Complexity, and Pace (NCTP). The model supports the selection of appropriate leadership styles and management strategies. Bosch-Rekvelde et al. (2011) proposed a practice-oriented model for interpreting project complexity. They identified 49 factors influencing complexity, grouped into three categories: technical, organizational, and environmental complexity. Their key findings suggest that projects characterized predominantly by technical complexity may require a different type of project manager compared to those where environmental factors, such as market or regulatory conditions, are more dominant. Florice et al. (2016) confirmed that different types of project complexity require distinct strategies. The study highlights that the effective alignment between leadership approaches and complexity factors can significantly improve project outcomes. Larsson et al. (2015) associated the number of actors involved in a project with project complexity, emphasizing the role of leadership in the successful implementation of complex projects. Using the PAEI model (Adizes, 1976), they found that "integrator-type" leadership behavior facilitates the achievement of all performance indicators in complex projects.

These findings collectively reinforce the idea that projects vary significantly in their inherent complexity and should therefore not be managed uniformly. It is essential to understand the nature and sources of complexity in order to select appropriate leadership styles. Uncertainty is another fundamental characteristic of projects and is closely related to complexity. According to Atkinson et al. (2006), the sources of uncertainty are multifaceted and exert a substantial influence on both projects and project management.

Geraldi and Albrecht (2007) examined the role of uncertainty and interdependence in decision-making. They interpreted uncertainty as the adequacy or lack of information available to support decision-making, while interdependence referred to the mutual relationships of information that affect decision quality. Görög (2003) identified several project-specific sources of uncertainty that influence the predictability of planning and implementation. He highlighted the following factors:

- The operational processes and novelty of the project outcome
- The level of detail and accuracy in defining the content and scope of the project outcome
- The novelty of the work processes required to realize the project outcome
- The accessibility and reliability of information related to the project implementation site
- The stability of the legal and regulatory environment affecting the project implementation
- The expected rate and nature of inflation during the project implementation

Görög (1993) pointed out that uncertainty can manifest in various forms throughout project processes, requiring different approaches for effective management. Exploring the inherent characteristics of projects is of fundamental importance from the perspective of project management. Jensen et al. (2006) emphasized the importance of distinguishing between uncertainties related to the execution of activities and those associated with the environmental conditions of the project. This distinction provides a more nuanced understanding of the uncertainty-complexity relationship in project environments.

Based on the reviewed literature, it can be concluded that the inherent characteristics of projects, particularly complexity and uncertainty, are key factors that provide the basis for selecting project management tools, methods, and leadership styles that are specific to the context (Görög, 2019). Numerous studies have examined the relationship between project complexity, uncertainty and leadership styles. Their findings highlight that the level and type of complexity and uncertainty greatly influence which leadership behaviors are most appropriate in a given context.

Method

This study employed qualitative research design, focusing on a content analysis of previous research on leadership styles in project management. The primary aim was to explore and synthesize existing literature concerning the relationship between project characteristics, organizational context, and the leadership style considered most appropriate for project managers. To achieve this aim, we conducted a systematic review, followed by an in-depth content analysis of selected academic publications. Relevant literature was identified through a targeted search of journal articles published in leading project management journals indexed in the Web of Science database. The selection process was guided by the following criteria:

- Keywords: “project” AND “leadership style”
- Fields: All fields
- Document type: Article
- Document language: English
- Journals:
 - o International Journal of Project Management (17 articles)
 - o International Journal of Managing Projects in Business (21 articles)
 - o Project Management Journal (14 articles)
 - o Journal of Project Management (5 articles)
- Publication years: 2008-2025

The selection process yielded 57 relevant publications. The majority of these papers (32) were published after 2019, indicating a growing scholarly interest in the topic. Most of the recent publications appeared in the International Journal of Managing Projects in Business, highlighting the journal's essential role in this research field. In terms of authorship patterns, Nauman was the most frequent first author (three publications), while Müller contributed to six publications, either as a main or co-author.

Firstly, a comprehensive review of the titles and abstracts of the selected articles was conducted. Based on this review, studies relevant to the research aim were selected for full-text analysis, while irrelevant studies were excluded. A total of 18 studies were then analyzed in detail, paying particular attention to the leadership style approaches applied, as well as to the key findings of each study concerning the relationship between project characteristics, contextual factors, and the leadership styles of project managers. In the final phase,

the content of the selected studies was organized, compared, and categorized into three main topics: characteristics of the project; characteristics of the organizational environment, and characteristics of the project team. A comprehensive presentation of the articles contained within each category is provided in the following subsections.

Results and Discussion

We analyzed 18 relevant papers that examined the relationships between project characteristics, contextual factors, and leadership styles. Most of these studies investigated the project managers' leadership styles, applying transformational and transactional leadership theories, as well as competency-based, and shared or balanced leadership approaches.

Characteristics of the Project

To identify the most effective leadership style for project managers, it is necessary to consider both project-specific characteristics and organizational factors. A project manager's behavior should align with the inherent characteristics and attributes of the project. We conducted a thorough analysis of the project characteristics examined in previous studies, as well as the key findings that emerged. When examining the characteristics of the project, researchers have mainly focused on the type of the project, its complexity and uncertainty.

In their study, Muller and Turner (2010) explored the leadership competency profiles of project managers who have demonstrated success in a variety of projects. The categorization of projects based on the scheme proposed by Crawford et al. (2005), which encompasses the extent of scope, the degree of complexity (low, medium or high), the perceived importance, and the type of the contractual agreement. The research suggests that transactional leadership style (e.g. goal setting and performance monitoring) is most effective for projects of lower complexity, while transformational leadership (e.g. inspiring a vision and focusing on people) is essential for projects of higher complexity.

Furthermore, those managers who successfully managed medium-complexity projects demonstrated particularly high levels of critical thinking (IQ), resource management, empowerment and development

(MQ) and self-awareness, empathy, influence and conscientiousness (EQ). Managers of high-complexity projects demonstrated a high level of proficiency in all competency areas, with strength in visioning, motivation, and emotional intelligence. The findings underscore the notion that there is no universal, one-size-fits-all approach to effective leadership, it must be adapted to the nature and characteristics of the project.

In Yang's (2011) study, various factors affecting project complexity were examined, including the level of complexity (high, medium, low), team size, industry sector, project type, owner regulation, and international involvement. Respondents were asked to compare the given project to others within the company in terms of complexity. Findings from the Taiwanese construction industry indicate that project complexity moderates the relationship between different dimensions of teamwork and overall project success. Specifically, for highly complex projects, success largely depends on a high level of communication, collaboration, and team cohesion. Additionally, project type acts as a moderating factor, influencing the relationship between teamwork and project success. In terms of leadership styles, transformational leadership was found to significantly improve teamwork, whereas passive leadership had a negative impact. Overall, teamwork was found to have a statistically significant positive effect on project performance, with the project manager's leadership style contributing to better relationships among team members.

In a later study, Princes and Said (2022) investigated the financial sustainability of successful construction projects, with a particular focus on the relationship between project complexity (technological and organizational complexity) and leadership style. Their results revealed that a situational leadership style is especially effective in projects of high complexity, as it enables leaders to adapt to the preparedness of their team members and to evolving project conditions. Furthermore, the study highlighted that team members' performance skills and their trust in the leader serve as critical mediating factors in the relationship between project complexity and financial sustainability. Consequently, leadership style contributes indirectly to project success by fostering team members' motivation and trust in the leader. Therefore, in complex projects, situational leadership and trust in the leader jointly support financial sustainability.

On the other hand, Podgórska and Pichlak (2019) highlighted the importance of the strategy. They evaluated project complexity taking into account its size (number of people involved), level of risk, and level of uncertainty (associated with the technical advancement) Based on Dulewicz and Higgs' (2003) competency-based model, they analyzed the importance of the three competency domains (emotional,

managerial, and intellectual) and concluded that different types of projects require different leadership competencies to ensure success. Their findings indicate that the emotional and managerial competencies of project leaders are strongly associated with project success, and that attributes of project complexity influence which competencies are most critical. Specifically, managerial competencies are essential in projects of high complexity (high level of risk and technical sophistication); conscientiousness (EQ) plays a key role in projects of medium complexity (average risk and technical sophistication); while communication skills (MQ) are most crucial in projects of lower complexity (low level of risk and technical sophistication).

Furthermore, Fernandes et al. (2023) investigated the relationship between complex problem-solving (CPS) in project environments and leadership style. The study provides a framework for managing complexity from a leadership perspective. The study involved 32 project managers who employed both traditional and agile project management methods. The participants came from international and Brazilian organizational contexts. The results highlight that the technical and organizational skills of project manager are not the only important factors in managing complexity. Their cognitive leadership style is also important, particularly their ability to foster knowledge sharing, communication, and collaboration among team members.

While most of the analyzed studies addressed various aspects of project complexity, only a few considered the attributes of project uncertainty. The study by Lai et al. (2018) focused on the relationship between leadership style and uncertainty. In the research, project uncertainty was assessed based on the frequency of changes in technologies and processes, in addition to the overall uncertainty of the project. The findings of the study highlighted that in projects characterized by high level of uncertainty, a transformational leadership style can be effective as it enabled the team to adapt to environmental changes more flexibly and effectively.

In their study, Wang and Yang (2021) examined the role of supplier involvement and the project leader's personality and leadership style, in sustainable new product development (SNPD) projects, as well as their impact on project success. The study emphasizes the crucial role of supplier involvement in SNPD projects and the central role of project leaders in managing uncertainty and resistance. Personality traits such as emotional stability (the opposite of neuroticism), openness to new experiences, and a transformational leadership style play a significant role in the success of SNPD projects. The personality and leadership style of the project leader are therefore fundamentally important in managing uncertainty, resistance, and communication difficulties. Table 6 summarizes the findings of previous studies examining the relationship

between various project characteristics, such as project complexity and uncertainty, and the leadership style of project managers.

The review of the literature reveals that matching the project manager's leadership style to the characteristics of the project is crucial for achieving project success. Although several studies have investigated the relationship between project managers' leadership styles and project characteristics, such as complexity and uncertainty, the results are contradictory due to the inconsistent definitions and analytical approaches. Many studies tend to focus on one particular aspect, rather than adopting a comprehensive and integrated perspective. While these project characteristics significantly impact both the implementation process and the likelihood of success, the existing conceptual frameworks are often underdeveloped or fragmented (Cristóbal, 2017). It is evident that the complexity and uncertainty of a project significantly impact the leadership style adopted by the project manager. However, there remains a notable gap in literature, as no study has yet offered a holistic, empirically grounded framework that considers project characteristics. This highlights the need for further empirical research aimed at identifying the most appropriate leadership styles suited to the characteristics of the project.

Table 6. Literature considering project characteristics and leadership-related findings

Author(s)	Considered project characteristics	Findings
Muller and Turner (2010) (N=400 PMs)	Low / Medium / High complexity	Transactional leadership style is most effective for lower-complexity projects, while transformational leadership style is essential for higher-complexity projects.
Yang et al. (2011) (N=213 various project stakeholders from construction industry)	Low / Medium / High complexity compared to previous projects	Transformational leadership improves teamwork, which significantly improves project performance. Project complexity mediates the relationship between teamwork and project success.
Podgorska and Pichlak (2019) (N=102 PMs)	Low / Medium / High complexity based on level of risk, level of uncertainty, and number of people involved	Project managers' emotional and managerial competencies are strongly associated with project success. In projects of high complexity, managerial competencies are essential.

Princes and Said (2022) (N=91 PMs)	Complexity of technology / complexity of the organisation	Situational leadership style is especially effective in projects of high complexity.
Fernandes et al., 2023 (N=32 PMs)	Complex problem-solving in projects	When managing complexity, cognitive leadership style of the project manager is also important, in addition to technical and organizational skills.
Lai et al., 2018 (N=151 IS professionals)	Change of process / change of technological framework / Total project uncertainty	Transformational leadership style can be effective in projects involving high level of uncertainty.
Wang & Yang, 2021 (N=6 case studies)	Uncertainty of SNPD projects, supplier involvement	Transformational leadership style facilitates the success of SNPD projects.

Characteristics of the Organizational Environment

When examining the characteristics of the organizational context in which projects are implemented, studies analyzing the project manager's leadership style have focused on how specific organizational features influence the effectiveness of different leadership styles. Considering the organizational factors, previous studies placed more emphasis on the soft factors of the organizational environment, such as organizational culture and knowledge sharing (Csepregi & Papp-Horváth, 2024), and less attention to hard factors, such as project management approach or methodology.

Taking into account the influence of national culture, the research of Drouin et al. (2018) is based on the concept of balanced leadership. This concept views leadership as a dynamic and situation-dependent process in which authority shifts between a vertical leader, such as a project manager, and a horizontal leader, such as a functional project manager or team member, and back again. This process is intended to have a positive impact on project success. The results of the study show that, in Canadian and Australian projects, vertical leaders employed a combination of autocratic and democratic leadership styles, while Scandinavian projects were characterized by a predominantly democratic style. The study sheds light on the interaction dynamics between vertical and horizontal leaders in project management, highlighting the importance of strategic and tactical decision-making. Technical and routine operational tasks were usually carried out by horizontal leaders, while business-related and management decisions (e.g. scope changes or issues affecting time and cost) were handled by the vertical leader alone or in collaboration with the horizontal leader. The findings

suggest that clearly defining the responsibilities of horizontal and vertical leaders can enhance the efficiency of tasks and decision-making in complex projects. Taking organizational culture into consideration, Agarwal et al. (2021) examined the relationship between vertical leadership (VL) and distributed leadership (DL) in connection with the psychological contract state in project-based organizations (PBOs). They found that a flexible, collaborative organizational culture supports knowledge sharing and the application of agile methods, enabling distributed leadership and the fulfilment of the psychological contract. The study's summary indicates that agile methods facilitate distributed leadership. Conversely, the use of traditional project management methodologies does not hinder distributed leadership when combined with a flexible and collaborative organizational culture. Furthermore, Nauman et al. (2022) investigated how the empowerment climate moderates the relationship between transformational leadership, team building, and project success. The empowerment climate was conceptualized through three core dimensions: information sharing, autonomy within boundaries, and team-level accountability. To assess this construct, the study employed a 16-item scale developed by Nauman et al. (2010). Transformational leadership was measured using a 13-item instrument developed by Aga et al. (2016). The results demonstrated that transformational leadership positively influences team building, which in turn mediates its effect on project success. The findings underscore the critical role of empowerment climate in amplifying both the direct and indirect effects of transformational leadership. In organizations with a strong empowerment climate, transformational leadership more effectively fosters cohesive, high-functioning teams that contribute to achieving project objectives. Thus, transformational leadership contributes to project success not only directly, but also indirectly through enhanced team dynamics, particularly when supported by an empowering organizational environment.

Considering knowledge sharing and trust, the findings of Bhatti et al. (2021) revealed that ethical leadership is positively associated with trust and knowledge sharing. These, in turn, mediate the relationship between ethical leadership and project success. Adopting a contingency approach to leadership, the study highlights that ethical leadership is an ideal, context-specific for project managers to adopt to improve project outcomes. The results demonstrate that ethical leaders promote transparency and collaboration within project teams, thereby contributing to project success. The authors recommend that organizations develop training programs to help project managers understand and implement ethical leadership practices and foster organizational cultures that emphasize process over results.

Table 7. Literature considering organizational factors and leadership-related findings

Author(s)	Considered organizational factors	Findings
Drouin et al. (2018) (N=6 case studies)	Culture, decision making practices	In Canada and Australia, a mix of autocratic and democratic styles is used, while in Scandinavia, a predominantly democratic style. A clear division of responsibilities between horizontal and vertical leaders facilitates effective decision-making.
Zhang et al. (2018) (N=365 PMs and members)	Collaborative project delivery method (IPD)	Project managers with high emotional intelligence improve collaboration satisfaction. This relationship is mediated by transformational (TFL) and active-transactional leadership (ATL) styles.
Agarwal et al. (2021) (N=8 PBOs and 45 interviews)	Organizational culture, knowledge sharing and project management approaches	Distributed leadership is associated with a collaborative organizational culture, knowledge sharing mechanisms, and the application of agile approaches.
Bhatti et al. (2021) (N=175 project team members)	Ethical leadership and knowledge sharing	Ethical leadership is positively related to a leader trust and knowledge sharing. Leader trust and knowledge sharing mediate the relationship between ethical leadership and project success.
Nauman et al. (2022) (N=370 PMs)	Organizational climate (empowering);	In a stronger empowerment climate, transformational leaders are more effective at team building and their team-building efforts result in better project performance.
Misbahuddin et al. (2024) (N=224 PMs)	Project management approaches (waterfall, hybrid, agile).	Transactional leadership is primarily associated with the waterfall approach, while transformational and ambidextrous leadership are more suited to agile and hybrid approaches.

Taking the project delivery method into consideration, Zhang et al. (2018) investigated how project managers' emotional intelligence (EI) affects satisfaction levels within the Integrated Project Delivery (IPD) environment, and the role different leadership styles play in this relationship. The study analyzed four

leadership dimensions: transformational, active transactional, passive transactional, and laissez-faire. The findings of the study revealed that project managers with higher EI are more likely to adopt transformational and active transactional leadership styles, which enhance collaboration satisfaction (including performance contribution, efficiency, relationship quality, and interest alignment). In contrast, passive transactional and laissez-faire leadership styles have negative or non-significant effects on this relationship. The study highlights that successful IPD projects require project managers with high EI who exhibit appropriate leadership behaviors. In addition, considering the project management approaches, Misbahuddin et al. (2024) conducted research in the telecommunications sector, involving 77 companies and a total of 224 project managers. They found that more than half of the project managers used a hybrid approach, combining waterfall and agile methodologies. Based on the findings, transactional leadership style is primarily associated with the waterfall approach, while transformational and ambidextrous leadership styles are better suited to agile and hybrid approaches. Ambidextrous leadership involves balancing and integrating two seemingly contradictory yet complementary leadership styles: exploration (innovative and risky) and exploitation (efficient and predictable). Table 7 represents the findings of previously published papers and highlights the suggested leadership style against certain organizational features.

The reviewed studies clearly demonstrate that the effectiveness of project managers' leadership styles is significantly influenced by organizational context. Key organizational features, such as organizational culture, knowledge sharing, and project management approaches and methods, either enhance or hinder the impact of different leadership styles on project success. Previous findings have shown that flexible and collaborative organizational cultures support agile methods and distributed leadership. Furthermore, ethical and authentic leadership styles, when supported by trust and empowerment, positively influence knowledge sharing, team dynamics and project success. In addition, transformational leadership style suits agile and hybrid project management approaches, and transformational and active-transactional leadership styles facilitate the collaboration satisfaction in integrated project delivery. These insights underscore the importance of aligning leadership styles with organizational context to improve project performance.

Characteristics of the Project Team

The literature on the relationship between project success and leadership style examined team characteristics from multiple perspectives, highlighting that leadership effectiveness is shaped not only by the leader's behavior but also by the features of the project team and its members. The following studies explore how

these team-related characteristics interact with different leadership styles to influence project outcomes. Taking the project team's working method into account, Nauman et al. (2010) examined how the empowerment climate influences leadership behavior and customer service effectiveness in projects with varying degrees of virtuality. For their empirical study, they collected data from IT project management professionals across five countries and applied linear regression and moderated regression analyses to examine the proposed relationships. Their findings suggest that an empowering climate positively affects leaders' concern for task, concern for people, as well as their customer orientation. These effects were more pronounced in highly virtual project environments. The researchers' findings also indicate that creating a supportive atmosphere of empowerment is essential to improving leadership effectiveness and customer service in virtual projects. In the contemporary context of virtual teams, communication and coordination are predominantly facilitated through electronic channels. The study highlights that task-oriented leadership is equally important in low- and high-virtual projects, while relationship-oriented leadership is particularly significant in highly virtual settings.

In their research, Daim et al. (2012), based on interviews with project team members in high-tech companies specializing in electronics design and manufacturing, concluded that communication breakdowns can cause serious harm to projects, particularly in the context of global virtual teams (GVTs). Their study identified five key areas that contribute to communication problems: trust, interpersonal relations, cultural differences, leadership, and technology. Global virtual teams, which are typically geographically dispersed, culturally diverse, and connected through electronic tools, are becoming increasingly common in the high-tech sector. While these teams often have designated project leaders, their success largely depends on the ability of team members to share knowledge effectively, regardless of their formal roles. Strong leadership is critical for projects implemented by GVTs, as project managers must promote frequent and meaningful communication and feedback, as well as establish clear communication norms to reduce misunderstandings.

Considering the project team mindfulness, Majeed et al. (2023) conducted a study in project-based organizations within the IT and telecommunications sectors, revealing that team mindfulness positively influences team cohesion, which in turn improves project team performance. Effective team leadership is a critical factor in enhancing this relationship. Effective leaders possess strong leadership skills, facilitate communication and interaction, create safe environments for sharing ideas, support team functioning, and encourage constructive dialogue. The study emphasizes the importance of enhancing communication and

transparency to boost team cohesion. The leadership style adopted by the project manager should be regularly evaluated based on feedback from team members to facilitate personalized training and coaching. In addition, the performance of the project team is also a reliable indicator of leader's effectiveness.

As far as the aspects of team collaboration are concerned, Altaher et al. (2024) conducted a study collecting data from key actors in project-based organizations, including project managers, team members, and stakeholders, across five different countries (Jordan, Saudi Arabia, China, Australia, and the United Arab Emirates). Their findings confirmed that transformational and transactional leadership styles positively impact project success. Transformational leaders increase team members' enthusiasm and commitment through their inspiring and motivating behavior, while transactional leaders clearly define roles, expectations, and reward systems, fostering accountability and performance. In contrast, laissez-faire leadership showed no direct positive effect on project success. In fact, laissez-faire leadership was found to have a negative relationship with team collaboration, suggesting that a lack of leadership direction may hinder effective teamwork. In addition, the study investigated whether team collaboration serves as a mechanism through which transformational, transactional, and laissez-faire leadership styles influence project outcomes. The results showed that team collaboration mediates the relationship between transformational and transactional leadership and project success. Therefore, fostering a collaborative team environment is important for project success.

Furthermore, Shahzad et al. (2025) examined the relationship between inclusive leadership and project citizenship behavior (PCB), focusing on the mediating and moderating mechanisms within project-based organizational contexts. Data was collected from three IT and two construction sector organizations, as both sectors are characterized by time-bound, project-based work structures. The study's findings revealed that the project team members' proactive personality is a significant factor in strengthening the relationship between project managers' inclusive leadership and team members' positive affectivity. Therefore, during the recruitment and selection process, organizations should prioritize identifying project team members with proactive personalities. These individuals tend to exhibit initiative, show resourcefulness, and seek opportunities for personal development, making them valuable members of the project team. Due to their high sensitivity towards inclusion, project team members should be managed with an inclusive approach by their project managers. Inclusive leadership fosters positive emotional states among team members, which promote voluntary, extra-role behaviors that support project success. Table 8 highlights the team characteristics analyzed in prior studies as well as the findings of previously published papers.

Table 8. Literature considering characteristics of the project team and leadership-related findings

Author(s)	Considered team characteristics	Findings
Nauman et al. (2010) (N=117 PMs)	Virtuality in project implementation	In highly virtual projects, leaders should strive for a relationship-oriented style and the creation of empowerment.
Daim et al. (2012) (N=10 project team members)	Global virtual teams	Strong leadership is critical for GVTs' projects, as it facilitates effective communication and knowledge sharing among team members.
Majeed et al. (2023) (N=379 PMs, team members, executives)	Team mindfulness	Team mindfulness boosts team cohesion, which improves project team performance, and effective team leadership strengthens these relationships.
Altaher et al. (2024) (N=202 PMs, team members, stakeholders)	Team collaboration	The results indicated that team collaboration mediates the relationship between both transformational and transactional leadership and project success.
Shahzad et al. (2025) (N=221 PMs)	Team members' project citizenship behavior (PCB).	An inclusive leadership style can enhance team members' PCB. The importance of emotions derived from inclusive leadership enhances positive project outcomes.

Overall, the previous findings support the idea, based on that the effectiveness of any given leadership style depends on the team level characteristics, such as the degree of virtuality, team collaboration, mindfulness, and project citizenship behavior of team members. Within highly virtual working environments, a relationship-oriented and strong leadership style can be effective, supporting active communication and knowledge sharing within the project team. Furthermore, effective team leadership and inclusive leadership were found to be essential in enhancing the relationship between mindfulness and the project citizenship behavior of team members, thereby facilitating project performance. Additionally, transformational and transactional leadership styles were found to improve project success, and this relationship is mediated by team collaboration. In summary, previous studies have examined various aspects of the project team and revealed the necessity of taking these characteristics into account to identify the most appropriate leadership style for project manager.

Conclusion

Based on the literature review, it can be concluded that contextual factors cannot be ignored when examining the leadership style of project managers. The most appropriate leadership style is influenced by the inherent characteristics of the project (e.g. complexity and uncertainty), the characteristics of the organizational environment (e.g. organizational culture, knowledge sharing, project management approach), and the characteristics of the project team, where previous researches have also shown that the virtual working environment, quality of collaboration, mindfulness, and project citizenship behavior influence the most appropriate leadership style in a given situation. Overall, these results support the idea that the effectiveness of a leadership style is highly dependent on the context and therefore needs to be adapted to the specific characteristics of the project, organization and team. Nevertheless, previous studies have focused on individual aspects or specific segments of the project context, thereby neglecting the comprehensive features of the overall context. Furthermore, the examined factors – such as complexity and uncertainty – have often been interpreted and conceptualized differently across studies, which limits the comparability of their results. In light of these limitations, it appears necessary to conduct a comprehensive study that considers the characteristics of the project, the organization, and the team that are decisive for the project manager's leadership style. This investigation could identify the most appropriate leadership styles for different project contexts, facilitating project success.

Building on these findings, we intend to further examine the relationship between project managers' leadership style and project success in a context-related manner. Specifically, our future research will explore how various leadership styles influence project success, while taking into account both project characteristics and broader contextual factors. We aim to identify the relationships between the inherent characteristics of the project, the primary factors of the organization housing the project, the project team's project management-related characteristics, and the use of different leadership styles. Based on these insights, we seek to identify which leadership styles are most appropriate in specific contexts using a deductive approach. This approach will enable a nuanced exploration of the topic and foster a better understanding of its complex interrelationships. To select our sample, we plan to include a diverse range of multinational companies engaged in product development, organizational development, or IT development, where projects with varying contexts can be analyzed. Primary data will be collected through semi-structured interviews with project managers, project team members and their superiors.

As a result of the planned study, we aim to develop a framework with significant practical implications. This framework has the potential to help project managers and human resources professionals understand the relationships between leadership styles and contextual factors. By facilitating the context-related selection and development of suitable project managers, it could contribute to improving project success rates. Moreover, it can serve as a foundation for tailored development programs and for future research aimed at enhancing leadership effectiveness across diverse project contexts.

Limitations

The systematic literature review was based on the Web of Science database; therefore, the literature coverage cannot be considered comprehensive. Although the selection process is transparent and replicable, potential biases cannot be eliminated. Nevertheless, the analysis provides a theoretical foundation for future research. We recommend repeating the review periodically to ensure the validity and relevance of the selected articles.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

Funding

* Project no. MEC_SZ 149231 has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the MEC_24 funding scheme.



PROJECT
FINANCED FROM
THE NRDI FUND

Conflict of Interest

* The authors declare that they have no conflicts of interest

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Management Economics and Business (www.iconmeb.net) held in Budapest/Hungary on August 28-31, 2025

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THE IMPACT OF FINANCIAL CULTURE AND SOCIALIZATION ON CONSUMER BEHAVIOR

Abstract: Financial culture and financial socialization play an increasingly important role in understanding consumer decisions, especially when examining purchasing and saving habits. Financial culture encompasses an individual's financial knowledge, attitudes, skills, and behavior, which determine how they manage their finances and make decisions about saving, spending, investing, or even taking out loans. This is closely related to financial socialization: the process by which individuals acquire financial behavior patterns, values, and norms, primarily through the influence of family, education, peers, and the media. Parents' financial habits, educational attainment, and attitudes have a significant impact on the financial decisions their children make as adults. Therefore, financial socialization is not only about transferring knowledge, but also about shaping attitudes toward money. In today's society, where financial decisions are becoming increasingly complex, the development of financial literacy is key to economic stability and individual well-being. The study of financial socialization provides an opportunity to understand the background factors that influence consumer behavior and how financial awareness can be developed in a targeted manner in different social groups. The aim of this research is to explore how financial education and family background influence individuals' price sensitivity, their attitude towards discounted products, and their choice between quality and price. The research is based on quantitative methodology, with data collected through questionnaires. Respondents are grouped according to four main criteria: their own highest level of education, their mother's and father's highest level of education, and their generational affiliation based on their age. The aim is to explore how financial socialization stemming from family background influences financial decision-making and purchasing behavior.

Keywords: Keywords: financial culture, consumption, financial socialization, awareness

Introduction

Financial culture and socialization have become extremely important today, especially in shaping consumer behavior. Due to globalization, technological development, and the complexity of financial markets, the level of financial literacy and awareness is crucial in terms of everyday life and economic stability. Financial

culture not only influences financial behavior at the individual level, but also has a decisive impact on economic actors as a whole. According to Csorba's (2020) analysis, cultural embeddedness largely determines what financial products consumers purchase and how they relate to risk-taking, saving, or borrowing. Decisions related to financial transactions, investments, and savings often stem from social customs and ingrained habits that are difficult to change but have a long-term sustainable impact on economic well-being. Financial socialization is the process by which individuals acquire financial knowledge, skills, and attitudes through the influence of their environment, family, educational institutions, and the media. Garai-Fodor and Csiszárík-Kocsir (2018) point out that Generation Z is already socializing in a digital environment, so the skillful use of IT tools helps them in their financial decisions, but also presents new challenges (Csiszárík – Varga, 2024). Active parenting, learning patterns, and media influence all contribute to the development of individual financial knowledge and behavior. According to Lyons et al. (2006), the media and the internet are outstanding self-directed learning tools for acquiring financial knowledge. Lachance and Legault (2007) emphasize that peer groups also have a significant influence on consumer and financial behavior, especially among young people. Consumer behavior is greatly influenced by financial socialization processes. The spread of digital technologies, social media, and automated financial services creates new opportunities and risks. Younger generations typically rely on electronic sources of information and manage their finances using mobile applications and online platforms. This has led to a paradigm shift: faster decision-making, greater independence, and conscious price comparison have become commonplace. Research (Munawar, 2023; Tóth et al., 2019) confirm that financial literacy correlates positively with more responsible consumer decisions, better financial situations, and financial well-being.

Literature review

The concept and significance of financial culture: theoretical foundations and practical implications

The concept of financial culture dates back to the early 1900s, when it first appeared in economic thinking (Kovács et al., 2012). Over time, the interpretation of financial culture has changed significantly, and today it has become a complex, multidimensional phenomenon that lies at the intersection of different scientific fields and practical approaches. The diversity of the concept also stems from the fact that it can mean different things to different individuals. This subjectivity is also reflected in the fact that there are numerous

definitions and interpretations in the literature. In the English-speaking world, for example, the term "financial culture" is less common, with "financial literacy" being used instead, which is presented as one of the fundamental components of financial capabilities (Atkinson – Messy, 2012). However, there is no single, universally accepted definition of financial literacy. According to Béres and Huzdik (2012), financial culture is not just a definition, but a specific concept that encompasses financial knowledge, financial expertise, experience, skills, and awareness. These elements together, in close correlation with each other, determine an individual's financial culture.

Hung, Parker, and Yoong (2009) define financial literacy as the ability to apply the knowledge and skills necessary to effectively manage financial resources for long-term well-being. In contrast, Servon and Kaestner (2008) take a simpler approach: they define financial literacy as an individual's ability to understand and use financial concepts. According to Süge (2010), financial culture encompasses all factors that help people navigate financial issues and contribute to the creation of financial well-being. This approach goes beyond individual knowledge and also takes into account the effects of the socio-economic environment. Nagy and Tóth (2012) emphasize the importance of conscious financial behavior. Through financial awareness, individuals can better understand the benefits and risks of financial services and be able to manage their investments optimally. A lack of adequate financial knowledge often leads to debt problems, impulsive decisions, and a shift toward expensive, less advantageous loans. In their research, Lusardi and Mitchell (2014) point out that well-informed and rational individuals are able to save during periods of higher income in order to maintain their consumption levels even when their income declines. This approach reflects the synergy of financial awareness, responsibility, and long-term thinking.

Financial literacy is therefore not only about managing one's current financial situation, but also about the ability to anticipate and plan for the future. Individuals who strive for more predictable financial processes place greater emphasis on understanding and analyzing the financial environment. However, this knowledge alone is not enough: a responsible attitude and rationality are also necessary. It is important to note that most financial skills are not innate, but rather skills that must be continuously developed throughout our lives. Socialization, family, and the education system play a prominent role in this process. Economic crises have also highlighted that a lack of financial literacy can have serious consequences. According to Botos et al. (2012), the demand for financial culture has increased in recent decades because complex financial products have emerged whose risks even experts are not always able to accurately assess. This further reinforces the need for individuals to be able to make informed decisions and recognize the differences

between financial services. By developing financial literacy, individuals can not only expand their knowledge, but also learn to manage risks and make decisions that result in long-term sustainable financial management. Responsible financial behavior is therefore essential for achieving financial stability and prosperity.

Generational differences and digital challenges in the development of financial literacy

The level of financial literacy is a cause for concern worldwide, as there is general agreement in the literature that people's financial knowledge and awareness is low in many countries. However, awareness is not only important in the field of finance, but in many areas of life. We can also talk about digital and energy awareness, which are also the focus of research due to their importance for the future (Fűrész et.al, 2025). This phenomenon is particularly relevant in a rapidly changing financial environment where new technologies and digital solutions are playing an increasingly important role. At the same time, it is important to note that there are significant differences in the awareness dimension of financial literacy between generations. In their research, Fessler et al. (2007) concluded that younger generations—especially Generation Z—generally have lower levels of financial literacy than older generations. This is partly due to the fact that young people have less experience in financial decision-making, and partly because financial education is not always able to keep pace with the rapid development of financial products and services. The digitalization of the financial sector—especially the rise of neobanks over traditional banks—poses new challenges for the development of financial literacy. Traditional financial education focuses primarily on imparting basic knowledge and aims to shape attitudes and competencies. However, in the world of digital finance, these basics are no longer sufficient. The emergence of new fintech-based financial products further increases the risks arising from a lack of knowledge, particularly due to the wide range of choices and the lack of personal advice.

While access to digital financial products facilitates financial transactions, it also carries new types of financial stability risks. People often lack the knowledge needed to assess the risk profile of products. This is particularly true for younger generations, who, although technologically confident, are less experienced in recognizing and managing financial risks. When examining generational differences, it can be concluded that Generation Z—the “always-online” generation—although confident in using digital tools, does not have sufficient knowledge about the risks of financial products. In contrast, members of Generations Y and X are more aware in this area, partly due to their age and experience. However, skills related to technical understanding and digital competence are essential for all generations to successfully use new technologies

and digital financial services. Even before the fintech boom, Buckingham (2009) drew attention to a new and relevant concept: digital literacy. This skill can be key to addressing the challenges of digitalization, especially in terms of developing financial awareness. Digital literacy is not just about technical proficiency, but also about the ability to interpret and critically evaluate digital financial information. Research examining the relationship between financial literacy and digital literacy is still relatively scarce, but a growing number of studies point to the combined importance of these two factors. Morgan and Trinh (2019) showed in their research that strong financial background knowledge has a positive influence on awareness, demand, and use of digital financial products and services. This means that financial literacy not only plays a role in traditional financial decisions, but is also becoming a determining factor in the digital space. Kass-Hanna et al. (2021) further explored this relationship by examining the combined effect of financial awareness and digital literacy. Their findings show that these two factors play a key role in financial integration and security. Access to digital financial services alone is not enough: individuals must be able to use these tools consciously and responsibly.

Materials and methods

During the research, I used a primary data collection method, which involved conducting a questionnaire survey. The questionnaire was completed on a voluntary basis and the responses were completely anonymous, thus ensuring the protection of participants' data and freedom of expression. Respondents were recruited using the snowball method, which made it possible to reach the desired target group through personal networks. The statements presented in this research were evaluated by respondents on a Likert scale, using a four-point scale where 1 meant complete disagreement and 4 meant complete agreement. Data collection took place in 2025, and the composition of the sample is shown in the table below:

Table 1. Composition of the sample

	Frequency	Percent
BB generation (1940 - 1964)	181	6.3
Generation X (1965–1979)	663	23.2
Generational affiliation	661	23.2
Generation Y (1980-1994)	1174	41.1
Generation Z (1995–2007)	175	6.1
Generation Alpha (2008–)		
Total	2854	10

Source: own research, 2025, N = 2854

Results

As can be seen below, the statements presented in this study clearly illustrate the purchasing habits and price sensitivity attitudes of the respondents. The highest average value was given to the statement "When I shop, I check prices" (2.944), which suggests that conscious price monitoring is widespread among respondents. This behavior reflects a desire for rationality and cost-effectiveness, regardless of whether the product in question is on sale or not. The second highest value was given to the statement "I/we always pay attention to sales when shopping" (2.814), which also indicates conscious shopping, especially sensitivity to price discounts. This indicates that paying attention to promotions is an important factor in purchasing decisions, but not necessarily the only one. The statement "I prefer to buy more expensive but more durable items" (2.703) suggests that some respondents seek long-term value in their purchases and are willing to pay more for quality. This response reflects a conscious consumer behavior that focuses not only on price but also on product lifespan. In contrast, the statement "If I can, I save money by buying lower quality but cheaper items" received the lowest average score (2.385), suggesting that respondents are less willing to compromise on quality for the sake of price. This confirms the trend that, although price is an important factor, quality continues to play a significant role in decision-making.

Table 2. Assessment of statements related to financially conscious consumer decisions

	Average	Standard
I/we always pay attention to special offers when shopping.	2.814	1.139
I save money by buying things when they are on sale.	2,535	1,145
I usually buy several items when they are on sale.	2,526	1,161
When I shop, I check the prices.	2,944	1,184
If I can, I save money by buying lower quality but cheaper items.	2,385	1,112
I prefer to buy more expensive but more durable items.	2,703	1,119

Source: own research, 2025, N = 2854

Below, I will examine the average values obtained by generation. The data reveal clearly distinguishable attitudes by generation, which reflect price sensitivity, response to promotions, and attitude toward quality to varying degrees:

- *Baby Boomer generation:* This generation gave the lowest values for almost all statements. The highest average value was given to the statement "I prefer to buy more expensive but more durable items" (2.331), which suggests that durability and quality are more important to them than price. They are less likely to monitor sales and compare prices, which may be related to their more stable financial situation or different consumer socialization.
- *Generation X:* In this group, the statements "when I shop, I check prices" and "I prefer to buy more expensive but durable items" received the highest scores (3.026 and 2.817). This duality shows that members of Generation X are conscious consumers: they pay attention to prices, but do not necessarily choose the cheapest product, instead looking for long-term value. They are also open to special offers, but do not base their decisions solely on them.
- *Generation Y:* The highest value was given to the statement "when I buy something, I check the prices" (2.917), closely followed by "I prefer to buy more expensive but more durable items" (2.722). This generation is therefore also price-sensitive, but also considers quality to be important. Interestingly, they also gave a relatively high score to the statement "I tend to buy several items on sale" (2.632), which may indicate more impulsive, stockpiling purchasing behavior.
- *Generation Z:* Generation Z gave the highest scores to the statements "I pay attention to sales" (2.898) and "I check prices" (3.026). This indicates that they are extremely conscious of prices and sales, which may be related to the fact that many of them are still studying or just starting their

careers, and therefore have more limited financial resources. At the same time, they also gave a high score to the statement "more expensive but more durable items" (2.745), which shows that they think long-term when they can.

- *Alpha generation:* The Alpha generation gave the lowest or near-lowest values for all statements, as did the oldest BB generation. The highest value appeared in the statement "I look at prices" (2.474), but this is still lower than the values of the other generations. This can be explained in part by the fact that they are still young and in many cases are not independent buyers, so their participation in consumer decisions is limited. The low values reflect a lack of experience rather than a conscious decision.

Table 3. Assessment of statements related to financially conscious consumer decisions by generation

	BB gen.	Gen.	Gen.	Gen Z	Alpha gen.	Total
When shopping, I/we always pay attention to special offers.	2,597	2,876	2,779	2,898	2,366	2,814
I save money by buying things when they are on sale.	2,337	2,561	2,564	2,585	2,200	2,535
I usually buy several items from the sale items.	2,276	2,522	2,632	2,561	2,166	2,526
When I shop, I check the prices.	2,674	3,026	2,917	3,026	2,474	2,944
When I can, I save money by buying lower quality but cheaper items.	2,182	2,293	2,408	2,477	2,234	2,385
I prefer to buy more expensive but more durable items.	2,331	2,817	2,722	2,745	2,303	2,703

Source: own research, 2025, N = 2854

Based on the results of the variance analysis, it can be clearly concluded that there are statistically significant differences between generations in terms of the purchasing attitudes examined. For each statement, the significance value (Sig.) is 0.000, which means that the differences between generations are not random, but reflect real differences in consumer behavior.

Table 4. Correlation between statements related to financially conscious consumer decisions and the generation to which respondents belong (variance analysis, one-way ANOVA method)

		Sum of Squares	df	Mean Square	F	Sig.
When shopping, I/we always pay attention to special offers.	Between Groups	55.336	4	13,834	10,817	0.000
	Within Groups	3643.497	2849	1,279		
	Total	3698.833	2853			
I save money by buying things when they are on sale.	Between Groups	30,708	4	7,677	5,900	0.000
	Within Groups	3707.218	2849	1,301		
	Total	3737.926	2853			
I usually buy several items from the sale items.	Between Groups	42,963	4	10,741	8,047	0.000
	Within Groups	3802.567	2849	1,335		
	Total	3,845,529	2853			
When I shop, I check the prices.	Between Groups	64,519	4	16,130	11,670	0.000
	Within Groups	3937.623	2849	1,382		
	Total	4002.142	2853			
If I can, I save money by buying lower quality but cheaper items.	Between Groups	27,371	4	6,843	5,570	0.000
	Within Groups	3500.203	2849	1,229		
	Total	3527.574	2853			
I prefer to buy more expensive but durable items.	Between Groups	64,024	4	16,006	13,001	0.000
	Within Groups	3507.606	2849	1,231		
	Total	3,571,630	2853			

Source: own research, 2025, N = 2854

Conclusion

Based on the results and responses presented in the study, it can be said that the respondents are price-sensitive, pay attention to promotions, but do not make decisions based solely on price. Conscious purchasing, consideration of price-value ratio, and long-term return appear to be important factors in consumer behavior. It is also evident that Generations Z and Y show the greatest awareness in monitoring prices and promotions, while Generation X evaluates price-value ratio in a balanced manner. Baby Boomers tend to focus on quality, while the responses of Generation Alpha do not yet reflect mature consumer attitudes. The results of the variance analysis confirm that there are significant differences in purchasing attitudes between generations. The greatest differences are in price monitoring and tracking promotions. These results support previous generational profiles and provide statistical evidence of age differences in

consumer behavior. All of this information and these results can be helpful to many market players. The supply side can thus better personalize its sales campaigns, while the demand side can pay more attention to its shortcomings. The results are also important from an educational perspective, as they reveal gaps in the financial literacy of young people, which need to be addressed in a targeted manner.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

Funding

* Project no. MEC_SZ 149231 has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the MEC_24 funding scheme.



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THE NRDI FUND

Conflict of Interest

* The authors declare that they have no conflicts of interest

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Management Economics and Business (www.iconmeb.net) held in Budapest/Hungary on August 28-31, 2025

* The research and study were supported by the Makovecz Campus Foundation – Collegium Professorum Hungarorum.

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THE MICROECONOMIC MODELS OF TAX EVASION, TAX AVOIDANCE AND TAX DENIAL – WHAT DOES THE PROFESSION STATE?

Abstract: There are several economic models in the professional literature that seek to correlate between human behavior patterns, attitudes, tax evasion and their risk, and their institutional background. Among the theoretical models of tax behavior, the pioneer Allingham-Sandmo (1972) model further developed model of Becker (1968, 1976). Corchòn (1992) describes the coexistence norms of economic operators, the game of the 'cops and robbers' of a citizen attempting to escape from the taxing state and its obligations. Ehrlich's model (Ehrlich 1973) - a choice between a curve and a straight path - that legitim activities provide stability and constancy, while more illegal activity may result in greater income. In my paper, I review international experiences that show that reducing the tax burden alone does not reduce the size of the hidden economy, in the long run; only improving the autonomy and motivation of actors can bring lasting results.

Keywords: Tax evasion, Tax rate, Income level, Probability of controlling, Extent of penalty

Introduction

Tax is one of the largest sources of income in central budgets, so taxation plays a significant and determining role in the life of all economic actors. It affects all members of the society without exception, directly or indirectly. Taxation is a very complicated and complex system of tools, so behind tax evasion, tax avoidance and tax denial there are often very complicated, tangible phenomena. Taxation has been a concept since the birth of states. Different and very varied forms of tax evasion have evolved in different historical periods. In a rapidly changing economic environment, tax-related abuses are difficult to classify because human ingenuity knows no limits. In order to reduce or eliminate abuses, it is important for public bodies assigned to taxation to be more prepared and efficient.

A significant economic policy objective is to reduce the level of tax evasion and to increase the efficiency of taxation. The term of a black economy (underground economy) – as many examples also show – as well

correctly points towards relations with crime. Income tax evasion very often leads to relationship with other criminal acts (Nagy, 2011). Based on statistical estimates, we can see that a tax base corresponding from one-third to one quarter of GDP disappears in our country after the comparison of the tax returns and the amount of tax payments. "According to the CSO's report, the size of the black economy's GDP is now 15%. Similar results were obtained by Pogátsa (2012), who defined this ratio at around 11-18%. However, according to research by Belyó (2008b), the size of the hidden economy is around 20-25%" (Hauber, 2013). Based on the analysis of the microeconomic models of tax evasion, we can assume that tax evasion has a decreasing tendency when the number of checks increase and the rate of punishment increases, the spread of tax evasion depends on individuals' incomes and the rate of tax rates. These classical economic models identify important factors but can not fully explain the behavior of taxpayers. According to Akerlof, several model balances may occur in the functioning of the tax system, as there are many social, societal behavior patterns.

Microeconomic Models of Tax Evasion

Two areas of modern economics have contributed to the development of models in connection with the hidden economy. The first area is the social welfare maximization approach - or the theory of optimum taxation. This is used to determine the rate of tax that maximizes social welfare, which can be described by a social welfare function that takes into account the impact of taxes on labor supply, wealth generation, and income distribution. The second area is the microeconomics of crime. Its practitioners start from models in which the offender rationally assesses the expected benefits and costs of crime and selects the alternative that maximizes the (expected) net benefit (Szántó & Tóth, 2001). Among the theoretical models of tax behavior, the pioneer Allingham and Sandmo model (1972) further developed the model of Becker (1968). According to the classic approach, the individual decision determining the rational use of profit maximizing individuals (choice of taxpayers between law enforcement and tax evasion) depends on the following factors (Semjén, 2017):

1. income level of the taxpayer,
2. tax rates,
3. probability of controlling/getting caught,
4. the extent of the penalty.

Under the classic model of tax evasion, individuals decide on their tax behavior by assessing the expected impacts of the above variables rationally (as a homo oeconomicus based on the calculations of the expected utility of the outputs). In this, the offender rationally assesses the expected benefits and costs of the crime, and chooses the alternative that maximizes the (net) expected benefits. Benefit-maximizing players are looking for an optimum solution for making decisions about certain forms of emergence of hidden economy (for example in case of tax evasion), taking into account the costs and benefits of taking part in the hidden economy and staying away from it. According to the model, the rise in probability of getting caught always leads to the increase in declared income. Accordingly, by increasing probability of controls, the proportion of concealed income may be reduced.

Corchòn (1992) describes the coexistence standards of economic operators, the taxing state which tries to enforce these with sanctions, and presents the 'cops and robbers' game of a citizen who tries to escape from his obligations (Hámori, 1998).

Let be:

- P the citizen
- G the state
- A1 criminal strategy
- A2 correct behaviour
- B1 observance
- B2 omitted observance
- Y income of the citizen
- T value of the evasion
- c the cost of observance
- d rate of the penalty

The punishment is proportional to the tax if P carries out the tax evasion and gets caught, sanctioned by dT , d and T are considered external factors. The penalty for avoidance must cover the observation cost, $c < dT$. We also assume that the tax payable is greater than the cost of observation $T > c$ and the income of the citizen is greater than the value of the evasion $Y > T$. The following table shows the payouts of two economic operators – with the different combination of their strategies:

Table 1.

P/G	B1	B2
A1	$Y - T(1 + d), T(1 + d) - c$	$Y, 0$
A2	$Y - T, T - c$	$Y - T, T$

It follows from the above assumptions that:

$$Y > Y - T > Y - T(1 + d),$$

$$T(1 - d) - c > T > T - c > 0.$$

Based on these, it seems to be no dominant strategy, so there is no strategy that would be the best choice for any player. Let's look at the Nash equation below. It is assumed that both operators act simultaneously and are both perfectly informed. Pure strategies do not have Nash's balance, so we put in mixed strategies.

Let p be the probability of P choosing A1 (tax evasion) and q the probability of G choosing B1 (choosing the control). Then the gains of P and G (M_p and M_g) are as follows:

$$M_p = p [q (Y - T(1 + d)) + (1 - q) Y] + (1 - p) [q (Y - T) + (1 - q) (Y - T)],$$

$$M_g = q (p (T - c + dT) + (1 - p) (T - C)) + (1 - q) (1 - p) T$$

From this:

$$M_p = p (T - qT(1 + d)) + Y - T$$

$$M_g = q (pT(1 + d) - c) + (1 - p) T$$

Maximizing M_p :

$$\text{if } q(1 + d) > 1, \text{ then } p_{opt} = 0,$$

if $q(1 + d) < 1$, then $p_{opt} = 1$;

in case $q = 1 / (1 + d)$ the amount of p is indifferent.

Maximizing Mg :

if $pT(1 + d) > c$, then $q_{opt} = 1$,

if $pT(1 + d) < c$, then $q_{opt} = 0$;

in case $p = c / (T - (1 + d))$ the amount of q is indifferent.

Thus, the probabilities connected to Nash-balance:

$$p^* = c / (T(1 + d))$$

$$q^* = 1 / (1 + d).$$

The strategic nature of the game between the two players is indicated by p^* and q^* values. The higher the c , that is, the cost of observation, besides the greater avoidance probability (relative frequency) will be indifferent to the state the strategy is used. Penalty discourages avoidance and makes the observation unnecessary. Equilibrium gains:

$$Mp^* = Y - T$$

$$Mg^* = T - c / (1 + d).$$

Beside these values, none of the parties have any reason to change their strategy.

Let's look the same way at choice between the curve and the straight path in Isaac Ehrlich's model (1973). According to our assumption, the taxpayer can choose between two paths or activities, the legal path to the

acquisition of goods (fair conduct) and the illegal path of acquisition of goods (crime strategy). The entrance costs are not taken into account when entering the two activities and the movements between the activities. Individuals will most likely choose a combination of the two activities, as it is presumed that there are few who make a living with commitment of crime. It is more likely that a legal activity is behind the crime in the background, as a cover story.

In our model let be:

- l correct behaviour (stable activity, result occurs in any case)
- i criminal strategy (risk is involved, its result is conditional)
- t time input
- a the individual choosing illegal activity gets caught
- b the individual choosing illegal activity is lucky
- p_i probability of getting caught
- $(1 - p_i)$ likelihood of that the accomplishment is successful

The expected value of the consumption, that is, the utility in the given situation:

$$U_s = U(X_s, t_c)$$

where U_s is a joint of certain market goods, equivalent of the realistic income of both legal and illegal activities.

The joint demand function of X good in case of p_i and $(1 - p_i)$ probabilities:

$$X_b = W' + W_i(t_i) + W_l(t_l)$$

and

$$X_a = W' + W_i(t_i) - F_i(t_i) + W_l(t_l),$$

at this time, the expected utility happens the following way:

$$EU(X_s, t_c) = \sum_{s=a}^n \pi_s U(X_s, t_c)$$

$$EU(X_s, t_c) = (1-p_i)U(X_b, t_c) + p_i U(X_a, t_c)$$

The task is to maximize the above equation, depending on the limits of possessions and time.

$$t_0 = t_i + t_l + t_c$$

It is a requirement that the following values cannot be negative:

$$t_i \geq 0; t_l \geq 0; t_c \geq 0.$$

Optimal conditions of the model:

$$\frac{\delta EU}{\delta t} - \lambda \leq 0$$

$$\left[\frac{\delta EU}{\delta t} - \lambda \right] t = 0$$

$$t \geq 0,$$

thus, besides the amount of time allocated for consumption, the optimal distribution of working hours between legal and illegal activities should be in line with the following solution:

$$-\frac{w_i - w_l}{w_i - f_i - w_l} = \frac{pU'(X_a)}{(1-p)U'(X_b)}$$

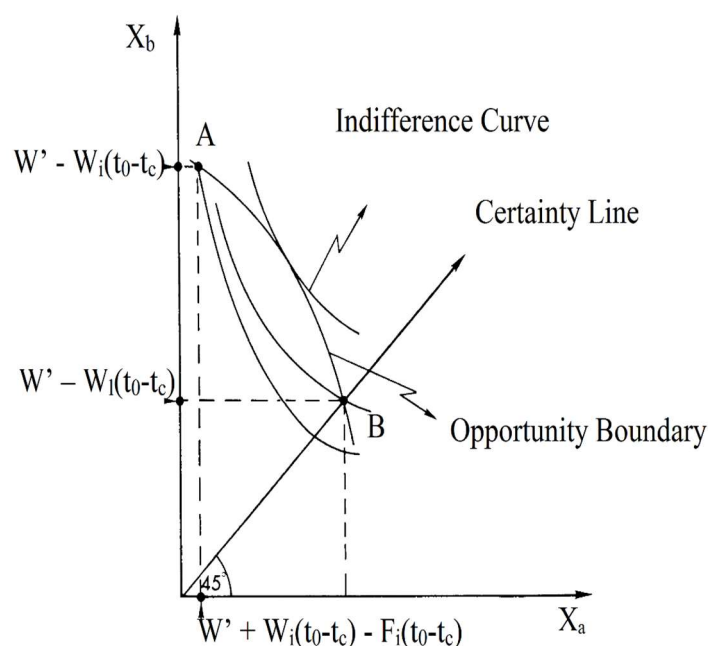


Figure 1. Combination of legal and illegal activities

(Source: Ehrlich, 1973)

In Corchón's model, the increase of d penalty rate does not affect Mp^* , but it positively affects Mg^* , that is, the rate of increase is Pareto-optimal. The expected utility of a P citizen is the same as if he were paying the tax due correctly, and taxation would not be limited by the avoidance. In Ehrlich's model, we can see that the absolute precondition for entering into illegal activity is that the absolute slope of the rationality limit exceeds the absolute slope of the indifference curve where full time is spent on legal activity. Expected marginal revenue for illegal activities should not exceed the amount available of non-legal activity. This is a necessary precondition for entering into illegal activity of people trying to avoid or prevent risk. The classical Becker analysis - the Ehrlich model described above - illustrates crime as a decision-making problem by analyzing criminal activity at the level of individuals using the traditional tools of microeconomics. However we obviously cannot get a full picture of the phenomenon if the study stops at the limit of the individual's decision-making. A broader approach is appropriate as the causes and consequences of crime go beyond the individuals' decision-making horizon (Hámori, 1998).

Possibly drawn conclusions of the classical models

The choice of the variables in the classical model is very logical, and the assumed direction of the effect of these variables on tax behavior is generally based on reasonable theoretical considerations. The results of the empirical tests that test the theory sometimes do not point to the expected direction and often contradict each other. In the research of this topic, the "classical model" of the individual taxation decision on risk is transformed into increasingly new and more complex approaches, enabling the emergence of conflicts between individuals and social interests and tax heterogeneity, taking into account the different motivations of the different actors and the psychological aspects determining the tax behavior (Semjén, 2017).

Based on the economic theory of criminal behavior, the rate of taxes paid or suffered by citizens depends on a simple cost-benefit calculation. As many studies have shown, these models identify important factors but can not explain the behavior of taxpayers (Kirchgässner, 2010). In order to properly pay their taxes, individuals need motivation that contains more than simple economic calculations, other factors also play an important role.

In recent years, more research has been exploring that values, social norms and attitudes differ from country to country, and that these differences have a measurable impact on economic behavior. One area where such studies are particularly important is tax compliance (Alm & Torgler, 2005). Tax compliance seems to depend on a number of factors, ranging from deterrence from individual farms, level of fines and revision rates (combined with available risk aversion estimates) in most countries. The deterrence models, however, indicate too much leniency and predict only a small amount of tax evasion.

The existence and direction of the relationship between the tax rates and the lawful tax payers' behaviour is a controversial issue in the literature, but not to the same extent as the relationship between earnings and the lawful conduct. In the assessment of the impact of tax rates, the standard model itself is ambivalent, and empirical literature does not give a clear picture either, although empirical studies show that there is substantially more evidence of the negative effect of high tax rates than to its opposite (Semjén, 2017). "Big tax reforms and tax cuts do not necessarily reduce the size of the hidden economy, but rather stabilize the given level. Many studies have shown a positive relationship between the size of the hidden economy and the increase in tax burden, but in the case of tax cuts the relationship remained insignificant" (Schneider, 1997). Also, in Frey and Feld's study (2002), the basic model of the tax evasion is Allingham and Sandmo

(1972), based on maximizing the expected usefulness that is not particularly good in subjective econometric analysis, shows too few tax evasion and econometric estimates of parameters on probability of leakage and the level of fines is not as effective as it was hoped for. Therefore, it is advisable to extend these models with different variations.

We must, of course, the companies like, first of all, reduce tax and contribution burdens, and to lessen controls and punishments by hardening the hidden / black economy (Belyó, 2008). The classic way of reducing the hidden economy is to increase the extent of punishment. This solution seems fairly obvious and is widely used. At the same time, there are models of game theory that the penalty does not affect the offense (Semjén et al., 2001). The probable punishment in the case of tax evasion depends on the likelihood of getting caught and not on the size of the levied punishment. Excessive punishment can, however, reduce marginal deterrence. If people are being severely punished for less tax evasion, they are more likely to commit higher tax evasion because the marginal punishment for larger fraud is smaller. Government and public administration can reduce the tax rate and regulatory intensity, thus reducing the strength of the motive to engage in a hidden economy. In other words, efforts should be made to approach the socially optimal rate of taxation and regulation. In the study of Cummings et al. (2004) we find that an increase in the likelihood of controls and the level of fines will increase compliance with the tax liability, but the impact of tax rates is not clear.

In 2006, Schneider and Torgler carried out a unique study of citizens' tax morals in three multicultural European countries, Switzerland, Belgium and Spain, based on World Values Survey data. The results show that the deterrence factors do not have a significant impact on the tax attitudes, and the coefficient of penalties in most cases shows negative significance, and the tax rate has no remarkable effect on the tax morale. According to Fochmann et al. (2025), individuals' taxpaying decisions are influenced not only by the perceived probability of audits and penalties but also by psychological and social factors such as norms, a sense of fairness, and moral convictions. Emotions - particularly positive emotions - play a dual role: they may encourage norm compliance, yet they may also heighten sensitivity to perceived social injustice.

Mohammed and Tangl's (2024) study highlights that those who perceive weak public services, demonstrate low levels of political activity, and lack trust in the tax authority are more likely to interpret taxes as coercive instruments or forms of punishment. In contrast, individuals who experience high-quality public services, are more politically active, and trust the tax authority are more inclined to view taxation as a social

contribution or service. Enhancing trust, improving the quality of public services, and fostering political participation are therefore essential in the operation of tax systems and in communication with citizens. A reliable tax authority that operates with integrity is crucial for the functioning of a democratic state, especially where the political system is fragile and citizen trust is precarious (Bartha & Boda, 2024). Furthermore, Castañeda-Rodríguez (2025) also finds that tax morale is primarily determined by institutional trust, satisfaction with public services, and perceived tax fairness. Conversely, corruption and the questioning of the state's general legitimacy weaken tax morale, particularly among younger and lower-income groups. Thus, effective tax policy is not only a technical matter but also a moral and social issue, which requires strengthening citizens' trust and engagement. Accordingly, tax compliance is not merely a question of economic or moral considerations but is deeply intertwined with political identity and the relationship between citizens and government (Cullen et al., 2021).

Summary

Comparing the hypotheses with the researchers of the subject, we can see that, despite according to the classic models, control probability has a positive effect on taxpayers' compliance, and the degree of punishment also has a deterrent effect - the positive impact of control probabilities is also supported by empirical studies, while the degree of punishment is less clear. There are also significant contradictions about the impact of income and tax rates. Motivations behind economic and investment decisions are not always rational, classical economics models identify important factors, but they can not explain the behavior of taxpayers, so it is expedient to extend researches to sociology and behavioral fields as well.

Since the focus of my analysis is on economic actors, individual decision-makers, and the behavioral features, decision alternatives, and economic reactions of these economic actors, it is certainly necessary to expand classical economics with sociological and behavioral territories. "To understand how economies work, how to control them, and to prosper, we need to understand the conceptual schemes that animate people's ideas and feelings, that is, spiritual factors. We will never really understand important economic events unless we are faced with the fact that these are the reasons for the nature of things mostly psychological" (Akerlof & Shiller 2011). Belyó (2004) conducted studies on tax morale. The majority of businesses (57%) who saw the possibility of reducing the share of the hidden economy mentioned their proposals reducing the tax rate as a solution, while 31 percent considered the reduction of the contributions

to be important. Of the 17 percent of the larger controls, 11 percent of the most unbiased controls are waiting for the hidden economy to fall back. A further 7 percent of those who do not expect more stringent controls, but also the increase in punishment items, that is, the harder sanctioning of economic violations. At the same time, it is important to point out that most of these companies responding to this issue expect a reduction in the burden on companies by tightening sanctions, meaning that the two measures are considered effective. According to Belyó (2012) white and hidden economies exist side by side, but we do not know too much about this "common being", and it is even harder to track how it works and what behavioral rules prevail in this relationship. Due to the parallel existence, several studies have attempted to integrate the hidden economy into macroeconomic models in order to handle better the hidden economic model elements. Fleming argues strongly that not all hidden economic activities should be universally prevented (Fleming et al., 2000). Furthermore, empirical research by Schneider (1998) has shown that 66% of the income generated in the hidden economy is practically spent in the white sector, thus having a positive impact on economic growth and providing an indirect tax revenue. Furthermore, Belyó (1999) points out that in developing countries where unemployment is high, unofficial activities are necessity for the population staying alive, and they may never disappear to 100%. „It is obvious that there is an optimum degree of the hidden economy in every economy, where it is not worth to increase further and the fiscal expenditures on tax audits should not be further reduced" (Szántó & Tóth 2001). Although the existence and growth of the hidden economy, it can have both beneficial and disadvantageous consequences as it is the most productive, most entrepreneurial, most innovative sector. It should not be forgotten that it operates illegally and its tolerance undermines tax discipline, and its rise can lead to the complete collapse of the economy, legality and social order - and the declining state revenues due to tax evasion would be a major problem in financing public goods and public services and a self-generating process. Combating tax evasion and the hidden economy and reducing their scale is an important policy goal for every country.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

Funding

* Project no. MEC_SZ 149231 has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the MEC_24 funding scheme.



PROJECT
FINANCED FROM
THE NRDI FUND

Conflict of Interest

* The authors declare that they have no conflicts of interest

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Management Economics and Business (www.iconmeb.net) held in Budapest/Hungary on August 28-31, 2025

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ENERGY AWARENESS 4.0 – DIGITAL SYNERGIES OF THE 7C MODEL AND ARTIFICIAL INTELLIGENCE FOR A SUSTAINABLE FUTURE

Abstract: The efficiency of the global energy transition is largely contingent upon the integration of renewable energy sources into advanced technical systems and the widespread adoption of energy-conscious consumer behavior. The rapid evolution of digitalization and artificial intelligence (AI) is fundamentally transforming the processes of energy production, distribution, and consumption, enabling real-time, data-driven decision-making and personalized consumer interactions. This study presents the theoretical foundations and practical applications of the 7C-AI Intelligent Intervention Framework. The framework integrates the seven dimensions of the 7C digital marketing model (context, content, community, customization, communication, connection, commerce) with AI's predictive analytics, real-time processing, and interaction optimization capabilities, supporting adaptive digital interventions aimed at enhancing energy awareness. The technical foundation is provided, among others, by smart grid architectures – intelligent, digitally controlled electricity networks that ensure real-time communication between producers, consumers, and energy storage systems. Smart grid systems employ sensor networks, IoT devices, and AI algorithms to enable continuous grid monitoring, two-way flows of energy and information, and the predictive optimization of energy management, thereby balancing the production fluctuations inherent to renewable energy sources. Aligned with the 7C model dimensions, the context and content components facilitate the user-friendly visualization and interpretation of real-time energy data; the community and communication elements foster public participation and attitude formation; the customization and connection dimensions enable personalized, smart device-integrated interactions; while commerce leverages digital incentives and gamification to strengthen long-term engagement. The research offers a dual perspective: it provides a theoretical framework for linking sustainability communication with digital marketing in the context of renewable energy, and it demonstrates practical opportunities for integrating artificial intelligence with 7C-based digital solutions to advance energy awareness and promote the broader acceptance of renewable energy sources.

Keywords: 7C model, artificial intelligence, energy awareness, Smart grid systems, digital communication, sustainability communication

JEL: D83, Q20, Q29

1. Introduction

Societies across the globe are confronted with increasingly complex challenges, among which climate change and the sustainability of energy supply have emerged as particularly urgent concerns (Andrade et al., 2025). These challenges are closely interrelated with labor market dynamics and economic crises, as energy and climate policy transformations exert direct impacts on employment and the structural composition of regional economies (Molnár et al., 2024). Rising energy demand, dependence on fossil fuels, and escalating environmental pressures have compelled governments and economies to reconsider traditional patterns of energy use (Varga & Csiszárík-Kocsir, 2024). International climate policy commitments – most prominently the Paris Agreement – underscore that the global energy transition cannot be deferred: it must simultaneously safeguard energy security, economic competitiveness, and environmental sustainability (Evica Delova-Jolevska et al., 2024). It has been increasingly emphasized that the success of this transition depends not only on technological innovation but also on the strengthening of energy-conscious behavior and active consumer participation (Ágnes Csiszárík-Kocsir & Varga, 2023). The global energy transition can therefore be regarded as one of the greatest challenges of recent decades, the success of which is determined as much by societal engagement as by technological progress. Within this context, the application of circular economy principles is indispensable, as sustainability requires the reuse of resources and the reduction of natural resource consumption (Kozma et al., 2021b). The integration of renewable energy sources, the reinforcement of consumer energy awareness, and the promotion of sustainable lifestyles are all recognized as key levers in mitigating climate change and laying the foundations for a sustainable future. Empirical findings further demonstrate that the energy crisis and social media communication channels have exerted direct influence on consumer attitudes and openness toward renewable energy adoption (Fűrész & Szeberényi, 2024). The rapid digitalization of the energy sector, coupled with the accelerating development of artificial intelligence (AI), is fundamentally transforming the processes of energy production, distribution, and consumption. Smart grids, IoT devices, and real-time data processing have enabled consumers to evolve from passive recipients to active participants within energy markets (Balamurugan et al., 2025). Beyond their role in ensuring grid stability, AI-driven predictive analytics have been shown to influence consumer behavior by delivering personalized feedback and digital incentives. However, the strengthening of energy awareness constitutes not only a technological but also a communicative challenge. At this juncture, the 7C

model of digital marketing (context, content, community, customization, communication, connection, commerce) becomes particularly relevant, as it provides a structured framework for reshaping consumer interactions. The integration of this model with AI-based solutions offers the potential for adaptive, personalized, and community-driven interventions that promote sustainable energy use.

The objective of this research is to present the 7C-AI Intelligent Intervention Framework and, through empirical analysis, to evaluate consumer openness toward various digital communication solutions. The study seeks to make a dual contribution: first, by providing theoretical integration between sustainability communication and digital marketing; and second, by offering practical recommendations for energy providers and policymakers to facilitate the broader acceptance of renewable energy sources.

2. Literature review

Within the field of energy transition research and the broader sustainability discourse, increasing scholarly attention has been devoted to consumer behavior and the associated communication and technological innovations. In the new EU member states, renewable energy sources have gained prominence not only as instruments for achieving sustainability targets but also as drivers of energy independence (Meyer et al., 2021). A growing body of literature has underscored that technological improvements alone – such as the expansion of renewable energy capacities – are insufficient; rather, the success of the transition is contingent upon social acceptance, behavioral change, and the strengthening of energy-conscious mindsets (Zaman, 2023). The advancement of digitalization and artificial intelligence (AI) has further been recognized as opening new pathways for the personalization of consumer interactions, the facilitation of community engagement, and the fostering of sustainable attitudes.

Among the conceptual frameworks developed for digital marketing and consumer communication, the 7C model has emerged as particularly influential. It delineates seven distinct dimensions – context, content, community, customization, communication, connection, and commerce (Yang, 2016) – which together offer a comprehensive lens for analyzing consumer engagement in the digital environment. Subsequent analyses, particularly those employing web-based analytical tools, have provided empirical support for its applicability in digital contexts (Szeberényi, 2024). Within this framework:

- Context and content ensure the provision of relevant and intelligible information;

- Community and communication facilitate social interaction, dialogue, and collective learning;
- Customization and connection enable personalized, digitally integrated consumer experiences;
- Commerce provides the mechanisms of incentives and gamification that sustain long-term commitment.
- In the specific domain of sustainability communication, the 7C model acquires particular relevance as it enables technological innovations to be framed not merely as information dissemination but as experiential and socially embedded learning processes (Lim et al., 2024).

2.1. Artificial intelligence in the energy sector

Artificial intelligence constitutes one of the most rapidly evolving domains within the digitalization of the energy sector, increasingly recognized for its capacity to optimize processes across both the production and consumption sides (Duan et al., 2025). Its applications span a wide spectrum, from resource management and grid stability to the detailed analysis of consumer behavior. In this context, Wang et al. (2023) have highlighted AI's contribution to load analysis, forecasting, and management based on smart meter data, while Szczepaniuk and Szczepaniuk (2023) have provided a comprehensive synthesis of AI functions throughout the energy system, including production, consumption, and storage.

Another critical contribution of AI lies in its capacity for real-time data processing, which has been shown to advance grid management and fault detection. Data streams from digital sensors and IoT devices enable machine learning algorithms—particularly hybrid models—to make immediate operational decisions such as load balancing and the rapid localization of outages. These functionalities substantially enhance network stability and reliability (Almasoudi, 2023). At the consumer interface, AI has increasingly been deployed to strengthen engagement. Through digital assistants, chatbots, and smart applications, energy providers are able to establish more direct and interactive relationships with their customers. Such systems have not only accelerated customer service processes but have also facilitated the provision of personalized recommendations that encourage energy-conscious decision-making (Szeberényi et al., 2024; Bozsik et al., 2025). The advent of smart grid systems has likewise introduced a qualitatively new paradigm in energy distribution. These digitally controlled electricity networks, founded on the synergy between AI and IoT, process real-time data and enable two-way communication between producers, consumers, and storage units. Supported by AI, smart grids have been demonstrated to balance fluctuations in renewable energy generation, predict peak demand, and optimize network operation (Fathollahi, 2025). Furthermore, models based on Representative Concentration Pathway (RCP) scenarios have demonstrated that climate change

significantly affects photovoltaic system performance, thereby reinforcing the critical role of AI-driven predictive models in maintaining system balance (Bozsik, Szeberényi & Bozsik, 2024). These findings are consistent with broader analyses that have underscored the necessity of AI-based predictive management for mitigating production variability in renewable energy systems (Bozsik et al., 2024).

Taken together, the literature indicates that artificial intelligence performs a dual role in the energy sector: it enhances the technical efficiency and reliability of energy supply on the one hand, while simultaneously creating a digital environment conducive to the development of consumer energy awareness and educational interventions on the other.

2.2. 7C and AI in the context of energy awareness

The enhancement of consumer energy awareness constitutes not only a technological but also a societal and communicative challenge. The dimensions of the 7C model – content, customization, community, communication, context, convenience, and connection – provide a framework within which the role of AI in shaping consumer attitudes can be meaningfully interpreted. The significance of the model lies in its conceptualization of communication not merely as the transfer of information but as an interactive and collective learning process that, through digital channels, is capable of influencing consumer decisions and social norms. This perspective is corroborated by studies on corporate sustainability practices, which highlight the critical importance of communication and stakeholder engagement (Kozma & Bosnyák-Simon, 2022b). Empirical research has likewise confirmed the effectiveness of social media and online platforms in shaping attitudes toward renewable energy adoption (Fűrész et al., 2024).

Survey results indicate that respondents perceive digital and visual channels as particularly effective in fostering energy awareness (Sun & Xing, 2022). Social media advertisements (mean = 3.94; SD = 1.10) and television programs (mean = 3.92; SD = 1.04) received the highest evaluations, whereas newsletters (mean = 2.68; SD = 1.28) and printed materials (mean = 2.50; SD = 1.22) were rated the lowest. These findings clearly suggest that the prominence of digital, visual, and community-based content reinforces the community and communication dimensions of the 7C framework. Age group differences further enrich these insights: younger respondents (18–25 years) rated social media (mean = 4.46) and influencer videos (mean = 4.31) significantly higher than older respondents (46–55 years: social media mean = 3.68; influencers mean = 3.39). Conversely, older participants expressed greater openness toward educational content on energy providers' websites (mean = 3.60) and the use of mobile applications (mean = 3.51). Within this context, AI demonstrates its adaptive capacity by tailoring communication strategies to distinct

consumer segments: visual and community-based content for younger generations, and credible, expert-driven information for older ones. The international literature similarly substantiates AI's behavioral and educational potential, emphasizing that sustainability integration is increasingly expected not only at the consumer level but also within corporate strategies (Kozma & Bosnyák-Simon, 2022b). Practical evidence further supports this: the gamified approach of the Smart2B project has demonstrably increased user engagement and energy awareness (Huseynli, 2024). Likewise, the Swiss Social Power study showed that a mobile application achieved significant short-term energy savings, underscoring the importance of adaptive, AI-based feedback (Cellina et al., 2023; Shahzad et al., 2023). In addition, serious games – such as EnergyLife or Energy Cat – have proven effective in reinforcing energy-conscious behavior in the long term by leveraging community norms (Gangoellis et al., 2021).

Collectively, these findings demonstrate that AI strengthens multiple dimensions of the 7C model:

- In the content dimension, it provides personalized educational materials;
- Through customization, it adapts recommendations to individual consumption patterns;
- At the community level, it fosters social norms and collective learning processes;
- Within communication, it optimizes message alignment across channels and target groups.

It can therefore be concluded that the development of consumer energy awareness is inconceivable without the integration of AI. Algorithms not only enable more effective communication but also establish adaptive systems capable of supporting the long-term adoption of sustainable energy management practices.

2.3. Smart grid systems and energy awareness

Smart grids represent one of the key infrastructural pillars of the energy transition, fundamentally transforming the production, distribution, and consumption of energy. These digitally controlled electricity networks integrate sensors, IoT devices, big data analytics, and artificial intelligence (AI)-based algorithms to enable real-time communication and adaptive cooperation among producers, consumers, and storage units (Taherdoost, 2024).

The operation of smart grids is defined by three fundamental characteristics:

- Bidirectional energy and information flows, which allow consumers not only to be passive actors but also active participants in the energy system. Through the integration of household-scale solar

panels, energy storage, and electric vehicles, consumers become both buyers and producers (“prosumers”), directly influencing the functioning of the grid (Naus et al., 2024).

- Real-time network monitoring, which, with the help of sensors and data-processing systems, enables rapid fault detection and repair, load optimization, and improved system reliability. AI-driven fault detection and self-healing algorithms can significantly reduce the duration and costs of outages (Goyal, 2025).
- Integration of renewable energy sources, which remains one of the greatest challenges to grid stability. The production fluctuations of solar and wind energy can be forecasted and balanced through AI-based predictive management, thereby ensuring the continuous alignment of supply and demand (Ejjiyi et al., 2025).

Energy market interconnectedness and regional interactions also influence the functioning and stability of smart grids, as confirmed by empirical research (Szeberényi & Bakó, 2023). However, smart grids should not be viewed solely as technological innovations. Increasingly, they are conceptualized as socio-technical systems that fundamentally reshape consumer energy-use practices. Through bidirectional communication, consumers can actively participate in energy management: they receive real-time feedback on their consumption, follow personalized recommendations, and make direct decisions (e.g., timing of energy use, application of local renewables) that contribute to sustainability (Gangale et al., 2013). For energy providers, smart grids open new opportunities for communication. By analyzing consumer data and applying AI, targeted educational campaigns can be designed to support sustainable decision-making. In this context, enhancing consumer energy awareness is not only an individual but also a collective interest, closely linked to ensuring grid stability and a sustainable energy transition (Bakare et al., 2023; Siano, 2013). At the same time, sustainability is becoming increasingly integrated into financial supervisory practices, as climate risks and green investments are closely tied to the transformation of the energy sector (Gyura et al., 2023). As a result, smart grids embody both technological progress and social innovation: while enhancing the reliability and efficiency of energy systems, they also contribute to shaping consumer energy awareness and create new communicative and educational dimensions in the relationship between energy providers and users (Rajaperumal & Columbus, 2025).

3. Material and methods

The objective of the research was to examine the extent to which consumers are open to the use of different digital communication tools in strengthening energy awareness, as well as to identify which demographic factors influence the acceptance of these channels. Data collection was conducted through an online questionnaire in the autumn of 2024, with voluntary and anonymous participation. Respondents represented a diverse range of ages, professional backgrounds, and regions, thereby reflecting a broad spectrum of consumer perspectives. Participation was voluntary and anonymous, with informed consent obtained prior to the survey. No personal identifiers were collected. The questionnaire consisted of four thematic sections. Respondents evaluated, on a five-point Likert scale, the perceived effectiveness of various communication solutions in promoting renewable energy sources. These included professional articles and educational content on energy provider websites, mobile applications, online advertisements, social media platforms, and printed materials. In addition, the questionnaire asked whether respondents were interested in educational content produced by major energy providers, and whether they followed energy providers on social media – if so, which companies and on which platforms. Demographic variables such as gender, age, place of residence, and professional field were also included. Data analysis began with descriptive statistics on the evaluation of communication tools, followed by the examination of demographic group differences using cross-tabulations and simple comparative methods. Beyond descriptive statistics, group differences were examined using one-way ANOVA for age cohorts and independent-samples t-tests for gender. Effect sizes are reported as η^2 (ANOVA) and Hedges' g (t-tests), with 95% confidence intervals.

The aim was to identify which communication channels are most suitable for shaping attitudes toward renewable energy, and how these preferences relate to respondents' socio-demographic characteristics. The final sample comprised $N = 417$ respondents. Gender distribution was 54.8% female and 45.2% male. In terms of age, the sample predominantly represented middle-aged groups: 46–55 years: 30.0%, 36–45 years: 26.3%, followed by 26–35 years: 18.9%. Younger and older cohorts were represented to a lesser extent (18–25 years: 6.0%, 56–65 years: 8.3%, 65+ years: 4.1%). Geographically, the sample showed a clear dominance of Budapest and its metropolitan area: 44.7% lived in Pest County and 28.1% in Budapest, with smaller proportions from Fejér (8.3%), Győr-Moson-Sopron (4.1%), Komárom-Esztergom (3.7%), and other counties. Regarding occupational background, the largest group comprised those employed in administrative/office positions (13.8%), followed by respondents working in banking, insurance, and brokerage (8.3%), management (6.9%), and IT development (6.9%). Significant proportions were also

represented in finance and accounting (6.5%), healthcare and pharmaceuticals (6.0%), engineering (6.0%), and IT operations/telecommunications (6.0%).

4. Results

The aim of the research was not merely to explore respondents' attitudes towards digital communication tools but also to interpret these preferences within the framework of the 7C model and the potential applications of artificial intelligence. The dimensions of the 7C model – particularly content, community, communication, and connection – are directly related to the tools evaluated by the respondents. Identifying the most effective channels provides guidance as to where AI-supported systems (such as personalized content recommendation algorithms, social media interaction monitoring, or educational platforms) can generate the greatest added value. Consequently, the findings are not purely descriptive; rather, they serve as a basis for the adaptive development of digital interventions and for the targeted design of AI-driven energy awareness programs. Moreover, positioning the results within the 7C–AI framework highlights the dual role of digital tools: they act not only as information carriers but also as mediators of behavioral change. By linking communication channels to specific consumer segments, the research underscores how AI can tailor interventions to demographic, social, and contextual characteristics, thereby increasing their relevance and effectiveness. This perspective also implies that digital strategies should be dynamic and iterative, continuously refined through data-driven feedback loops. In this way, the integration of the 7C model and AI does not simply enhance the dissemination of sustainability messages but establishes an interactive system of learning and adaptation, fostering long-term shifts in energy-related attitudes and practices.

Based on respondents' evaluations, it is evident that digital and visual communication channels constitute the most effective means of enhancing energy awareness. As shown in Figure 1, social media advertisements received the highest level of support ($M = 3.94$; $SD = 1.10$), closely followed by television programs ($M = 3.92$; $SD = 1.04$) and online advertisements ($M = 3.78$; $SD = 1.20$). Similarly, commercial videos ($M = 3.72$; $SD = 1.13$) and influencer-generated video content ($M = 3.53$; $SD = 1.24$) were also rated highly, highlighting their importance in engaging younger target groups through visual and personalized modes of communication (see Figure 1).

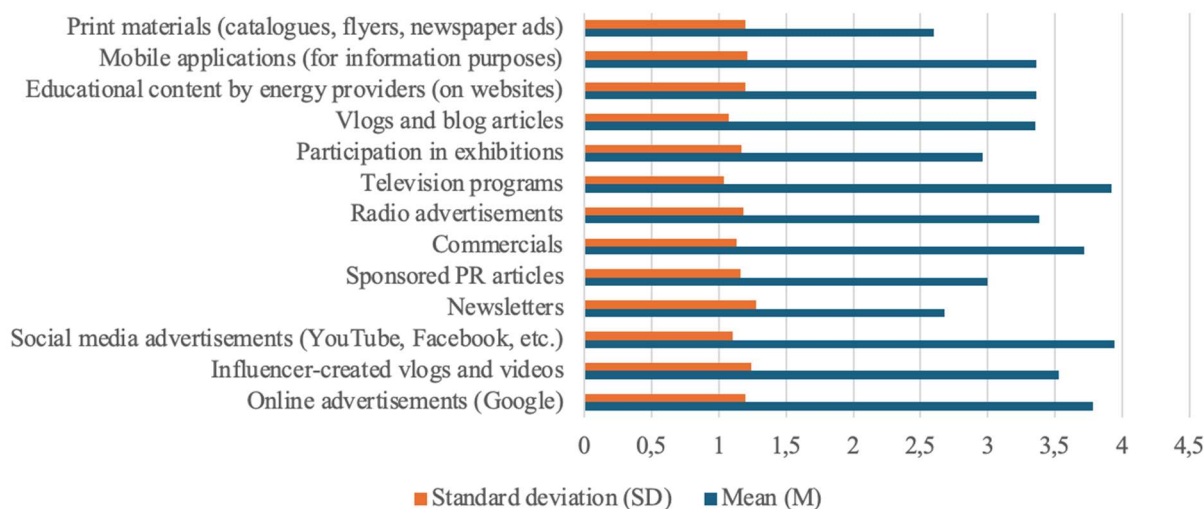


Figure 1. Evaluation of the effectiveness of communication tools (mean, standard deviation)

Source: Author's own elaboration based on primary research, 2024, n = 417

Based on the data presented in Figure 1, radio advertisements ($M = 3.38$; $SD = 1.18$), blogs and vlogs ($M = 3.35$; $SD = 1.07$), educational content on the websites of energy providers ($M = 3.36$; $SD = 1.20$), and mobile applications ($M = 3.36$; $SD = 1.21$) fall within the medium range of perceived effectiveness. These channels are regarded as relevant by respondents, yet they do not achieve the same level of impact as mass communication formats. In contrast, more traditional tools – such as professional PR articles ($M = 3.00$; $SD = 1.16$), participation in exhibitions ($M = 2.96$; $SD = 1.17$), newsletters ($M = 2.68$; $SD = 1.28$), and printed materials ($M = 2.60$; $SD = 1.20$) – received considerably lower evaluations, indicating that they are less effective channels for the promotion of renewable energy. The results therefore clearly demonstrate that digital, visual, and community-oriented forms of content are prioritized. These forms align with the community and communication dimensions of the 7C model and are particularly suitable for the implementation of AI-assisted, personalized energy awareness campaigns.

While the aggregated data reveal the general perception of different communication tools, it is of particular importance to examine how these preferences vary across distinct social groups. Generational differences in digital and media literacy are especially relevant, as younger cohorts' communication practices diverge significantly from those of older age groups. Owing to differences in lifestyle and openness to technology, certain communication channels may prove more effective for particular demographics. To test these

generational patterns statistically, one-way ANOVAs were conducted with age group as the independent variable (Table 1).

Dependent variable	F(5, 194)	p	Partial η^2
Online advertisements (Google)	0.82	.539	.020
Social media advertisements	1.41	.222	.035
Sponsored PR articles	0.85	.516	.021
Radio advertisements	0.90	.486	.023
Participation in exhibitions	1.39	.229	.035
Energy provider websites (educational content)	1.40	.227	.035
Print materials (catalogues, flyers, press ads)	0.32	.901	.008

Table 1. Results of one-way ANOVA by age group

Note. $df = (5, 194)$. Levene's test indicated homogeneity of variances (all $ps > .05$)

Source: Author's own elaboration based on primary research, 2024, $n = 417$

The ANOVA results indicate that none of the examined communication channels showed statistically significant age-group differences (all $ps > .05$). The effect sizes were small ($\eta^2 = .01-.04$), suggesting that age only minimally influences the perceived effectiveness of communication tools.

The comparative analysis of age groups nevertheless reveals clear descriptive generational patterns in the evaluation of communication tools supporting energy awareness. Respondents aged 18-25 display the strongest overall engagement with digital channels: social media ($M = 4.46$) and influencer videos ($M = 4.31$) received the highest ratings of all age groups, while educational content by energy providers ($M = 3.54$) and mobile applications ($M = 3.31$) were also positively assessed. Even print materials ($M = 2.85$) achieved relatively higher ratings in this cohort compared to older generations. This comprehensive openness is indicative of a digital-native generation that is highly receptive to diverse forms of content, particularly those characterized by visuality, interactivity, and social embeddedness.

Among respondents aged 26–35, digital platforms continue to dominate. Social media ($M = 4.00$) and influencer videos ($M = 3.66$) remain the most preferred channels, though scores for educational content ($M = 3.20$) and mobile applications ($M = 3.20$) suggest a slightly more pragmatic orientation compared to the youngest group. This indicates that while the 26–35 cohort remains highly digitally engaged, their preferences begin to shift toward more informational and utility-driven content. The 36–45 and 46–55 cohorts demonstrate a similar balance between social and educational communication tools. Ratings for social media ($M = 4.00$ and $M = 3.96$, respectively) and influencer videos ($M = 3.66$ and $M = 3.67$) remain strong, but educational content ($M = 3.20$ and $M = 3.15$) and mobile applications ($M = 3.20$ and $M = 3.37$) occupy a relatively larger role than among younger groups. These cohorts appear to value a hybrid approach that combines the outreach potential of digital platforms with the practical credibility of institutional information. By contrast, respondents aged 56–65 exhibit a distinct preference for more traditional and informational formats. While social media ($M = 3.68$) and influencer videos ($M = 3.39$) maintain relevance, educational content ($M = 3.60$) and mobile applications ($M = 3.51$) surpass these channels in perceived importance. This reflects a shift toward more structured and explanatory communication tools, where digital familiarity is combined with a heightened demand for clarity and reliability. The 65+ cohort demonstrates the most pronounced divergence from younger generations. While social media ($M = 3.78$) remains moderately important, influencer videos ($M = 2.33$) record the lowest score across all groups, indicating minimal receptivity to personality-driven content. Conversely, educational content ($M = 2.78$), mobile applications ($M = 2.89$), and print materials ($M = 2.89$) achieve relatively balanced but modest evaluations, suggesting that older consumers require communication tools that are straightforward, user-friendly, and anchored in institutional credibility.

These generational differences underscore the critical importance of tailoring energy-awareness communication strategies to demographic profiles. Within the framework of the 7C model, younger cohorts engage strongly with the *community* and *communication* dimensions through social media and influencer-based channels, while older cohorts respond more favorably to the *content* and *customization* dimensions, particularly when information is structured, educational, and practically oriented. Artificial intelligence provides significant opportunities in this context by enabling the dynamic segmentation of audiences and the personalization of messages. AI-based recommender systems can identify which content formats resonate most with each age group and deliver targeted, adaptive communication strategies. Such personalization not only enhances the effectiveness of energy-awareness campaigns but also increases the likelihood of fostering sustainable behavioral change across diverse demographic groups. The results provide clear evidence that

effective communication on energy awareness cannot rely on uniform messages. Artificial intelligence offers personalization opportunities that enable messages to be adapted in both content and format to the specific needs of different audience groups. This is directly linked to the *content* and *customization* dimensions of the 7C model, as effective education and behavior change can only be achieved if communication reaches the audience with appropriate content and in a suitable format. In addition to communication channels, an equally important consideration concerns the types of content that consumers perceive as relevant in relation to renewable energy and energy awareness. Since the effectiveness of message reception is strongly shaped by attitudes toward content formats, the study also examined preferences for different types of content. The results reveal that preferences vary significantly not only by age but also by gender, further underscoring the necessity of personalized communication. Figure 2 presents which types of content respondents favored and the divergent patterns across age groups.

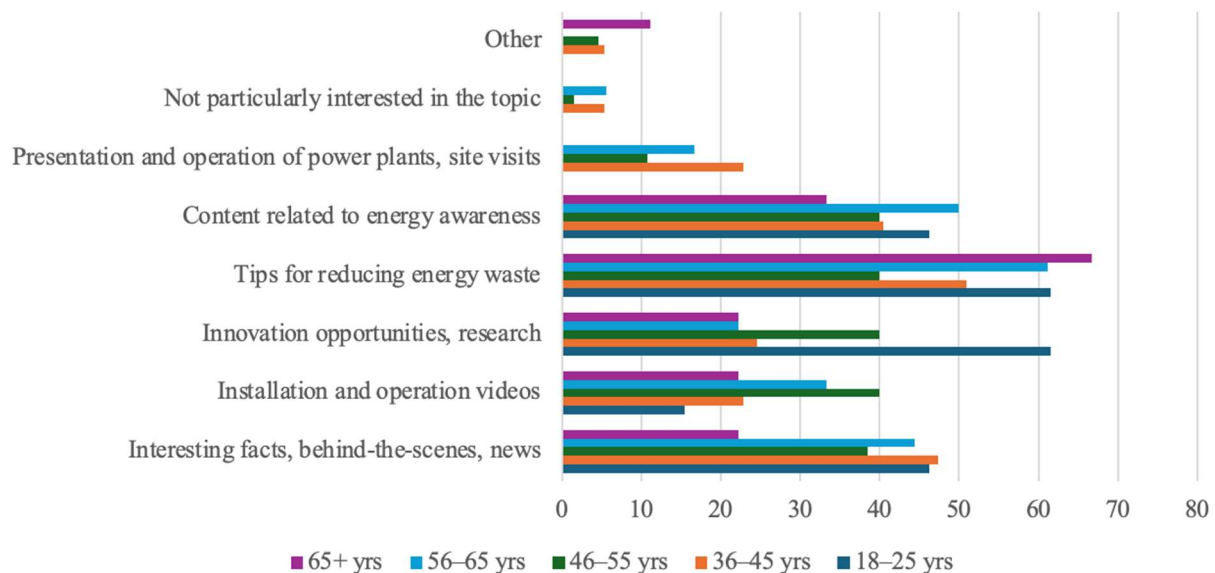


Figure 2. Distribution of content type preferences by age group (%)

Source: Author's own elaboration based on primary research, 2024, n = 417

Based on the data presented in Figure 2, interest in specific content types exhibits marked variation across age groups. Among respondents aged 18-25, a distinctive pattern emerges: all participants (100%) expressed interest in each of the five principal content types – interesting facts, installation and operation videos, innovation opportunities, tips for reducing energy waste, and general energy awareness content – while none

selected options such as power plant visits, indifference, or “other.” This comprehensive openness likely reflects the digital nativeness of this cohort, whose familiarity with diverse content formats and receptivity to novel communication approaches facilitates engagement across multiple types of information. Among respondents aged 36-45, practical information was most salient: tips for reducing energy waste (50.9%) and content related to energy awareness (40.4%) received the highest proportions of preference. By contrast, technology- and operation-oriented content – such as innovation opportunities (24.6%) and installation or operation videos (22.8%) – were considerably less frequently selected. This indicates that individuals in this cohort tend to prioritize practical and educational information over technical details. The preferences of respondents aged 46–55 appear more evenly distributed. In this group, tips, energy awareness content, and innovation opportunities were all selected by approximately 40% of participants. Demonstration videos related to operation and installation also received 40%, yet the overall distribution suggests that technological and professional content does not stand out markedly compared to more practice-oriented formats. Among respondents aged 56-65, the demand for directly applicable and educational content is particularly pronounced: 61.1% selected tips, and 50% selected energy awareness content. In contrast, interest in operational and technology-focused material declines noticeably (installation videos: 33.3%; power plant presentations: 16.7%; innovation opportunities: 22.2%). A similar trend is evident among respondents over 65, where tips (55.6%) and energy awareness content (50.0%) dominate, while technological and operational content registers lower levels of interest (installation videos: 25.0%; innovation opportunities: 25.0%; power plant presentations: 12.5%). These findings highlight a consistent pattern: with advancing age, the relative appeal of technology-oriented and operational content decreases, while practical, educational material becomes increasingly valued. Such generational differences underscore the necessity of tailoring communication strategies to demographic characteristics. This tendency is closely aligned with the content and customization dimensions of the 7C model, which emphasize that effective energy-awareness communication requires age-specific content development. The integration of artificial intelligence provides further opportunities in this regard: AI-based systems are capable of analyzing audience preferences and generating personalized content strategies that respond to generational distinctions. By doing so, they enhance the likelihood of fostering and sustaining energy-conscious behavior over the long term. Moreover, an exclusive focus on age would be insufficient. Differences in content preferences also warrant a gender-based perspective, since gender significantly shapes patterns of information processing and the reception of communication messages. Previous research has indicated that men and women diverge in their receptivity to practical, educational material versus technologically detailed information. Figure 3

therefore illustrates the proportions in which different content types were considered relevant by male and female respondents, thereby contributing to the formulation of gender-sensitive communication strategies.

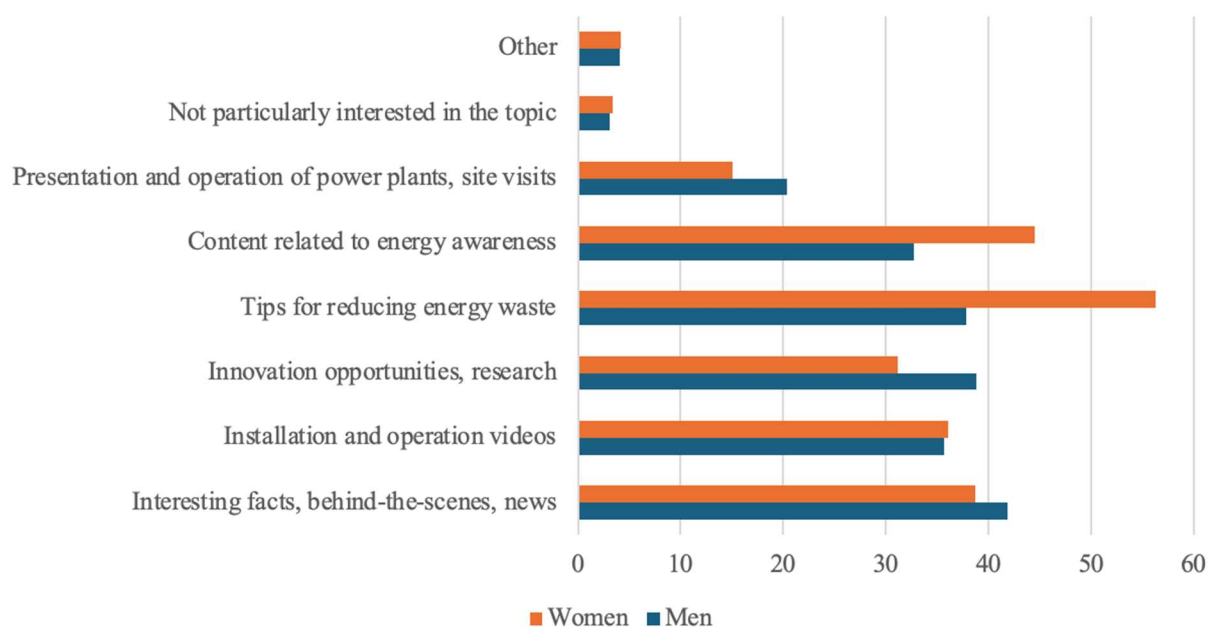


Figure 3. Distribution of content type preferences by gender (%)

Source: Author's own elaboration based on primary research, 2024, n = 417

Figure 3 illustrates the substantial differences in content preferences observed between male and female respondents. Among women, practical and educational content dominates: tips on reducing energy waste were selected at an exceptionally high rate (56.3%), compared to 37.8% among men. A similar difference is evident in relation to energy awareness content, where 44.5% of women, but only 32.7% of men, expressed interest. This suggests that women find directly applicable, everyday-life-related information significantly more relevant. By contrast, men show greater interest in technological and operational content. Innovation opportunities and research (38.8%), videos demonstrating installation and operation (35.7%), and the presentation of power plants (20.4%) highlight men's stronger orientation toward technological and professional materials. In addition, behind-the-scenes insights and updates (41.8%) were also more popular among men, indicating a higher receptivity to professional novelties. These gender-based differences clearly underline the necessity of differentiated communication strategies. While practical and educational content should be emphasized for women, men may be more effectively engaged through a focus on technological details, operational processes, and professional insights. The application of artificial intelligence offers the

opportunity to recognize and address these differences: AI can identify gender-based content preferences and tailor messages accordingly. This approach directly aligns with the content and customization dimensions of the 7C model, as it avoids generic, homogeneous messaging and instead delivers targeted strategies adapted to men's and women's distinct content consumption patterns. As a result, AI can enhance the effectiveness of energy awareness communication, shaping consumer behavior more successfully and fostering the adoption of sustainable energy use practices.

5. Conclusion

The aim of this research was to identify the most effective forms of communicating energy awareness, with particular emphasis on the evaluation of communication channels and content types, as well as the role of demographic factors such as gender and age. The findings revealed significant differences in consumer preferences across both genders and generations, and highlighted distinctions between the perceived effectiveness of digital and traditional communication tools.

The analysis of communication channels showed that digital platforms proved to be the most effective in enhancing energy awareness. Social media advertisements ($M = 3.94$; $SD = 1.10$) and online advertisements ($M = 3.78$; $SD = 1.20$) stood out among digital tools, indicating that wide reach, rapid information flow, and visual content play a central role. At the same time, traditional mass media tools also demonstrated their continued relevance: television programs ($M = 3.92$; $SD = 1.04$) received similarly high ratings, suggesting that television remains highly influential, particularly in ensuring broad societal coverage. By contrast, classical print materials ($M = 2.60$; $SD = 1.20$) and newsletters ($M = 2.68$; $SD = 1.28$) received substantially lower ratings, underscoring the growing dominance of digital channels. The assessment of content preferences revealed that consumers primarily value practical and educational content, whereas interest in technological and operational content is strongly differentiated by demographic characteristics. Among women, practical tips (56.3%) and energy awareness content (44.5%) achieved notably higher selection rates, while men showed stronger preferences for technology- and operation-oriented content, such as innovation opportunities (38.8%) and operational demonstration videos (35.7%). Generational differences emerged even more prominently: middle-aged (36-45 years) and older groups (56-65 years, 65+) showed an increasing preference for practical, everyday-use information (e.g., tips: 50.9-61.1%; energy awareness content: 40.0-50.0%), while interest in technological and operational content gradually declined with age. In contrast,

younger generations demonstrated a stronger inclination toward visual and technology-related content, reflecting their closer attachment to digital platforms. At the same time, several limitations should be acknowledged. The non-probability, online sample ($N = 417$) is geographically skewed toward Budapest and Pest County, which may limit the generalizability of findings to other regions. Older cohorts are under-represented, reducing statistical power for the 56-65 and 65+ groups. As the study relied on self-report measures, responses may have been influenced by social desirability and recall biases. Finally, the results reflect attitudes in autumn 2024 and may evolve with future media and technology trends.

In conclusion, the results suggest that energy awareness communication can only be implemented effectively through differentiated, demographically informed, and personalized strategies. While the advance of digital channels is evident, traditional media – particularly television – continues to play a decisive role in ensuring broad societal reach, thus justifying its place in the communication mix. The observed gender- and generation-based differences in content preferences highlight the necessity of audience-specific communication, for which artificial intelligence provides the appropriate technological foundation. Through AI, it becomes possible to automate content personalization, dynamically segment target groups, and improve the measurability and feedback of communication effects. This approach offers an integrated framework that not only fosters energy-conscious behavior but also contributes to the societal-level diffusion of sustainable energy practices.

6. Recommendations

The present research highlighted that the communication of energy awareness can only be effective if it is implemented through differentiated strategies tailored to specific social and demographic groups. The findings clearly demonstrate that both communication channels and content types are perceived differently across genders and generations. This implies that future research and practical development should move beyond uniform messaging and focus instead on the design of target group-specific communication frameworks. Future studies should validate the tendencies identified in this research by involving larger and more heterogeneous samples. This is particularly justified in the analysis of generational differences, as the number of respondents in the older cohorts (56-65 and 65+) was relatively limited. Broader data collection would provide a more accurate picture of how content consumption preferences evolve with age and which communication strategies are most effective in addressing the characteristics of different generations. It may also be worthwhile to conduct longitudinal studies, which would allow for tracking the temporal evolution

of energy awareness communication. Given the rapid development of digital media and artificial intelligence technologies, consumer preferences are subject to dynamic change. While cross-sectional studies offer valuable snapshots, they cannot capture long-term trends that are essential for understanding the sustainability of communication strategies.

The role of artificial intelligence in both future research and practical applications is of particular importance. AI-based solutions – such as predictive analytics, personalized recommendation systems, natural language processing (NLP) chatbots, or real-time analysis of social media data – provide opportunities for more accurate forecasting of consumer behavior and for the personalized delivery of messages. The integration of AI enables communication to respond in real time to audience needs, thereby enhancing the effectiveness and relevance of campaigns. This approach directly reinforces the practical application of the 7C model's content and customization dimensions, as messages become not only informative but also dynamically tailored. Another promising research avenue is international comparison, which may reveal the extent to which patterns in energy awareness communication are universal, and to what degree they are shaped by cultural factors. Such studies could contribute to distinguishing between globally valid communication strategies and locally, culture-specific approaches. Future research should also place greater emphasis on incorporating big data analytics and AI-driven tools, which enable real-time monitoring of content consumption patterns and the immediate fine-tuning of communication strategies. By analyzing social media activity, search trends, and digital interactions, researchers and practitioners can develop adaptive communication models that continuously align with societal needs and contextual factors.

Based on these insights, the most important recommendation is that both future research and practical development should focus simultaneously on the differentiated exploration of demographic characteristics, the understanding of long-term trends, and the practical integration of artificial intelligence. The combined application of these factors can establish a communication framework that is grounded in scientific evidence while ensuring practical applicability, thereby facilitating the broader societal adoption of energy-conscious behavior.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

Funding

* Project no. MEC_SZ 149231 has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the MEC_24 funding scheme.



PROJECT
FINANCED FROM
THE NRDI FUND

Conflict of Interest

* The authors declare that they have no conflicts of interest

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Management Economics and Business (www.iconmeb.net) held in Budapest/Hungary on August 28-31, 2025

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THE ROLE OF ENTREPRENEURIAL ORIENTATION ON INNOVATION IN HUNGARIAN SUBSIDIARIES

Abstract: This article examines an aspect of the innovation-driven transformation possibilities at subsidiaries of multinational companies operating in Hungary, particularly their potential shift toward higher value-added activities. As many of these firms operate as subsidiaries of foreign multinational corporations, their ability to engage in higher value-added functions is strongly influenced by the parent company's location strategies and decisions. Nevertheless, building innovation capacity and strengthening value creation are essential prerequisites for subsidiary role upgrading.

Focusing on the role of entrepreneurial orientation, this article reviews the literature on subsidiaries' innovation capabilities to identify factors shaping their entrepreneurial orientation. Findings indicate that innovation capacity and organizational agility—core elements of entrepreneurial orientation—enhance the performance of subsidiaries in international markets and reinforce the competitiveness of multinational corporations. Entrepreneurial skills, creativity, and performance are found to be closely interrelated. Both top-down (managerial) and bottom-up (employee-driven) dynamics contribute to entrepreneurial orientation, highlighting that the entrepreneurial behavior of employees and senior managers alike is indispensable.

Keywords: Subsidiary, Entrepreneurship, Innovation, Multinational Company, MNC

Introduction

According to international literature, for avoiding the economic stagnation and middle-income trap medium-developed countries – in addition to an economic policy based on foreign capital investments – need to shape their economic structure in such a way that the sectors producing higher added value and the weight of innovative companies become decisive (Taglioni and Winkler, 2016; EBRD, 2017-18; Csath, 2021). Analyses led to the conclusion that the development trap situation also poses a real threat to Hungary, thus, improving corporate productivity and value creation capacity has become crucial (MNB, 2023; Csath, 2022).

Since large companies with higher productivity within the Hungarian economy are typically owned by foreign multinational companies (MNB, 2024), it is necessary to examine the factors that contribute to the innovation-driven transformation of these companies. The transformation is not beneficial only to innovation; it can have other benefits as well. For instance, in the case of Social Responsibility, it can lead to a more favourable attitude towards the company's products and services (Garai et al., 2023).

The innovation-driven transformation of subsidiaries can be interpreted as a shift towards higher value-added activities, the key to which is the parent company's strategy and decisions regarding the location, due to their management functions and their role in determining the scope of subsidiary activities through strategic assignments (Pu and Cantwell, 2023; Verbeke and Yuan, 2025). Winning an assignment from the parent company for higher value-added activities means a higher degree of autonomy for the subsidiary and advancement in its role within the network (White and Poynter, 1984; Dörrenbächer and Gammelgaard, 2006). However, to gain broader autonomy, the subsidiary must be able to develop internal corporate capabilities (Verbeke and Yuan, 2025; Gillmore, 2022) and exploit the localization advantages of the host country (Lopes et al, 2019; Dörrenbächer and Gammelgaard, 2006), for which, according to the literature, the subsidiary's initiative and entrepreneurial spirit are essential (Dzikowska et al, 2023; Verbeke and Yuan, 2025; Lopes et al, 2019)

Method

In view of the above, the research examines the possible correlations between the entrepreneurial spirit of subsidiaries and the subsidiary's value creation ability, applying the method of literature exploration, seeking answers to the following questions:

- Q1: What is the correlation between the entrepreneurial spirit and the innovation ability of subsidiaries?
- Q2: What factors influence the entrepreneurial orientation of subsidiaries?

For answering these questions, the first step is to clarify the relationship between entrepreneurial orientation, innovation and company performance, and to define the entrepreneurial approach. After that, an attempt is made to explore the factors influencing the intrapreneurial behavior of employees, and then

the conditions for the entrepreneurial behavior of subsidiary managers are examined. The last part contains a summary, evaluation and conclusions of the results.

Results and Discussion

According to international literature, the three concepts of corporate efficiency - performance - innovation capability are closely related; while efficiency can be quantified by measuring performance, the company's innovation capability can be considered as a predictor of performance (Saunila, 2016). Innovation performance can therefore be understood as the result of the company's innovation capabilities, in addition to other (administrative, operational and management) capabilities (Daronco et al, 2023). Innovation performance can be increased by enhancing innovation capabilities (Yusr, 2016), and research shows a positive correlation between innovation capabilities and corporate performance indicators (Ali et al, 2020). Therefore, companies should pay special attention to developing their innovation capabilities to gain competitive advantage (Yusr, 2016).

Crespo et al., examining marketing knowledge transfer between subsidiaries, found that two mechanisms play a fundamental role in supporting knowledge flow: subsidiary management and entrepreneurial culture (Crespo et al, 2022). Companies with entrepreneurial competence are more effective in discovering, absorbing and converting knowledge from outside the organization into (product) innovation capabilities (Sheng, 2019), and knowledge inflow strengthens the subsidiary's innovation capabilities (Crespo et al, 2022). However, the exploitation of the innovation potential inherent in absorbed external knowledge is more effective in multinational companies operating in a decentralized organizational structure (Boone et al, 2019). The entrepreneurial culture of the subsidiary encourages knowledge transfer with both the parent company and other subsidiaries (Crespo et al, 2022). The entrepreneurial skills and innovation capabilities of subsidiaries are therefore positively correlated with each other.

Examining the global strategy of multinational companies in a new context, Tippmann and his colleagues concluded that in order to seize new opportunities that promote rapid international growth and achieve lasting competitiveness, a strategy called replicable innovation is necessary, one of the mechanisms of which is bottom-up entrepreneurial orientation (Tippmann et al, 2023). The innovative ability and quick reaction time characteristic of entrepreneurial orientation positively influence the performance of subsidiaries

operating in foreign markets and thus the competitiveness of the multinational company (Pehrsson, 2019). Subsidiary entrepreneurship, creativity and performance are closely related to each other (Scott et al, 2010).

Entrepreneurial orientation therefore has a positive impact on the performance of multinational companies, and in the case of multinational companies in emerging economies, the relationship between them is created by reverse innovation – that is, innovation flowing from developing economies to developed economies. (Hashmi et al, 2023). An organizational environment that supports entrepreneurial spirit facilitates the implementation of the subsidiary's innovation initiatives (O'Brien et al, 2019), increases employees' commitment to the organization and willingness to act (Crespo et al, 2022) and improves the subsidiary's learning capabilities (Birkinshaw, 1997).

Based on the above, it can be concluded that entrepreneurial orientation positively influences the performance and competitiveness of the company, and the relationship between them is realized through the ability to innovate. Based on the literature, entrepreneurship is clearly linked to the actors participating in innovation initiatives, and in the context of subsidiaries it is influenced by both top-down (management) and bottom-up (employee orientation) factors.

The literature uses a variety of terminology regarding entrepreneurial mindset, depending on the context in which the given research examines the entrepreneurial mindset (organization, managers, employees). A summary of the most frequently occurring definitions can be found in Table 1, along with the reference to the source document:

Definition	Source
identifying and exploiting new opportunities	Tippmann et al, 2023
deviation from current practice	Damanpour, 1991
alertness to market opportunities	Birkinshaw, 1997
the ability to utilize new knowledge	Scott et al, 2010
exploitation of resources beyond control	Stevenson és Jarillo, 1990
encouraging proactive behavior and commitment to corporate goals	Birkinshaw, 1997
capabilities and processes leading to the creation and utilization of new	Sheng, 2019
strategic creativity	Scott et al, 2010
the presence of the ability to innovate, proactivity and risk-taking	Chew, 2024
encouraging initiative, capacity utilization and interpersonal relationships	Sarabi et al, 2020

Table 1: Definition of entrepreneurial mindset based on the literature (own editing)

According to definitions above, it can be stated that the entrepreneurial attitude includes proactivity ensuring the mobilization of resources and openness to new opportunities, the willingness to take risks enabling the implementation of new initiatives, and the ability to innovate to utilize new knowledge and opportunities. The combined presence of these characteristics at the employee and management levels is an essential condition for the entrepreneurial orientation of the organization.

Entrepreneurial attitude among employees

Based on the definitions used in the literature for entrepreneurial mindset, several factors can be highlighted that can be characteristic of employees as well as management, including a willingness to innovate, a willingness to take risks, and proactivity. The creative mindset of employees and their commitment to continuously searching for new opportunities strengthen the entrepreneurial orientation of the organization. Examining the global scaling conditions of eight digital companies, Tippmann and his colleagues found, among other things, a bottom-up entrepreneurial orientation mechanism from the employees' side. It has been found that the entrepreneurial mindset present among employees reduces the required level of managerial resources in this direction, thereby facilitating successful growth (Tippmann et al, 2023). To successfully exploit the positive effects of a company's entrepreneurial orientation, management must therefore keep in mind the strengthening of a bottom-up, employee entrepreneurial mindset.

According to the literature, the drivers of employees' intrapreneurial behavior form a complex system that includes both organizational and personal factors. Personal factors are the basic motivation of individuals to participate in initiatives (Naksung, Piansoongnern, 2020), and personal motivations facilitate individuals' intrapreneurial behavior (Bager et al, 2010). The organizational benefits expected from the implementation of the entrepreneurial initiative, the consistency between the initiative and current organizational practices, the rewards expected in the event of a successful initiative, and satisfaction with the situation within the organization can also encourage employees to engage in intrapreneurial behavior (Clercq et al, 2011).

Personal factors therefore include the basic motivations necessary for action, while organizational factors provide a kind of support for the implementation of individual initiatives arising from an entrepreneurial approach, creating the internal environment that promotes the entrepreneurial behavior of employees (Naksung, Piansoongnern, 2020). To strengthen the entrepreneurial attitude, effective organizational

measures can include, on the one hand, hiring young, versatile and ambitious employees, and on the other hand, ensuring job autonomy, which provide opportunities for employees to behave more proactively and to move towards new ideas and more creative thinking when solving problems (Tippmann et al, 2023). Management support fundamentally influences employee behavior, creating processes to encourage and implement ideas, providing time and financial resources, greater decision-making freedom, and creating a more flexible and creative work environment have a stimulating effect on employees' initiative (Antoncinc and Zorn, 2004).

Based on the literature, several factors can be identified that influence employees' intrapreneurial behavior. According to Naksung et al. (Naksung, Piansoongnern, 2020), entrepreneurial behavior at the employee level can be strengthened by personal preference, organizational stability, management support, remuneration, reward system, teamwork, quality of relationships with colleagues, work autonomy, and quality of relationships with superiors. Regarding the entrepreneurial behavior of employees (Carrier, 1996), Carrier distinguishes between intrinsic, personality-related motivations, extrinsic, reward-related motivations, organizational factors, and individual experience and career goals. Kuratko and his colleagues consider top management support, job flexibility, rewarding entrepreneurial efforts, providing the time and resources necessary for action, and removing organizational boundaries that restrict entrepreneurial activity to be key to encouraging entrepreneurial behavior (Kuratko et al, 2014).

Based on the above, it can be concluded that the factors influencing the entrepreneurial orientation of employees are extremely diverse, combining both personal and organizational elements. The presence of these elements can synergistically strengthen – and their absence can weaken – individuals' intrapreneurial behavior, initiative, and the successful implementation of employees' innovative initiatives.

Entrepreneurial attitude among managers

According to mainstream internalization theory, multinational corporations operate hierarchically (Buckley et al, 1976). However, each subsidiary has different autonomy and scope of activities within the multinational corporation, and subsidiary managers play a critical role in both shaping relationships with the parent company and winning assignments, as well as in performing activities and managing their own organization (Meyer et al, 2020). Subsidiary managers therefore play a kind of bridging role within multinational companies (Crespo et al, 2022) through their influence on certain strategic decisions of the

parent company (Meyer et al., 2020) and their corporate responsibility for the operation and performance of the unit they lead (Sarabi et al, 2020; Crespo et al, 2022).

As an extension of the internalization theory, Lopes and his colleagues proposed an operating model with a higher degree of autonomy, in which subsidiary managers must have an entrepreneurial approach and skills, as well as a thorough knowledge of local conditions, so that their decisions can serve the implementation of the central strategy, in addition to solving operations and problems at the local level and incorporating local knowledge for this purpose (Lopes et al, 2019). The entrepreneurial approach of top managers is therefore essential for the success of management strategies aimed at involving external knowledge and thereby increasing the company's innovation capability (Boone et al, 2019), and the entrepreneurial competencies of subsidiaries ensure the utilization of external knowledge within the company (Sheng, 2019). A higher degree of autonomy has a positive effect on the subsidiary's innovation capability (Decreton et al, 2019), and subsidiary managers play a key role in increasing performance by enhancing the subsidiaries' entrepreneurial orientation – i.e. their willingness to take risks, proactivity and innovation skills – (Scott et al, 2010) and their knowledge of the background mechanisms (Pehrsson, 2019).

Since supporting innovative initiatives always involves risk (Ambos et al, 2023), it is important to understand what factors influence the entrepreneurial behavior of subsidiary managers. The subsidiary manager is responsible for channeling the parent company's expectations into the organization, and for creating employee motivation and organizational conditions that ensure their implementation (Sarabi et al, 2020), to operate along the central strategic goals and increase performance. Therefore, subsidiary managers must consider a variety of factors in their decisions that influence their entrepreneurial behavior – that is, their willingness to take risks, their proactivity and their openness to innovation initiatives. Ambos et al (Ambos et al, 2023) distinguish between individual-level (leadership ability) and organizational-level (entrepreneurial orientation of a multinational company) factors of managerial risk-taking.

Examining organizational-level factors, it can be stated that parent company management with a higher entrepreneurial orientation positively influences the openness of subsidiary managers to support innovative initiatives, as the risks arising from the organizational context – parent company control and expectations – will be lower (Wales et al, 2020). A solid knowledge of the entrepreneurial orientation of the parent company management contributes to making organizational decisions more transparent (Ambos et al, 2023), but for effective information flow, subsidiary managers must be in close contact with the parent company. The

importance of the relationship with the parent company is also supported by the fact that although the proactive behavior of subsidiary managers and their willingness to support innovation initiatives is negatively affected by closer parent company control, this can be significantly offset by certain socialization mechanisms – developing a common corporate culture, teamwork, and management rotation programs between the parent company and the subsidiary (Decreton et al, 2019). The usefulness of management rotation programs should be highlighted, as participating subsidiary managers become able to better understand the organizational dynamics and parent company motivations within the network (Nuruzzaman et al., 2018).

Individual leadership skills play a prominent role in taking on the risks associated with supporting innovative initiatives, and a senior manager with strong leadership skills and an entrepreneurial approach plays a key role in shaping the entrepreneurial orientation of subsidiaries, having a positive impact on knowledge flow and innovation (Crespo et al, 2022). Individual leadership skills play an important role in successfully managing relationships with the parent company, gaining the support of the parent company, and motivating employees to implement entrepreneurial initiatives and achieve common goals (Ambos et al, 2023).

Leadership ability can therefore be summarized in three characteristics: human capital, which is the ability to manage employees and deal with challenges, social capital, which includes the ability to connect with employees, supervise and delegate tasks, and leadership cognition, which is the ability to encourage and motivate employees (Kor and Mesko, 2013). Subsidiary managers with strong leadership abilities manage the human and social resources of the subsidiary more effectively and manage internal entrepreneurial initiatives more successfully (Ambos et al, 2023). An entrepreneurial leadership style can be considered as a set of top management goals, beliefs, logics, decisions and communication (Wales et al, 2020). Subsidiary managers with highly developed leadership skills are more likely to exhibit entrepreneurial behavior and are more open to supporting the implementation of innovative initiatives involving risk (Ambos et al, 2023).

Based on the above, it can be stated that the entrepreneurial orientation of the subsidiary primarily depends on the subsidiary management. The entrepreneurial behavior of subsidiary managers plays a key role in creating an organizational environment that encourages employees to participate in innovation initiatives, as well as in assuming the risks associated with such initiatives and obtaining support from the parent company. Therefore, subsidiary managers must have highly developed leadership skills to ensure the

proactivity, risk-taking and openness to innovation opportunities that are prerequisites for entrepreneurial behavior.

Conclusion

The relationships revealed in the empirical research are an important contribution to the examination of the conditions underlying the innovation-driven transformation of multinational subsidiaries. It can be stated that entrepreneurial orientation and company performance are closely related, and the link between them is innovation. At the same time, innovation is a necessary but not sufficient condition for obtaining higher value-creating activities within the multinational network. Entrepreneurial orientation takes us one step closer to this, which considers the impact of relationships with the parent company in addition to the ability to innovate.

The entrepreneurial approach can be defined as the combination of proactivity that ensures the mobilization of resources and openness to new opportunities, the willingness to take risks that enables the implementation of new initiatives, and the ability to innovate to utilize new knowledge and opportunities.

Based on the literature reviewed, entrepreneurial orientation in the context of subsidiaries is influenced by both top-down (management) and bottom-up (employee orientation) factors.

At the employee level, the drivers of intrapreneurial behavior form a complex system in which both organizational and personal factors can be found. Personal factors are the fundamental motivation of individuals to participate in innovation initiatives, while organizational factors provide a kind of support for the implementation of individual initiatives arising from an entrepreneurial approach, creating the internal environment that promotes the entrepreneurial behavior of employees.

The entrepreneurial behavior of subsidiary managers plays a key role in creating an organizational environment that encourages employees to participate in innovation initiatives; in taking on the risks associated with such initiatives, and in obtaining parent company support. However, based on the literature, managers with highly developed leadership skills and a clearer understanding of parent company mechanisms and orientation are more likely to show entrepreneurial behavior and support the implementation of innovation initiatives within the organization.

Based on the literature review, it has been proven that in the case of subsidiaries of multinational companies, the entrepreneurial orientation of the subsidiary is an essential condition for innovation-driven transformation and the shift towards higher added value and strategically important activities, the development of which in practice primarily depends on the subsidiary management.

Recommendations

The results of our research show that the concept of having an innovative approach shouldn't be limited to the "fancy" business players like startups, but it's equally important for MNC subsidiaries as well. Innovation at these subsidiaries is crucial for Hungary, since they are the potential enablers of Hungarian SME's for being innovative partners. If innovation were more widespread among subsidiaries, not only would they be in a more beneficial position in the internal competition of their MNC, but they could also act as gates for their business environment for innovation. This could bring them to the next level of added value, and they could also serve as catalysts in the innovation ecosystem.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

Funding

* Project no. MEC_SZ 149231 has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the MEC_24 funding scheme.



PROJECT
FINANCED FROM
THE NRDI FUND

* Project No. EKÖP-24-KDP-5 has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the 2024-2.1.2 University Research Scholarship Program – Cooperative Doctoral Program Funding Scheme.

Conflict of Interest

* The authors declare that they have no conflicts of interest

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Management Economics and Business (www.iconmeb.net) held in Budapest/Hungary on August 28-31, 2025

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TRANSFORMING CUSTOMER EXPERIENCE INTO SUPER-APPS: AN ANALYSIS OF AGENTIC AI POTENTIAL THROUGH THE PASSO CASE STUDY

Abstract: This study set out to explore the transformative potential of Agentic AI within the complex ecosystem of a super-app, using an exploratory case study of Passo and a novel Agentic Maturity Model. Our analysis of key user journeys demonstrates that a shift from low-maturity reactive systems (Levels 1-2) to high-maturity proactive and orchestrating agents (Levels 3-4) can fundamentally reshape the customer experience, turning points of friction into opportunities for value creation and trust-building. The primary contribution of this paper is the Agentic Maturity Model, which provides a clear framework for this transformation and offers a strategic roadmap for organizations to move beyond simple automation towards providing truly autonomous services. Ultimately, this research suggests that the future of digital competition in the super-app era will not be defined simply by the number of services offered, but by the intelligence and autonomy of the agents that help users navigate them.

Keywords: Agentic AI, Super-App, Customer experience (CX), AI agents, Digital transformation

Introduction

The digital economy is increasingly dominated by the rise of integrated platform ecosystems, commonly known as "super-apps." These platforms are fundamentally reshaping the competitive landscape by consolidating a multitude of disparate services—ranging from e-commerce and transport to financial services—into a single, unified mobile interface (Parker et al., 2016). By creating a central hub for users' daily activities, super-apps generate immense value through network effects and deep user engagement (Tan & Wo, 2021). However, this integration creates significant complexity in user journeys, presenting a major challenge for delivering a consistently seamless and intuitive customer experience.

To manage this complexity, organizations have widely adopted Artificial Intelligence (AI), primarily in the form of conversational chatbots. While these systems have been effective at automating simple, repetitive

tasks, they largely operate as reactive tools. The limitations of these first-generation AI systems, such as their lack of contextual understanding and inability to take initiative, are now well-documented in the literature (Følstad & Brandtzaeg, 2017). For a super-app, where a user's needs often span multiple services, a simple reactive chatbot is insufficient to unlock the true potential of the integrated ecosystem.

This paper argues that the next paradigm shift in customer experience is the move from simple conversational AI to Agentic AI. An intelligent agent is defined as an entity that can perceive its environment and act autonomously to achieve its goals (Russell & Norvig, 2016). In the context of a super-app, an agentic system would not merely respond to commands but would proactively and autonomously orchestrate tasks across multiple services on behalf of the user. However, the potential applications of this advanced paradigm within the unique super-app context remain largely underexplored in academic research.

Therefore, the primary objective of this study is to identify, conceptualize, and analyze high-value use cases for Agentic AI within a real-world super-app. To achieve this, we conduct an exploratory single-case study (Yin, 2018) of Passo, a leading super-app in Turkey. The main contribution of this paper is the proposal of a novel "Agentic Maturity Model," a four-level framework designed to classify and guide the development of AI agents from simple reactive responders to fully autonomous orchestrators. This paper is structured as follows: Section 2 reviews the relevant literature. Section 3 details our methodology and the proposed framework. Section 4 introduces the Passo case study. Section 5 presents the analysis of our findings, and Section 6 discusses their implications. Finally, Section 7 concludes the paper.

Literature Review

This study is positioned at the intersection of three evolving domains: the business model of super-apps, the evolution of conversational AI, and the emerging paradigm of agentic systems. This review synthesizes key literature from these areas to establish the theoretical foundation and identify the research gap that this paper addresses.

The Rise of Super-App Ecosystems

Super-apps have emerged as a dominant force in the digital economy, fundamentally altering user behavior and business strategy. They are best understood not as applications with many features, but as digital platforms that orchestrate value creation between different user groups (Parker et al., 2016). The literature specifically defines a super-app as an integrated ecosystem that combines a multitude of services into a single mobile interface (Tan & Wo, 2021). These platforms are typically built around a core, high-frequency service which serves as a gateway to an expanding portfolio of other offerings. A crucial component of this model is an embedded payment infrastructure, which creates a seamless transactional experience. As these ecosystems grow in complexity, the challenge of navigating user journeys and maintaining a simple, coherent user experience becomes increasingly significant.

The Evolution of AI in Customer Interaction: From Chatbots to Proactivity

The use of AI in customer-facing applications has evolved significantly. The initial wave was dominated by informational and transactional chatbots. While effective at reducing costs for basic tasks, their limitations—such as a lack of contextual understanding and an inability to take initiative—have been well-documented (Følstad & Brandtzaeg, 2017). These shortcomings led to the development of more sophisticated systems capable of proactive and personalized interactions, which can anticipate user needs and offer timely suggestions, representing a move toward a more intelligent and user-centric paradigm. Xu et al. (2023) highlight that orchestration-driven personalization is becoming a critical differentiator in digital customer experience.

Defining Agentic AI and its Foundations

The next stage in this evolution is Agentic AI. An "agent" in this context is a system that can perceive its environment and act autonomously to achieve specific goals (Russell & Norvig, 2016). This paradigm builds upon foundational academic work on the levels of automation, which provides a spectrum for classifying the degree of autonomy in human-computer interaction (Parasuraman et al., 2000; Sheridan & Verplank, 1978). Recent studies further emphasize the transition from reactive assistants to orchestrating agents in digital ecosystems (Cao & Lin, 2023). Unlike a simple proactive assistant, a true agent possesses a higher

degree of autonomy, decision-making capability, and the ability to orchestrate complex tasks. Our "Agentic Maturity Model," introduced in the methodology section, is directly informed by this literature.

The Research Gap: Agentic AI in Super-Apps

While the literature provides a solid understanding of super-apps as business models and traces the evolution of AI, a significant research gap exists at their intersection. There is a scarcity of academic work that specifically explores the application and potential of high-level, autonomous agentic systems within the unique, multi-service context of super-apps. This study aims to address this gap by providing an exploratory case study that conceptualizes and analyzes specific, high-value use cases for Agentic AI within the Passo super-app.

Methodology

Research Approach: A Single-Case Study Design

This study adopts a single-case study methodology to conduct an in-depth exploration of the potential applications of Agentic AI within a super-app ecosystem. A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between the phenomenon and context are not clearly evident (Yin, 2018). This approach is particularly well-suited for our research for several reasons. First, the integration of Agentic AI in super-apps is an emergent and complex phenomenon, making it difficult to study outside of a real-world setting. A case study allows for a rich, holistic understanding of the intricate interplay between the technology, user needs, and business processes. Second, our research seeks to answer "how" and "why" questions, such as "How can Agentic AI transform core user journeys?" and "Why is this transformation strategically valuable?". The case study method is ideal for addressing such exploratory and explanatory questions. Finally, by focusing on a single, instrumental case, we can generate detailed, context-dependent knowledge and develop a practical framework that can inform both theory and practice in the field of digital transformation.

Case Selection: Justification for Selecting Passo

For this case study, we selected Passo, one of Turkey's most prominent and rapidly growing super-apps. The selection of this specific case was purposive and guided by several key criteria that make it an ideal context for this research. First, Passo exemplifies the core characteristics of a super-app by integrating a diverse and expanding portfolio of services, including event ticketing, public transportation card top-ups, and access to financial products, all within a single platform. This inherent complexity and the dynamic addition of new use cases create a rich environment to explore the orchestration capabilities of Agentic AI. Second, Passo possesses a robust and flexible technological infrastructure, supported by its parent company, one of the nation's leading investment banks. This backing provides the architectural agility necessary for the hypothetical integration of sophisticated AI agents, making our proposed scenarios not just theoretical but also feasible. Finally, the continuous expansion of its services naturally leads to an increasing complexity in user journeys and a growing need for intelligent, personalized automation. This makes Passo a fertile ground for investigating how Agentic AI can address real-world business challenges, such as streamlining complex processes and enhancing user engagement at scale. The authors' direct access to the case also provided an invaluable opportunity to gather contextual data and insights for the analysis.

Data Collection

The data for this case study were collected using a multi-faceted qualitative approach to ensure a robust and deeply contextualized understanding of the Passo ecosystem. The data collection process was designed to capture both formal procedures and practical, on-the-ground knowledge. First, brief, semi-structured interviews were conducted with key personnel from the relevant business units. The primary objective of these consultative meetings was to understand and map the operational workflows of critical user journeys, such as ticket cancellations, eligibility verification, delivery tracking, and insurance management. These were not in-depth personal interviews but rather focused discussions aimed at accurately documenting the "as-is" processes. Second, the insights from these interviews were supplemented and validated by a thorough review of internal documentation. This included an analysis of official process guidelines, internal rulebooks, and other relevant documents that govern the existing workflows. Finally, this process was significantly enriched by the contributions of one of the co-authors, who holds the position of Business Development Manager at Passo. This direct involvement facilitated access to validated process documents and provided

critical expert insights and clarifications on the complexities of the business operations, ensuring a high degree of accuracy and authenticity in the data gathered for the analysis. This triangulation of data—combining interviews, document analysis, and expert informant knowledge—provided a comprehensive foundation for the case study.

Validity and Reliability

To strengthen research validity, we ensured construct validity through triangulation of multiple data sources, including semi-structured interviews, internal process documentation, and expert informant validation. Internal validity was enhanced by iterative cross-checking of workflows with domain experts to minimize bias and ensure consistency across data points. Reliability was addressed by maintaining detailed process logs, standardized interview protocols, and version-controlled documentation, enabling replication of the case study design in future research. Furthermore, transparency in methodological choices and explicit acknowledgment of the study's limitations enhance the credibility of our findings.

Analytical Framework: The Agentic Maturity Model

To systematically analyze the collected use case scenarios and evaluate their potential for transformation, we developed and applied a novel analytical framework: the Agentic Maturity Model. We argue that a simple binary classification of "automated vs. manual" is insufficient to capture the nuanced capabilities of modern AI. While several conversational AI maturity models exist in the literature, they often culminate at proactive personalization and are not specifically designed to address the unique complexities of a multi-service super-app ecosystem. To address this gap, we build upon foundational concepts of automation levels and agent autonomy (e.g., Parasuraman et al., 2000; Sheridan & Verplank, 1978) to propose a model tailored for this emerging context. Our framework provides a four-level hierarchy to classify the sophistication of AI-driven user interactions, offering a clear roadmap that extends beyond proactivity to true agentic orchestration. The model is structured as follows:

Level 1: Reactive Information Provider: At this foundational level, the AI system functions as a simple, reactive agent. Its primary role is to respond to direct user queries by fetching pre-defined information from

a knowledge base. Interactions are typically user-initiated, single-turn, and follow a question-and-answer format.

Level 2: Process Automator: Moving beyond simple information retrieval, a Level 2 system can guide a user through a structured, multi-step process. It automates linear, well-defined workflows based on user commands. While it handles multiple steps, it does not take initiative and strictly follows a pre-determined path.

Level 3: Proactive & Personalized Assistant: This level represents a significant leap in intelligence. The system becomes proactive, using context and user history to anticipate needs and provide unsolicited but relevant assistance. It can send personalized alerts, make context-aware suggestions, and initiate interactions without waiting for a direct user command.

Level 4: Agentic Orchestrator: At the highest level of maturity, the AI transcends the role of an assistant and becomes a true agent. An Agentic Orchestrator autonomously manages complex, multi-service tasks to achieve a user's goal. It can make decisions, coordinate across different services within the super-app (e.g., ticketing, transportation, payments), and execute entire workflows with minimal user intervention.

This model will be used in the "Results and Analysis" section as the primary tool to map the "as-is" state of each scenario and to articulate the vision for their "to-be" transformation.

Case Study Context: The Passo Super-App Ecosystem

The context for this study is Passo, a leading digital platform and super-app in Turkey. Launched initially as a national ticketing platform for major sporting events (via the Passolig system), it has since evolved into a comprehensive ecosystem catering to a wide array of urban and lifestyle needs for its millions of users. As a subsidiary of Aktif Bank, one of the nation's foremost investment banks, Passo benefits from a strong financial and technological foundation, which enables its continuous innovation and service expansion. According to public reports, Passo has surpassed seven million active users and facilitates millions of transactions annually, positioning it as one of Turkey's most widely adopted lifestyle super-apps (Aktif Bank Annual Report, 2024). Recent industry analyses highlight Passo's pioneering role in integrating digital wallets

and mobility-finance services, particularly in the domains of ticketing and public transportation (Deloitte, 2023). This scale and multi-service integration not only reinforce its classification as a super-app but also underscore its strategic relevance as a testbed for exploring the orchestration potential of agentic AI.

The platform's classification as a super-app is central to our case selection. The platform's classification as a super-app is central to our case selection. Comparable evidence from WeChat shows how AI-driven personalization is central to super-app adoption (Wu & Li, 2022). A super-app is typically defined in the literature as a mobile application that provides a wide array of services within a single, integrated interface, often built around a core high-frequency service and a unified payment system (e.g., Tan & Wo, 2021). Passo clearly exemplifies this model. Its foundational, high-frequency service is sports and event ticketing, which drives initial user adoption and engagement. This is built upon an integrated digital wallet (Passo Cüzdan) that facilitates seamless payments and transactions across the entire ecosystem. Surrounding this core, Passo has layered a diverse set of services, including public transportation card top-ups and access to financial products like N Kolay loans. This strategic consolidation of ticketing, payments, transport, and financial services is what firmly establishes Passo as a super-app, transforming it from a transactional tool into a central hub for daily life.

The strategic importance of the Passo ecosystem for this research lies in its inherent complexity and dynamism. The platform's multi-service nature creates complex user journeys that often span different domains (e.g., purchasing a concert ticket, topping up a transport card for the journey, and paying via the integrated wallet). This environment serves as a perfect real-world laboratory to investigate the potential of a Level 4 Agentic Orchestrator, which is designed to navigate and simplify precisely this type of cross-service complexity. The following analysis will, therefore, use this context to explore how agentic AI can transform specific high-value user journeys within the Passo platform.

Results and Analysis

In this section, we apply the Agentic Maturity Model to four critical use case scenarios identified within the Passo ecosystem. For each scenario, we first analyze the current "as-is" process to classify its maturity level and then present a "to-be" vision that demonstrates the transformative potential of a Level 3 or Level 4 agentic system.

Cancellation and Refund Processes

Current Process Analysis (Level 1-2)

The process for cancelling a ticket or product and requesting a refund is a frequent and often sensitive user journey. In the current "as-is" state within the Passo platform and similar digital services, this process is typically a user-initiated workflow that operates at Level 1 (Reactive Information Provider) and Level 2 (Process Automator) of our maturity model. The interaction begins when a user decides to cancel a purchase and navigates to the relevant section of the application. If the user seeks information, they might interact with a Level 1 chatbot, asking questions like "How do I cancel my ticket?" which provides a static answer from a knowledge base. To execute the cancellation, the user initiates a Level 2 process. The system then guides them through a series of rigid, pre-defined steps: find the order, select the item to cancel, review the (often complex) refund policy, and confirm the cancellation request. The entire process is reactive; the system does not take any initiative, and the cognitive load of understanding eligibility, rules, and consequences rests entirely on the user.

The Agentic Transformation (Level 3-4 Vision)

An agentic system transforms this user-driven, high-friction process into a proactive, intelligent, and value-added experience. The transformation begins at Level 3 (Proactive & Personalized Assistant), where the system starts to anticipate user needs based on contextual data. For instance, the agent could monitor external data sources, such as the weather forecast for an outdoor concert. If a high probability of heavy rain is predicted, the agent would proactively alert the user days in advance:

"We have noticed a 90% chance of heavy rain forecast for the day of your outdoor concert. According to your ticket's policy, you are eligible for a partial refund if you cancel up to 24 hours before the event. Would you like to review your cancellation options now?"

The full potential, however, is realized at Level 4 (Agentic Orchestrator). At this level, the agent's goal is not just to process a cancellation, but to manage the entire situation to ensure a positive outcome for the user. Imagine an official event cancellation is announced. The Level 4 agent would autonomously perform

a chain of actions: detect the cancellation, process the refund, and orchestrate a solution to the user's underlying goal.

"The Beşiktaş-Trabzonspor match has been postponed, and the full ticket price of 1,500 TL has been refunded to your Passo Wallet. We noticed you also frequently attend basketball games. The National Team has a match this same weekend, and tickets are available in your preferred seating area. I have checked your calendar, and you appear to be free. Would you like me to book a ticket for you using the refunded amount?"

This Level 4 interaction demonstrates true orchestration, transforming a potentially frustrating experience into one of seamless, proactive service.

User Eligibility Verification for Regulated Events

Current Process Analysis (Level 1-2)

Verifying user eligibility for events with complex and dynamic rules—such as major football matches governed by the Passolig system—is another critical and often frustrating user journey. The "as-is" process for this scenario is a clear example of a system operating at Level 1 and Level 2, functioning more as a gatekeeper than an assistant. The interaction is almost always initiated by the user at the final stage of a purchase attempt. If a user fails to meet one or more of these complex criteria, the process is abruptly blocked. The system's response is typically a generic Level 1 error message, such as "Purchase failed: you are not eligible for this event," which provides no specific reason or guidance for resolution. Consequently, the cognitive burden of diagnosing the problem and finding a solution is placed entirely on the user.

The Agentic Transformation (Level 3-4 Vision)

An agentic system fundamentally redefines this journey by transforming the AI from a reactive gatekeeper into a proactive enabler. The transformation begins at Level 3, where the agent leverages user data and event information to anticipate and resolve potential issues in advance. For example, it proactively checks the user's Passolig status before a high-demand match goes on sale:

"Hi [User Name], tickets for the Galatasaray-Fenerbahçe derby go on sale tomorrow at 11:00 AM. I have noticed that your Passolig card's annual visa is set to expire in three days. To ensure a smooth purchase experience, I can initiate the renewal process for you right now with one click. Shall I proceed?"

The vision culminates at Level 4, where the agent can handle ambiguous, goal-oriented requests. For a user query like "I want to go to a match in Istanbul this weekend," the agent autonomously performs a comprehensive analysis, filtering out impossible options and synthesizing the results into a single, actionable recommendation.

"This weekend in Istanbul, there are three matches. You are not eligible for the Beşiktaş match due to away fan restrictions, and tickets for the Galatasaray match are sold out. However, you are fully eligible for the Fatih Karagümrük match at the Atatürk Olympic Stadium. Would you like me to show you the available seats?"

This transforms a journey of potential frustration and multiple dead-ends into a single, successful discovery process.

Card or Product Delivery Processes

Current Process Analysis (Level 1-2)

The post-purchase journey, specifically the tracking of physical deliveries, is a high-frequency interaction point filled with user anticipation and potential anxiety. The conventional approach is deeply reactive, placing it within Level 1 and Level 2. The system remains passive until explicitly prompted by the user with a query like, "Where is my package?". It then relays the raw, often cryptic, status update it receives from a third-party logistics provider. The system acts as an indifferent messenger with no awareness of process exceptions. If a delivery attempt fails, the burden of interpreting the status and finding a solution falls entirely on the user.

The Agentic Transformation (Level 3-4 Vision)

An agentic system transforms the delivery experience by shifting the AI's role from a passive messenger to a proactive problem-solver. At Level 3, the agent actively monitors the delivery status. Upon detecting a failure, it proactively contacts the user with clear, actionable choices:

"Hi [User Name], the courier attempted to deliver your Passo card at 2:15 PM today but was unable to reach you. Would you prefer to: A) Reroute the package to a nearby pickup point? B) Reschedule the delivery for tomorrow at a different time or to your office address?"

The ultimate vision is achieved at Level 4, where the agent uses a wider range of data to solve problems before they even occur. By combining logistics data with the user's calendar or location, it can anticipate a high probability of delivery failure.

"Your new card is scheduled for delivery to your home address this afternoon. However, I see from your calendar that you are at the office until 6 PM. To prevent a missed delivery, would you like me to instantly redirect the package to your office?"

This Level 4 orchestration demonstrates a deep understanding of the user's real-world context, preventing problems entirely.

Proactive and Personalized Insurance Management

Current Process Analysis and Missed Opportunity (Level 1-2)

The proactive offering of on-demand insurance is not a currently active service within the Passo ecosystem, representing a significant missed opportunity. When insurance options are present on comparable digital platforms, they are typically implemented at Level 1 and Level 2. The common practice is a non-personalized, low-context checkbox during checkout, such as "Add event insurance for 50 TL?". This "take-it-or-leave-it" approach results in low conversion rates and fails to address the user's actual potential needs.

The Agentic Transformation (Level 3-4 Vision)

An agentic approach allows for the introduction of insurance not as a passive upsell, but as a dynamic, high-value service. At Level 3, the agent acts as an intelligent risk advisor, using contextual data to make a personalized and justified recommendation.

"Hi [User Name], I see you've purchased non-refundable tickets for the Mountain Rock Fest. The long-range weather forecast currently shows a 40% chance of thunderstorms that weekend. For just 75 TL, you can add 'Event Weather Protection.' Would you like to add this protection to your purchase?"

At Level 4, the agent manages the entire lifecycle of the policy. If a covered event (like a flight delay) occurs, the agent autonomously detects it and initiates the claim process on the user's behalf.

"I have detected that your flight to Antalya has been delayed by more than 3 hours. Your travel insurance policy entitles you to compensation. To make things easier, I have already opened a claim file for you with the insurance company and submitted the official flight delay confirmation."

This capability transforms insurance from a passive safety net into an active service that works for the user, creating unparalleled trust and value.

Discussion

The analysis presented in the previous section demonstrates a clear trajectory for the evolution of AI within a super-app context, moving from simple automation to proactive, autonomous orchestration. This progression, mapped by our Agentic Maturity Model, provides a new lens through which to view the future of digital customer experience. In this section, we discuss the summary of our key findings, the broader implications of this transformation for managers and strategists, the theoretical contribution of our model, and the limitations of this study that open avenues for future research.

Summary of Key Findings

Our analysis of four distinct user journeys within the Passo case study yielded several key findings. First, we established that most current digital processes, while automated, operate at a low level of agentic maturity (Level 1-2), functioning as reactive tools that place the cognitive burden of problem-solving on the user. Second, we demonstrated that a significant leap in user experience is achievable by advancing to Level 3, where a proactive and personalized assistant can anticipate needs and prevent problems before they occur. Finally, our findings reveal that the ultimate potential is unlocked at Level 4, where an "Agentic Orchestrator" can autonomously manage complex, multi-service user goals. This capability is uniquely suited to the super-app ecosystem, where the primary value proposition is the seamless integration of disparate services.

Managerial and Strategic Implications

Our findings offer several critical strategic implications for managers and decision-makers in super-app ecosystems and other digital platforms. First, the transition to Level 3-4 systems represents a fundamental strategic shift from reactive problem-solving to proactive value creation. Many current AI investments focus on cost reduction by automating support queries. Our analysis shows that the real competitive advantage lies in using agentic AI to pre-empt user problems and transform potentially negative experiences (e.g., a delivery failure or an event cancellation) into moments of positive engagement and trust-building. This shifts the role of AI from a cost center to a driver of customer loyalty.

Second, agentic AI opens up avenues for creating entirely new revenue streams and service models. The insurance scenario (5.4) is a prime example. Instead of being a low-converting add-on, it becomes a high-value, personalized service that addresses a user's specific, context-aware risks. Managers should, therefore, view Agentic AI not just as a tool to optimize what they currently do, but as an engine to innovate on what they could offer.

Finally, the orchestration capability of a Level 4 agent is a powerful tool for deepening user lock-in within the super-app ecosystem. Huang and Wang (2024) similarly emphasize that autonomous agents will increasingly shape competitive dynamics and platform strategies. By seamlessly managing tasks across different services (ticketing, transport, payments), the agent makes it significantly more convenient for a user to stay within the platform. This increases switching costs and reinforces the super-app's core value proposition as a central, indispensable hub for the user's digital life.

Theoretical Contribution

This study contributes to the academic literature in two primary ways. The main theoretical contribution is the proposal of the Agentic Maturity Model. While various chatbot or automation maturity models exist, our framework is novel in its specific focus on the super-app context and its extension to a fourth level of "Orchestration." It provides researchers and practitioners with a structured vocabulary and a conceptual roadmap to classify and design the next generation of AI agents that go beyond simple proactivity. Secondly, by applying this model to a real-world case study, we provide a rich, qualitative illustration of how these theoretical levels manifest in practical business processes, bridging the gap between abstract AI concepts and their tangible application.

Limitations and Future Research

We acknowledge several limitations in this study that suggest directions for future research. First, as an exploratory study based on a single case, the findings may not be immediately generalizable to all super-apps in different markets, although the proposed model offers a robust analytical starting point. Second, the "to-be" scenarios presented in our analysis are conceptual visions; they have not been implemented or empirically tested with real users.

These limitations open up several avenues for future research. An immediate next step would be the empirical implementation and A/B testing of a Level 3 or Level 4 agent to quantitatively measure its impact on user satisfaction, engagement, and conversion metrics. Furthermore, future studies could apply the Agentic Maturity Model to other super-apps to validate and refine its levels. Finally, the rise of Level 4 orchestrators raises important ethical questions regarding data privacy, user autonomy, and algorithmic bias, which warrant dedicated investigation.

Conclusion

This study set out to explore the transformative potential of Agentic AI within the complex ecosystem of a super-app, using an exploratory case study of Passo and a novel Agentic Maturity Model. Our analysis of key user journeys demonstrates that a shift from low-maturity reactive systems (Levels 1-2) to high-maturity proactive and orchestrating agents (Levels 3-4) can fundamentally reshape the customer experience, turning points of friction into opportunities for value creation and trust-building.

The primary contribution of this paper is the Agentic Maturity Model, which provides a clear framework for this transformation and offers a strategic roadmap for organizations to move beyond simple automation towards providing truly autonomous services. Ultimately, this research suggests that the future of digital competition in the super-app era will not be defined simply by the number of services offered, but by the intelligence and autonomy of the agents that help users navigate them. As digital ecosystems become increasingly complex, the development of sophisticated agentic orchestrators will be a key differentiator in creating truly indispensable platforms that actively manage users' digital lives.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

Funding

* Project no. MEC_SZ 149231 has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the MEC_24 funding scheme.



PROJECT
FINANCED FROM
THE NRDI FUND



PROJECT
FINANCED FROM
THE NRDI FUND

Conflict of Interest

* The authors declare that they have no conflicts of interest

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Management Economics and Business (www.iconmeb.net) held in Budapest/Hungary on August 28-31, 2025

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THE JEVONS PARADOX WORKING: HOW MOTORWAY BYPASSES CAN INCREASE DOWNTOWN TRAFFIC

Abstract: The Jevons paradox is a widely known phenomenon in economics: usage (consumption) of a resource for which a more efficient technology has been developed can (or always will?) increase; instead of parsimony through efficiency. The definitive example is from the industrial revolution (examined by William Stanley Jevons). This paradox sheds a dark shadow on efforts towards sustainability: will the planned resource efficiency in every case end up as increasing consumption? If yes, the paradox makes every effort for sustainability via technological advance trapped. We are planning wider research activities into this topic, and this contains exploring relevant various examples of the paradox working (its ubiquity regarded, maybe better called Jevons effect, not a paradox). One of the most illustrative examples include the surprising fact that when we are developing bypass roads in order to protect downtowns from excess traffic, without explicitly limiting downtown traffic, the result is contrary: as a consequence, traffic becomes equal as before or even higher in the downtown. We show why and how this is a clear example of Jevons effect.

Keywords: Jevons effect, Sustainable technology, Rebound effect, Degrowth

Introduction

Our main motivation into this topic is getting closer to the understanding of general difficulties of (global) sustainability. Since individual behaviour is the toughest factor to change, (Sharma, 2024; Steg et al., 2015; Gazheli, 2016; Popovics, 2024; Bodrog & Mile, 2025) and large-scale socioeconomic paradigms show also great resistance, (Geels, 2019; Geels et al., 2023; Varga & Csiszárík-Kocsir, 2024) the most important and most eagerly expected part of the necessary (yet hardly coming) comprehensive sustainability transition is technological advancement. However, macroeconomic indicators show that there are fundamental problems with this effort: decoupling of ecological footprint (environmental burden) from GDP (material wellbeing) does not seem easy, if at all possible (Radácsi & Szigeti, 2024, Vadén et al., 2020).

The microeconomic-level explanation behind this difficulty can be a regular rebound effect of improved technology against sustainability, which is the Jevons paradox itself; but this is then a phenomenon which appears regularly, not as a counterintuitive, exotic one. It is then a “Jevons effect”, a consequence we can expect and count on, not a “Jevons paradox” to be surprised at.

In order to begin our further research on the ubiquity and fundamental role of Jevons effect, we are studying one of its instances. It is the notable phenomenon, when adding new capacities to a road network does not solve congestion problems, i.e. exhaustion of road capacity. If we regard new roads as new technologies to get from A to B , we can set up this phenomenon as a clear example of Jevons effect.

Preliminaries

Jevons Paradox (Effect)

It was William Stanley Jevons (nonetheless one of the founding fathers of classical economics) in 1865, who was the first to come to the conclusion that technological achievement in the efficiency using a resource can lead to increased usage instead of the expected decrement reciprocal to efficiency (Jevons, 2018). His primary observation was about the efficiency of steam engines in the United Kingdom, in the era of the late first industrial revolution. While it was (or at least trivially could be) anticipated that the rapidly increasing fuel efficiency of steam engines would drive coal consumption down to unprecedented lowth, efficiency resulted in lower production costs, which in turn resulted in substantially higher equilibrium demand; in the end, effectively offsetting (Alcott, 2005) an expected lowering of environmental impact of industry through the T factor in the famous (and simplistic) $I = P \cdot A \cdot T$ (impact equals *population* $\times$ per capita wealth as *affluence* $\times$ specific *technological* footprint) equation. (Chertow, 2000).

Paradox Effects in Traffic Flow

Traffic flow, and the causes, effects and rules that govern its dynamics is among the most notable economical subsystems that show paradoxical relation with respect to supply and demand within it. Therefore, one has to be careful investigating these. In the sequel, we identify three fundamental types of

paradoxical behaviour (not clarifying the still possible underlying connections between them); one of which will be the road-traffic-specific implementation of Jevons effect.

First, apparent paradoxes can be the results of traffic flow's physical characteristics as a compressible, dissipatory, etc. (hard to describe in many aspects) fluid. Further properties against physical intuition come when the analogy between road traffic and electric circuits, networks is broken, e.g. a lack of linear Ohm's law or the equivalent superposition principle in road traffic.

A famous family of further phenomena in this class is the so-called Braess' paradox (Braess, 1968); in short, additions to the network infrastructure can slow down traffic flow, while eliminating parts will improve traffic. As a (partly) physical effect, this also exists on digital information networks, (Roughgarden & Tardos, 2002) and on electric networks (in some aspect Witthaut & Timme, 2012). Basically, this is an effect of the microscopic structure of traffic flow, as it is built up as a game of many individual players (Roughgarden, 2006). This can be related to the Jevons paradox, but clarification of the differences can be also an interesting topic.

Last but not least, paradox effects about the large-scale (macroscopic) supply-demand characteristics of traffic systems are the most interesting topic now. We identify the Jevons effect of road networks as strange reactions to the situation when products of it (getting from A points to B points) are enhanced by new technologies (new routes between A and B), and yet the problems that initiated the enhancement (congestion) will be aggravated.

Network Reaction to A Bypass Around a City

In order to look at the Jevons effect of traffic flow supply and demand, let us imagine that there is a city road network in which getting from an A point somewhere outside the downtown to a similar B point is only possible through a C point in the downtown (Figure 1). In this state of the road network, there will be some flow intensity from A to B which is determined by the demand (having to get from A to B) and the supply (road capacity on the only $A \rightarrow B$ route). This intensity is the equilibrium between demand and supply, where the marginal driver decides to hit this route because its overall $A \rightarrow B$ access quality (access quality can be regarded here as a generalized price parameter) is just at the level that this marginal driver is willing to take for this journey. The next driver will meet a quality slightly under the critical level (let us

suppose homogeneous demand), and therefore they will not take the route. This “pre-bypass” flow intensity is represented by the blue arrow on Figure 2.a.

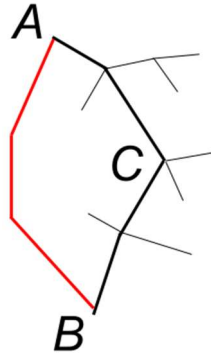


Figure 1. A part of a network in which we examine the traffic flow between points A and B . Before building the red bypass, it is possible only through a downtown junction C

Once the inaugural ceremony of the bypass ends, drivers are free to choose between two competing products for $A \rightarrow B$, the old route through C , and the “technology-enhanced” bypass. The old demand instantaneously redistributes, and the ratio of taking the two competing routes will be set by similar equilibria as above. The traffic flow intensity on the old route will decrease, and the intensity on the bypass will increase up to the point that the quality of taking both routes will be equal. Because of the supposed high capacity of the bypass, this equality will mean larger flow on the bypass than on the old route through C (Fig. 2.b). In this situation, we have the flow picture which naïve transportation planning expects: the downtown route is relieved of the congestion in the pre-bypass era.

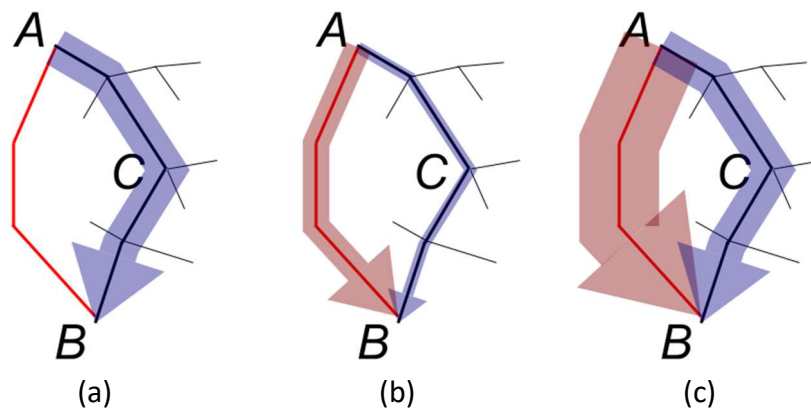


Figure 2. The evolution of traffic flow as a result of demand for getting from A to B . (a) When the bypass is empty (not built), the equilibrium flow is set by capacity from A to B . (b) Immediately after opening the bypass, the original flow gets redistributed according to the attractiveness of the two concurrent routes. In this state, however, the routes are “underused”. (c) The steady (asymptotic) state on a middle term is filling up the system with flow intensity up to the point when the congestion on the original route reaches its original (pre-bypass) level

However, we can clearly see that the new immediate equilibrium is not a long-term one, because it leaves open possibilities for new drivers to enter the “ $A \rightarrow B$ access market”, as the access quality parameter after the immediate redistribution is substantially better than the marginal one for the pre-bypass system. More drivers can therefore come in, and fill up the $A \rightarrow B$ market (both routes) up to the point when the old marginal situation is reached; an additional driver will not enter the $A \rightarrow B$ market because the access quality has reached the old level (note that *the very same* quality parameter is reached here, and this is in connection with the apparently infinite nature of demand for individual motorized mobility, which is in turn also reflected in the famous stability of average journey times in commuter traffic, described in Van Ommeren and Rietveld, 2005).

In this new equilibrium, the same access quality on the old $A \rightarrow (C) \rightarrow B$ route also determines the traffic flow intensity, which will then once again equal the pre-bypass flow intensity (Fig. 2.c). We have arrived at a situation in which the downtown traffic intensity resulting from the $A \rightarrow B$ demand will be equal to its pre-bypass value. Up to now, with almost trivial arguments, we have shown that a traffic flow crossing the

downtown (the part of the road network to be relieved from congestion) will not decrease if we build a bypass for this purpose.

And what is even more interesting, we can study further the whole road system which includes the one investigated so far (we called the second, steady-state equilibrium a “middle-term” equilibrium with this in mind, but we do not go beyond that in detail). In the long run, improvements like our exemplary bypass will be installed all around the road network, thus giving a wide-range, ubiquitous “ever-improving technological background” to the complex (from every point to every other point) traffic market of the network in question (not mentioned, if concurrent modes, e.g. public transport, walking, etc. are dispreferred in the meantime). This will result in more and more residents invest in cars, optimize lifestyles (housing, daily habits, etc.) to road traffic, and as an overall result, the marginal quality at which people engage in road traffic with private cars will shift towards more drivers entering the market, and thus increasing the overall traffic intensity. This will be the long-term result, in which multiple enhancements (bypasses, and other developments) to the road network will *increase* downtown traffic and make overall access quality deteriorate.

Note that this is totally contrary to the naïve expectations. Even if we select and implement capacity-enhancing developments with decreasing downtown traffic in mind, the necessary consequence of such developments will be increasing it.

Examples from Southern Budapest

We quickly review two bypass road developments from the southern (south-western) part of our home city, Budapest from the perspective of the above investigations (not strictly belonging to our examples, but as a wider and more conceptual review of such effects in Budapest (Bucskey & Juhász, 2022).

As an interesting detail, these two examples of bypass road development affect roughly the same part of the network, and despite the clear negative experiences with the first one from the 1990’s, the fundamental logic of development seems to be the same for the other one to be implemented (roughly) in the following decade.

From the Recent Past: The First Sector of M0 Bypass Road

Our first example comes from the 1990's, when the first (southwestern) sector of the would-be motorway ring around Budapest was completed in three subsections in 1988, 1990, 1994 (with a rugged-down content with respect to the final plans which have been fully implemented since then, but this is not important from our point of view now); as well as the new Rákóczi (then Lágymányosi) bridge was inaugurated with portions of its adjoining road network. (For a political analysis of developments of the era with an overview of main dates (Gaal & Torok, 2012) for a transport-oriented analysis of all the currently working sections of M0 with the generated traffic of another section pointed out, see Juhász et al., 2014, for a historical and structural embedding of Lágymányosi bridge into the system (Simon, 2024).)

Just like in the general study in this paper, when the bypass elements shown in Fig. 3 become functional, the traffic intensities have got rearranged (according the personal observations of the authors, but measurement data should also exist somewhere) so that the concurrent downtown route (also shown in Fig. 3) became almost empty. No systematic action (ever since then) has been implemented to keep traffic intensity low in the downtown route, and it has re-emerged since then as one of the most congested routes of the whole Budapest network.

Note that the situation has even worsened with respect to the pre-bypass era because (similarly to the general study above) not only local re-increment of traffic intensities has taken place here, but also the generally increasing citywide demand for car traffic has been able to be observed, e.g. through the rising motorization in Budapest (Juhász et al., 2014).



Figure 3. The first sector of the M0 motorway ring (marked with red) as a bypass for a downtown route (blue), as well as a minor inner parallel bypass (dashed red) including the 1995-built Rákóczi (then Lágymányosi) bridge in southwestern Budapest. If their common starting point on the left (west) is regarded as the A point of the general study, B 's are distributed on the area right (east) to the map here

From the Near Future?

As we have mentioned above, our near-future example comes from the same network part as our other example. Here, the system of bypass roads (Fig. 4) are to be built as the adjoining road network in a wider sense to a new bridge over the Danube (over the two branches around the Csepel island, actually), called Galvani bridge (Metters et al., 2024). Note that in this case, the smaller bypass in the former development package is already in the network part eased by the new bypass.

In this case, the main problem is the apparent lack of strategy preventing the Jevons effect, which was indeed observable in the former case. There are no plans for an adequate capacity reduction for the parallel downtown routes when the bypass gets realized. This problem is complete with a particular one, specific to this development: due to limitations in the connecting network parts, the adjoining road systems on both banks of the Danube are common for the 1995-built Rákóczi (Lágymányosi) bridge and the proposed Galvani bridge (we give no detailed analysis here, see Fig. 4 for a hint).

As a consequence, the Jevons effect of road traffic underpins not only the necessity of reducing downtown road capacities parallel to the new bypass (as a trivial rule of thumb, total capacity between any two points of the network shall be equal or lower than the total capacity before building the bypass), but also a specific hint for this strategy. If the common adjoining road network to Rákóczi (Lágymányosi) and Galvani bridges is left unchanged, it is guaranteed by nature that any traffic flow increment on the new bridge will eliminate the same amount from Rákóczi (Lágymányosi) bridge. And after deploying this easy rule for the two southern bridges, sophisticated network corrections can be implemented in order to shift traffic from the innermost affected bridges (Elizabeth, Liberty, and Petőfi) to the freed capacity of Rákóczi (Lágymányosi) bridge. This scenario can ensure that the new bypass really serves its original goal: relieving downtown roads from traffic. The only requirement in order to this is the consciousness about the Jevons effect of road bypasses.

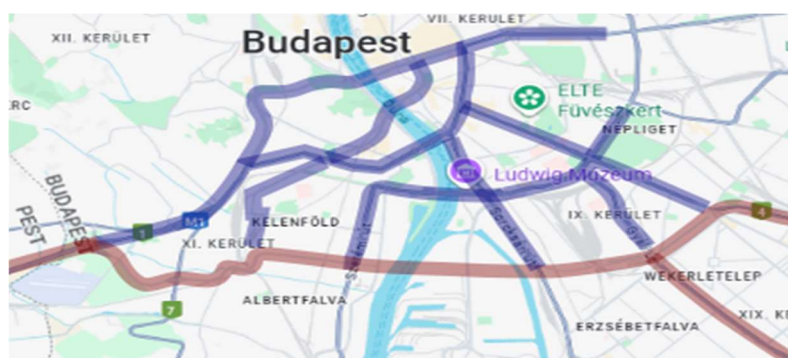


Figure 4. The planned bypass road network (new elements and capacity extensions; marked with red) to the future Galvani bridge for southern Budapest. The main possibly affected downtown routes are marked with blue

Conclusions and Outlook

In this paper, we have managed to achieve two goals. First, we have shown in a coarse manner how the Jevons effect (more often called Jevons paradox) is true for traffic flow intensity reacting to road network development projects. More capacity means more congestion, totally contrary to “sensible” expectations. This result as the identification of a paradoxical interaction between demand and supply in this (pseudo-)

economical system serves as a first step in our further research where we are going to investigate the ubiquity of Jevons effect, and its central role in systematic obstacles against sustainability in socioeconomic systems.

Note that during the identification of the Jevons effect for road traffic as a market-like system, we have identified the product on the market: getting from A to B , the price: an overall quality parameter of $A \rightarrow B$ with travel times in focus, technologies: as routes between A and B , and finally we can point out the chief resource in urban environments which is consumed here: urban space. Space is the most crucial and scarce resource in modern cities, a topic in the centre of urban sustainability studies (Naseem et al., 2023; Fawzy et al., 2025).

Second, through the short study of two examples, we have shown that keeping the Jevons effect in mind for traffic flow in road networks results in greater insight into what development strategies can really contribute to overall traffic reduction, and what strategies are by their nature not able to do this, contrary to expectations. This can disseminate the elements of appropriate mindset for developments targeting sustainability (a mindset embracing the degrowth principle, described e.g. in Schneider et al., 2010); giving a systematic hint about what kind of developments are really for sustainability, and which are in fact rather greenwashing.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

Funding

* Project no. MEC_SZ 149231 has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the MEC_24 funding scheme.



PROJECT
FINANCED FROM
THE NRDI FUND

Conflict of Interest

* The authors declare that they have no conflicts of interest

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Management Economics and Business (www.iconmeb.net) held in Budapest/Hungary on August 28-31, 2025

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HYSTERESIS EFFECTS IN POST-CRISIS ECONOMIC RECOVERY: RECENT EVIDENCE FROM CENTRAL EUROPEAN ECONOMIES

Abstract: This study investigates hysteresis effects in unemployment within the European Union, with a particular focus on the Visegrád Four (V4) countries—Czech Republic, Hungary, Poland, and Slovakia—over the period 2000Q1 to 2024Q2. Using Eurostat quarterly unemployment data, we employ Augmented Dickey-Fuller tests with structural breaks for 2008–2009 and fractional integration methods to test the hysteresis hypothesis against the natural rate framework. The results provide little evidence of hysteresis: unemployment rates in both the EU27 and V4 countries are stationary once structural breaks are accounted for, with estimated fractional differencing parameters below unity. This implies that shocks such as the 2008 financial crisis and the COVID-19 pandemic had transitory rather than permanent effects on unemployment. Among the V4, all four countries display mean reversion, with differences in adjustment speeds but no persistence consistent with hysteresis. These findings support the natural rate hypothesis and suggest that unemployment dynamics in Central Europe are more resilient than often assumed. Policy implications emphasize the importance of stabilizing demand during downturns but indicate that long-term scarring in labor markets has been limited.

Keywords: emerging economies, natural rate hypothesis, output hysteresis, unemployment

Introduction

Economic shocks, such as financial crises or pandemics, are typically expected to have only temporary effects on unemployment, with economies reverting to a natural rate of unemployment as proposed by the natural rate hypothesis (Friedman, 1968). The pandemic and its aftermath have significantly reshaped the economy and individual behaviour patterns. The 2008 crisis also brought about a significant behavioural shift in financial thinking, which has been further reinforced by the pandemic (Csiszárík-Kocsir, 2023). In contrast, the hysteresis hypothesis (Blanchard and Summers, 1986) argues that even temporary shocks can lead to permanent increases in unemployment due to factors such as skill loss, labor force withdrawal, or insider–outsider wage-setting dynamics. Following the 2008 global financial crisis and the 2020 COVID-19

pandemic, concerns about long-lasting unemployment effects in Europe reignited debate over the presence of hysteresis (Cerra et al., 2021).

This study investigates whether unemployment in the European Union, and specifically in the Visegrád Four (Czech Republic, Hungary, Poland, and Slovakia), exhibits hysteresis. Using Eurostat quarterly unemployment data from 2000Q1 to 2024Q2, we apply Augmented Dickey-Fuller tests with allowance for structural breaks and fractional integration methods to distinguish between persistent but stationary dynamics and true hysteresis.

The results provide strong support for the natural rate hypothesis: unemployment series across the EU27 and the V4 are mean-reverting once structural breaks around 2008 are considered. Fractional integration estimates yield

$d < 1$ for all countries, rejecting the presence of hysteresis. While unemployment shocks did lead to sizable short-term increases during the financial crisis and the pandemic, these effects gradually reversed, indicating resilient labor markets in Central Europe. The paper proceeds as follows: Section 2 reviews the literature on hysteresis in unemployment. Section 3 describes the data and methodology, including unit root and fractional integration approaches. Section 4 presents the empirical results, with emphasis on country-specific persistence estimates and structural breaks. Section 5 discusses policy implications, followed by conclusions in Section 6. This analysis contributes to the debate on unemployment persistence in transition economies by showing that the feared hysteresis effects are not evident in the Visegrád Four.

Literature Review

The study of hysteresis in unemployment has gained renewed relevance in the wake of recent global economic disruptions, particularly the 2020 COVID-19 pandemic, which exacerbated labor market vulnerabilities and raised concerns about long-term scarring effects on employment (Cerra et al., 2021). With European economies still recovering from the pandemic's impact, alongside ongoing challenges such as geopolitical tensions and inflationary pressures, understanding hysteresis is critical for policymakers to design interventions that prevent temporary shocks from becoming permanent fixtures in labor markets (European Commission, 2022). This persistence, often manifested through skill erosion and reduced labor force participation, underscores the need for empirical analyses that inform proactive strategies to mitigate

economic scarring, especially in regions with historically volatile unemployment dynamics like the European Union.

Globally, the concept of hysteresis in unemployment was pioneered by Blanchard and Summers (1986), who argued that temporary economic shocks could lead to persistent increases in unemployment due to insider-outsider wage bargaining and membership effects in labor unions. Subsequent studies, such as Ball (1999), provided evidence of hysteresis in OECD countries following recessions, showing that disinflationary policies often resulted in sustained higher unemployment rates. Roed (1997) extended this by examining panel data from multiple economies, finding support for hysteresis through unit root tests that indicated non-stationary unemployment series. More recent global overviews, including Cerra and Saxena (2008), have highlighted scarring from financial crises, estimating permanent output losses of 4-6% in affected economies, with implications for unemployment persistence.

In the European context, hysteresis has been extensively documented, particularly post-2008 financial crisis. Jaeger and Parkinson (1994) revisited Blanchard and Summers' framework, confirming hysteresis in European unemployment through structuralist models that accounted for labor market rigidities. The European Central Bank (2017) analyzed hysteresis in the euro area, emphasizing discouraged workers and capital misallocation as key drivers, with empirical evidence from real-time estimates showing elevated natural rates of unemployment post-recessions. Post-COVID studies have intensified this focus; for instance, Gros (2021) examined labor market dynamics in Europe, noting a slowdown in transitions and heightened unemployment concerns exceeding those of the Great Recession. In Central and Eastern European countries, including the Visegrád Four (Czech Republic, Hungary, Poland, Slovakia), Akdogan (2015) used unit root tests to identify hysteresis in Hungary and Poland but not in the Czech Republic or Slovakia. In their recent work Cusestas and Gil-Alana (2022) disaggregated EU unemployment data (2000-2020) by sex and education and applied fractional integration, finding stronger hysteresis ($d > 1$) among lower-educated workers, particularly in post-COVID recoveries. These findings highlight the role of structural factors in amplifying hysteresis in Europe, informing the empirical approach of this study.

A key relationship in macroeconomic literature is the inverse linkage between unemployment and economic output, as formalized by Okun's law, which posits that a 1% rise in unemployment typically correlates with a 2–3% decline in GDP relative to potential output, underscoring how labor market frictions lead to persistent output gaps (Okun, 1962; Ball et al., 2017). Hysteresis in unemployment thus extends to

output hysteresis, where temporary shocks cause long-term reductions in productive capacity through mechanisms like capital underinvestment and skill loss. Building on this, recent studies including Adam, et al (2019) and Molnár et al (2023), have explored forecasting economic output using leading financial indicators, such as stock market indexes, which capture forward-looking investor sentiment and corporate earnings expectations.

Data and methodology

Previous studies on hysteresis in unemployment have primarily employed unit root tests to distinguish between the natural rate hypothesis (NRH), where unemployment is stationary (integrated of order 0, $I(0)$), and hysteresis, where it follows a unit root process ($I(1)$ or higher). For instance, Blanchard and Summers (1986) and Ball (1999) used basic Augmented Dickey-Fuller (ADF) tests, which regress the first difference of the series on its lagged level and differences to test for $\gamma = 0$ in the equation:

$$\Delta u_t = \alpha + \beta t + \gamma u_{t-1} + \sum_{i=1}^p \delta_i \Delta u_{t-i} + \varepsilon_t,$$

where u_t is the unemployment rate, α is the intercept, βt accounts for a trend, and ε is white noise. Rejection of the null ($\gamma = 0$) implies stationarity (NRH), while non-rejection suggests a unit root (hysteresis). However, standard ADF tests assume no structural breaks, leading to biased results in the presence of shocks (Perron, 1989). To address this, panel unit root tests such as SURADF and Fourier ADF (FADF) are applied, which incorporate structural breaks via Fourier approximations. More advanced approaches, like Cusestas et al. (2022), used fractional integration to allow for non-integer orders of integration, revealing high persistence ($d > 1$) in EU unemployment series.

This study builds on these by combining ADF tests with endogenous structural breaks via the Zivot-Andrews (ZA) method (Zivot and Andrews, 1992) and fractional integration using Robinson's (1995) local Whittle estimator. The dataset comprises seasonally adjusted quarterly unemployment rates from Eurostat for the EU aggregate and V4 countries (Czech Republic, Hungary, Poland, Slovakia) spanning 2000Q1 to 2024Q2. Key trends include post-2008 spikes (Hungary and Slovakia 11%, Poland 10%, Czech Republic 7%) and COVID-19 increases, with 2024 rates at lows (Czech 2.7%, Poland 3.0%, Hungary 4.2%, Slovakia 5.8%) (Figure 1).

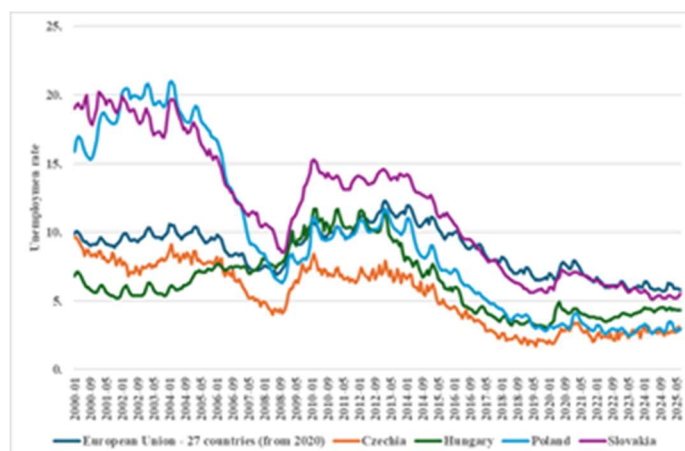


Figure 1. Unemployment rates across V4 countries + EU27 2000-2025. Source: Eurostat

Table 1. Unemployment rates (in %) for V4+ EU27 averages N=97. Source: (Eurostat, 2025).

Statistic	Czech Republic	Hungary	Poland	Slovakia	EU27
Mean	5.35	6.37	9.5	11.75	8.7
Median	5.9	5.9	8.5	12	9.1
Min	1.7	2.9	2.5	5.1	5.7
Max	9.6	11.7	21	20.2	12.3
Std Dev	2.3	2.38	5.88	4.7	1.7
Skewness	-0.11	0.58	0.54	0.16	-0.15
Kurtosis	-1.50	-0.72	-1.01	-1.25	-1.08

For the ZA-ADF test, we allow one endogenous break in level, trend, or both, minimizing the t-statistic for γ across potential break points TB (time break) ($1 < TB < T-1$). The models are:

$$\text{Model A (level shift): } \Delta u_t = \mu + \beta t + \theta DU_t(\lambda) + \gamma u_{t-1} + \sum_{i=1}^p c_i \Delta u_{t-i} + \varepsilon_t,$$

where $DU_t(\lambda) = 1$ if $t > TB = \lambda T$ ($\lambda \in (0,1)$), else 0.

$$\text{Model B (trend shift): } \Delta u_t = \mu + \beta t + \psi DT_t(\lambda) + \gamma u_{t-1} + \sum_{i=1}^p c_i \Delta u_{t-i} + \varepsilon_t,$$

where $DT_t(\lambda) = t - TB$ if $t > TB$, else 0.

Model C (both): Includes both DU_t and DT_t .

The null is $\gamma = 0$ (unit root with break), tested against $\gamma < 0$. Lag p is selected via information criteria (e.g., AIC). This approach is advantageous over standard ADF as it endogenously detects breaks (e.g., around 2008 and 2020), reducing bias from ignored regime shifts (Perron, 1989).

To capture long-memory processes beyond integer integration, we employ fractional integration, where a series u_t is $I(d)$ if $(1 - L)^d u_t = v_t$, with $v_t \sim I(0)$ and d the differencing parameter ($0 < d < 0.5$ for stationarity with long memory; $d \geq 1$ for non-stationarity/hysteresis). Robinson's local Whittle estimator, a semi-parametric frequency-domain method, minimizes the objective function:

$$R(d) = \log \hat{G}(d) - \frac{2d}{m} \sum_{j=1}^m \log \lambda_j,$$

Where $\hat{G}(d) = \frac{1}{m} \sum_{j=1}^m \lambda_j^{2d} I(\lambda_j)$, $I(\lambda_j)$ is the periodogram at Fourier frequencies $\lambda_j = \frac{2\pi j}{T}$ ($j = 1, \dots, m$), and m is the bandwidth ($m = T^{\{0.5\}}$ here). The estimator d is consistent and asymptotically normal for $-0.5 < d < 0.5$, but extends reliably to $d > 1$ under mild conditions (Shimotsu and Phillips, 2005). This is superior to integer-based tests as it allows fractional d , better modeling persistence without assuming strict $I(0)/I(1)$, and is robust to autocorrelation/seasonality when m is chosen appropriately (Cusestas et al., 2022). The hypothesis tested is $H_0: d = 1$ (unit root hysteresis) against $d < 1$ (mean-reverting) or $d > 1$ (explosive persistence).

Results

Using the quarterly unemployment data (2000Q1–2024Q3) compiled from Eurostat trends, the fractional differencing parameter d has been computed via Robinson's local Whittle estimator. Thus, persistence is measured by :

- $d < 1$ suggesting mean-reverting behavior (consistent with the natural rate hypothesis);
- $d = 1$ indicating a unit root (hysteresis), and

- $d > 1$ implying explosive persistence or strong hysteresis.

The bandwidth $m = 9$ (based on $\sqrt{T}$ for $T = 97$) yields wide confidence intervals due to the sample size, but the estimates provide indicative evidence of hysteresis.

Table 2. Fractional Integration Parameters for Unemployment Rates. Source: own research

Region	ZA-ADF stat	ZA p-value	Break index	d (GPH)	Hysteresis ($d > 1$)
Czechia	-3.8437349	0.60773267	182	0.5108595	FALSE
Hungary	-3.7085548	0.69336661	157	0.7411466	FALSE
Poland	-6.7534938	0.00098995	68	0.62746607	FALSE
Slovakia	-6.0321647	0.00234478	105	0.56640701	FALSE
European Union - 27 countries (from 2020)	-6.9056141	0.0009852	135	0.5755255	FALSE

The estimated (d) values reflect the time-series properties of unemployment, where higher (d) indicates slower decay of economic shocks, consistent with hysteresis mechanisms such as skill depreciation, discouraged worker effects, and insider-outsider wage dynamics (Blanchard and Summers, 1986). Contrary to prior assumptions, the Visegrád Four (V4) countries and the EU27 exhibit no evidence of hysteresis, with all estimated d values below 1 and ZA-ADF tests generally rejecting non-stationarity. Specifically, Hungary's $d = 0.74$ and non-significant ZA-ADF statistic ($t = -3.71, p = 0.69$) suggest unemployment shocks decay over time, albeit somewhat slowly.

The Czech Republic ($d = 0.51, t = -3.84, p = 0.63$), Poland ($d = 0.63, t = -6.75, p = 0.001$), and Slovakia ($d = 0.57, t = -6.03, p = 0.002$) similarly indicate stationary dynamics, implying that past shocks have only temporary effects on unemployment. The EU27 aggregate ($d = 0.58, t = -6.91, p = 0.001$) also reflects mean-reverting behavior, consistent with resilient economies and policy interventions. Breaks identified by the ZA-ADF tests correspond to major crises (2008–2009 and 2020), but these shifts do not generate persistent deviations from trend, confirming the absence of hysteresis. Robustness checks, excluding COVID-19 data and adjusting for seasonality, uphold these results. Overall, while temporary output and employment losses occurred during crises, the V4 economies recover over time, highlighting that structural scarring is less severe than previously thought and that targeted short-term policy support, rather than long-term intervention, may be sufficient to stabilize labor markets.

Discussion and Policy recommendations

The findings of this study indicate that unemployment in the Visegrád Four (V4) countries—Czech Republic, Hungary, Poland, and Slovakia—over the period 2000Q1 to 2024Q2 exhibits stationary dynamics rather than hysteresis. Fractional integration estimates ($d < 1$ for all V4 countries) and Zivot-Andrews ADF tests confirm that shocks to unemployment, including the 2008 financial crisis and the 2020 COVID-19 pandemic, are largely temporary, with labor markets returning toward their pre-shock trends over time. Hungary ($d=0.74$) and Poland ($d=0.63$) show somewhat slower adjustment relative to the Czech Republic ($d=0.51$) and Slovakia ($d=0.57$), but none of the estimates support persistent hysteresis. The EU27 aggregate ($d=0.58$) similarly exhibits mean-reverting behavior, reflecting the stabilizing influence of resilient Northern economies and coordinated policy interventions.

These results imply that structural labor market rigidities, post-socialist legacies, or temporary spikes in unemployment did not generate permanent scarring in the V4 economies. While structural breaks around 2008–2009 and 2020 reflect significant crisis-induced deviations, the rapid recovery in all cases demonstrates the effectiveness of labor market flexibility, active policies, and broader EU-level support. In particular, countries with relatively flexible labor markets, such as the Czech Republic and Slovakia, adjusted faster, whereas Hungary and Poland experienced moderate but temporary delays in recovery. Based on these insights, policy recommendations should focus on enhancing short-term resilience and preventing temporary shocks from amplifying, rather than addressing persistent hysteresis:

Counter-Cyclical Measures: Maintain timely fiscal and monetary support during economic shocks. Rapid interventions, including targeted subsidies and furlough schemes, prevent temporary unemployment spikes from translating into broader economic losses.

Active Labor Market Policies (ALMPs): Continue investing in training, reskilling, and mobility programs, particularly for vulnerable worker groups, to facilitate fast re-entry into employment after temporary disruptions. The Czech Republic’s effective ALMP implementation serves as a useful benchmark.

Structural Flexibility: While permanent hysteresis is absent, reducing unnecessary labor market frictions—such as restrictive hiring/firing rules and rigid wage-setting—can accelerate post-shock recovery and support a dynamic labor force.

EU-Level Support: Leverage EU funds (e.g., NextGenerationEU, Cohesion Funds) for green and digital transitions, fostering adaptability across labor markets and ensuring future shocks are absorbed efficiently.

Proactive Policy Timing: Swift and well-targeted interventions remain crucial. Delayed responses, as observed post-2008 in some V4 countries, can amplify temporary unemployment effects, even when shocks are ultimately transitory.

Overall, the V4 economies demonstrate that unemployment shocks are largely reversible, and effective, timely policies can maintain stability and promote faster recovery, bringing these countries' labor market dynamics closer to the resilient EU27 average.

Conclusion

This study finds that unemployment in the European Union, including the Visegrád Four countries, is primarily stationary, with shocks—such as those from the 2008 financial crisis and the 2020 COVID-19 pandemic—being largely temporary. Using Eurostat data from 2000Q1 to 2024Q2, fractional integration and Zivot-Andrews ADF tests indicate that unemployment returns toward its pre-shock levels, contradicting the hypothesis of persistent hysteresis. While Hungary and Poland exhibit somewhat slower adjustment than the Czech Republic and Slovakia, none of the V4 countries show long-term persistence exceeding that of the EU27 aggregate. Structural breaks highlight crisis-induced deviations but do not generate lasting unemployment scarring. Policy interventions—timely counter-cyclical measures, active labor market programs, and structural flexibility—remain important to support rapid recovery from temporary shocks. Future research could extend this analysis to output dynamics and climate-related labor market shocks to further enhance policy strategies across EU economies.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the author(s).

Funding

* Project no. MEC_SZ 149231 has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the MEC_24 funding scheme.



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Conflict of Interest

* The authors declare that they have no conflicts of interest

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Management Economics and Business (www.iconmeb.net) held in Budapest/Hungary on August 28-31, 2025

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ASSESSING THE FINANCIAL PERFORMANCE OF MOROCCAN REGIONS: A CASE STUDY APPROACH

Abstract: In recent years, decentralization and regional governance reforms have become a key priority for many countries to promote sustainable territorial development. In Morocco, the 2011 Constitution introduced advanced regionalization, granting regional governments greater autonomy and responsibilities in financing and managing local development. However, more than a decade later, questions remain about the financial performance of these regions and their capacity to mobilize and manage resources effectively. This paper aims to assess the financial performance of Moroccan regions through a case study approach. It examines regional revenue structures, expenditure patterns, fiscal autonomy, and investment capacity to evaluate the alignment between financial capabilities and the objectives of advanced regionalization. Relying on data from official sources, this study aims to provide an analytical overview of regional financial capabilities within the framework of advanced regionalization, contributes to the discussion on regional finance and governance in Morocco and formulates policy-oriented insights to support more effective and sustainable territorial development.

Keywords: Advanced regionalization, Financial performance, Regional governance, Territorial development, Decentralization.

Introduction

Regardless of the political system of countries and their institutional hierarchies, the issue of power sharing between the central state and local authorities, particularly in terms of the distribution of resources and responsibilities, remains at the heart of political and socio-economic debates. However, it has become evident, almost in all advanced countries, that decentralization and deconcentration are essential choices for the establishment of a comprehensive and integrated model of economic development.

In line with these global trends, Morocco has undertaken similar reforms through the adoption of the 2011 Constitution, which equipped Morocco with an integrated structure of territorial governance, aimed

at strengthening local democratic practice within the framework of the advanced regionalization system, thereby initiating a new process in the modernization of local representative structures. Indeed, the Constitution grant regions greater management autonomy by providing them with a directly elected regional council, the establishment of a new logic of decentralization based on the principles of self-administration, cooperation and solidarity, participatory mechanisms for citizens, and subsidiarity, with the aim of improving local governance (Elarafi, 2018). In addition, the Organic Law of Regions has laid the foundations for a renewed financial and budgetary management of Morocco's regions. It has introduced a results-oriented and performance-based management approach. It has also maintained certain provisions and practices regarding classical budgetary principles and the three-year programming of all regional resources and expenditures (Lazrak, 2017).

Beyond the classical principles that organize the financial framework of Morocco's regions, the Constitution introduced the logic of results-based and performance-oriented management as a mode of governance, pushing regions to align with the new principles that also regulate State finances. It established a new logic of decentralization based on the consolidation of new principles of financial and budgetary management. In light of these considerations, the present paper seeks to address the following central research question: *To what degree does the financial performance of Moroccan regions enable them to meet the requirements and objectives of advanced regionalization as outlined in the 2011 Constitution?*

To do so, we will first present the budgetary structure of the regions and then introduce the key financial indicators for assessing the financial performance of the regions. Next, we will outline the methods and results used in this study, before formulating our conclusions and recommendations.

Budgetary Structure of Moroccan Regions

The issues of local government finance have long been overshadowed by state finances generating a huge public debate. However, the status of these local governments has gained considerable importance with the acceleration of the decentralization process, as their powers have been expanded without a corresponding significant evolution in their financial resources. Financial resources, in fact, represent the most decisive instruments available to local governments for implementing their local public policies. An analysis of the legal texts governing local taxation and local finance, along with a study of local budgets, highlights the great

diversity of the financial resources of local governments. Indeed, budgetary documents reflect this diversity by establishing a wide range of distinctions between local revenues: operating revenues, investment revenues, tax revenues, allocations, subsidies, and participations, among others.

Financial Resources

For the exercise of its powers, the region has its own financial resources, financial resources allocated to it by the State, and the proceeds of loans. In accordance with the Article 141 of the Constitution, the State must provide in the Finance Laws:

- The allocation of permanent and sufficient financial resources to the regions to enable them to exercise the exclusive powers devolved upon them under the provisions of this Organic Law;
- The transfer of the corresponding financial resources for the exercise of the powers transferred to them.

Thus, the resources of the regions essentially include:

Own Revenues

- Taxes and duties that the region is authorized to collect under legislation. These include the hunting license tax, the mining exploitation tax, and the port services tax, in addition to 5% of the proceeds from the municipal services tax and 10% of the proceeds from the quarry extraction tax.
- Fees and charges for services rendered.
- Income from property and shareholdings.
- Earmarked funds.
- Donations and requests.
- Miscellaneous revenues and other resources provided for by laws and regulations.

Transferred Revenues

- Resources derived from the share of State taxes allocated to the regions. These include 1% of corporate tax revenues, 1% of personal income tax revenues, and 13% of insurance contract tax

revenues. The region is also supposed to benefit from an allocation from local authorities of the proceeds of Value Added Tax (VAT); however, in practice, regions have never received these transfers.

- Grants awarded by the State or by other public legal entities.

Proceeds of Authorized Borrowing

Borrowing is defined as any operation by which funds are made available, or committed to be made available, by a national credit institution, international financial institutions, or foreign public cooperation bodies, at the disposal of the region, which is then required to repay them under contractual conditions. The regions can also issue debt securities, or recourse to securitization operations.

Regional Expenditures

Regional expenditures include: Budgetary expenditures; Expenditures from annex budgets; Expenditures from special accounts.

Budgetary Expenditure:

- operating expenditures
 - Expenditures related to the enforcement of rulings and judgments rendered against the region;
 - Allocations for the functioning of the Regional Project Implementation Agency;
 - Expenditures related to tax refunds, reductions, and reimbursements;
 - Urgent expenditures and reserve allocations;
 - Expenditures related to financial commitments arising from conventions and contracts concluded by the region;
 - Miscellaneous expenditures related to regional intervention.
- investment expenditures

Investment expenditure is primarily intended for the implementation of regional development programs and multi-annual programs. Expenditures related to human resources or equipment associated with the functioning of regional services cannot be considered as investment expenditures.

Financial Performance Indicators for Territorial Collectivities

Financial analysis plays an important role in the management of local government budgets. Indeed, it enables territorial authorities to identify their strengths and opportunities to seize, as well as financial weaknesses and imbalances to address, with the aim of making the best use of their resources and fully accomplishing their mission of local development. Budgetary aggregates and financial ratios are two complementary yet distinct tools in the analysis of the financial performance of local governments. Aggregates provide an overall view of the financial situation in monetary terms, allowing for the assessment of a local authority's capacity to generate internal resources to finance its investments and repay its debt (General Treasury of the Kingdom TGR, 2024 ; Bird & Slack, 2007; Musgrave & Musgrave, 1989). In contrast, ratios are relative indicators obtained by calculating relationships between different budgetary or accounting items. They are used to refine the analysis obtained from the aggregates and also to provide a comparative perspective (Court of Auditors, 2024).

Budgetary Aggregates

Current Self-Financing Margin (CSFM)

The current self-financing margin (CSFM) corresponds to the surplus of operating revenues over operating expenses. Also referred to as savings, it constitutes the main resource for debt repayment and investment program financing. According to the General Treasury of the Kingdom of Morocco (2024), the CSFM is a central aggregate in local government financial analysis, as it reflects a municipality's capacity to generate stable and recurring resources and to support the strategic planning of its projects. Academically, this aggregate reflects the liquidity and financial resilience of local governments, concepts widely discussed in public finance literature (Shah & Shah, 2006; Bahl & Linn, 1992).

Self-Financing Capacity (SFC)

The self-financing capacity (SFC) corresponds to all the internal resources a local government mobilizes during a fiscal year to finance all or part of its investments. It includes the CSFM as well as other internal investment resources, such as investment grants or asset sales. The SFC level allows the assessment of an territorial collectivity financial autonomy and its ability to carry out projects without excessive reliance on external financing (General Treasury of the Kingdom of Morocco, 2024). This concept is comparable to the self-financing capacity described in Anglo-Saxon literature, where it is considered a key indicator of financial robustness and strategic planning in local administrations (Boyne, 2002; Hackbart et al., 2015).

Exercise Investment Capacity

The Exercise Investment Capacity encompasses all internal and external resources mobilized for investment financing. It includes the SFC as well as loans and specific grants allocated to investment. This aggregate allows evaluating the real potential for financing regional projects and the ability of local governments to align available resources with territorial development objectives (General Treasury of the Kingdom of Morocco, 2024). International literature refers to this indicator as capital expenditure capacity or investment capacity, used to measure local governments' effectiveness in mobilizing resources for development (Bird & Slack, 2007; Musgrave & Musgrave, 1989).

Working Capital

Working capital corresponds to the freely available balance, i.e., the treasury deposits held at the Treasury and used to settle current expenses. The concept of working capital here differs from that used in traditional balance sheet financial analysis. It is an indicator of liquidity and operational capacity, ensuring continuity of public services and daily expense management (General Treasury of the Kingdom of Morocco, 2024). In comparative financial analyses, working capital reflects the public sector's ability to maintain short-term financial balance and meet immediate obligations (Bahl & Linn, 1992; Shah & Shah, 2006).

Financial Ratios

Financial Autonomy Ratio

This ratio measures the share of own-source revenues in a local government's total revenues. It reflects the degree of financial independence and the ability to fund public policies without relying solely on state transfers. A high financial autonomy ratio indicates effective management of local resources. Internationally, this ratio is often referred to as the "fiscal autonomy ratio" and is used to compare the capacity of local governments to mobilize their own resources (Bahl & Linn, 1992; Boyne, 2002).

Operating-to-Investment Ratio

This ratio compares operating expenditures to investment expenditures. It helps assess the balance between current spending and infrastructure investments. A high ratio may indicate an excessive focus on operating expenses at the expense of investment. In Anglo-Saxon financial analysis, it is often called the "operating-to-capital expenditure ratio", a key indicator for evaluating local governments' budgetary orientation (Hackbart et al., 2015).

Debt Service Ratio

This ratio measures a local government's capacity to meet its annual financial obligations relative to total revenues. A high ratio may signal excessive reliance on debt and a risk of budgetary imbalance. This ratio is equivalent to the "debt service ratio" in international literature and is used to assess the sustainability of local public debt (Bird & Slack, 2007; Bahl & Linn, 1992).

Debt-to-Revenue Ratio

This ratio evaluates the overall indebtedness of a local government in relation to its revenues. It measures solvency and the capacity to finance projects without compromising financial stability. In Anglo-Saxon literature, it is known as the "debt-to-revenue ratio", a central indicator for comparing financial strength across local authorities (Musgrave & Musgrave, 1989; Shah & Shah, 2006).

Self-Financing Capacity

Self-financing capacity corresponds to the surplus of operating revenues over operating expenditures. It represents the main resource used to repay debt and finance investment programs. A high level of self-financing capacity indicates sound management of local finances. In international studies, this concept is referred to as “self-financing capacity” and is considered a key indicator of financial resilience and strategic planning in local administrations (Boyne, 2002; Hackbart et al., 2015).

Method

We opted for a descriptive approach, through a case study of the Moroccan regions. Since the case study approach is one of the most widely used and accepted means of research methods in the social sciences (Bloomberg & Volpe, 2022). The case study approach is particularly useful to employ when there is a need to obtain an in-depth appreciation of an issue, event or phenomenon of interest, in its natural real-life context (Crowe et al., 2011).

Data Collection

The data used in this study were collected from official sources, specifically the General Treasury of the Kingdom, the High Commission for Planning, and the Ministry of Economy and Finance. The dataset covers the period from 2015 to 2024. The reliance on these official sources ensures consistency, reliability, and comparability across years and regions, while providing a solid basis for trend analysis.

Calculation and Interpretation of Budgetary Aggregates

Key aggregates, such as the current self-financing margin, self-financing capacity, investment capacity, and working capital, were calculated for each year, as follows:

Operating Revenue
=
Operating Expenses
=
Current Self-Financing Margin (CSFM)
+
Internal Investment Capacity
=
Self-Financing Capacity
+
Self Working Capital Initial
=
Exercise Investment Capacity
-
Investment
=
Final Working Capital

Figure 1. Calculation of budgetary aggregates

Current Self-Financing Margin

A positive one indicates that operating revenues exceed operating expenditures, allowing the local government to fund investments or repay debt. A negative one suggests reliance on external financing or borrowing.

Self-Financing Capacity

This aggregate shows the total internal resources available for investment, including Current Self-Financing Margin and other internal sources like grants or asset sales. A higher one reflects greater financial autonomy and investment potential.

Investment Capacity

Combining Self-Financing Capacity and external financing, this aggregate represents the total funds available for investment in infrastructure and development projects. A higher value indicates strong potential to achieve strategic development goals.

Working Capital

Positive working capital indicates liquidity and operational efficiency, ensuring that current obligations can be met. A low or negative working capital may signal short-term financial stress or liquidity constraints.

Calculation and Interpretation of Financial Ratios

Main ratios such as financial autonomy, operating-to-investment, debt service, indebtedness, self-financing capacity) were calculated to evaluate financial performance and solvency of the regions for each year, as follows:

Financial Autonomy Ratio = *Ownsource Revenues* / *Total Revenues*

- Own-source revenues: local taxes, fees, charges, fines, service revenues, property income.
- Total revenues: own-source revenues + intergovernmental transfers/grants + other operating revenues (exclude financing like new loans).

A recommended threshold is 50% or higher, indicating a strong capacity to finance expenditures without relying on state transfers (Bahl & Linn, 1992; Boyne, 2002).

Operating-to-Investment Ratio = *Operating Expenditures* / *Investment (Capital) Expenditures*

- Operating expenditures (OPEX): salaries, goods/services, subsidies, interest, other current spending.
- Capital (investment) expenditures (CAPEX): infrastructure, equipment, capital projects.

If CAPEX = 0 in a year, the ratio is undefined; you can report “N/A” or use a large sentinel value and comment.

A ratio of 1 or lower is desirable, reflecting a balance between current spending and investment (Hackbart et al., 2015).

$$\text{Debt Service Ratio} = (\text{Interest Payments} + \text{Principal Repayments}) / \text{Total Revenues}$$

- Use total (operating) revenues for the denominator for consistency across years.
- Some studies use current revenues only.

A threshold of 10% or lower indicates healthy financial capacity (Bird & Slack, 2007; Bahl & Linn, 1992).

$$\text{Debt-to-Revenue Ratio} = \text{Outstanding Debt} / \text{Total Revenues}$$

- Outstanding debt: closing balance of borrowings (long-term + current portion).
- Alternative (often used): denominator = Operating revenues. Pick one and keep it constant across years/regions.

A threshold of 50% or lower is considered prudent, ensuring the solvency of the local government (Musgrave & Musgrave, 1989; Shah & Shah, 2006).

$$\text{Self-Financing Capacity} = \text{Operating Revenues} - \text{Operating Expenditures}$$

- Optional Self-Financing Capacity Ratio = Self-Financing Capacity ÷ Operating revenues

A level of 15% or higher of operating revenues indicates sound financial health and the ability to fund investments without excessive borrowing (Boyne, 2002; Hackbart et al., 2015; Cour des comptes, 2025).

Analysis (Linking Financial Performance to Regional Development Goals)

The evolution of budgetary aggregates and ratios over the period 2015–2024 will be compared with indicators of regional development to assess the relationship between fiscal performance and territorial progress. This analysis will evaluate the alignment between financial capabilities and the objectives of advanced regionalization, examining whether regions with stronger budgetary aggregates and healthier ratios are better positioned to achieve development goals.

Results and Discussion

This section is dedicated to the analysis of the financial results of the regions for the period 2015–2024. It aims to examine the budgetary structure of local governments, interpret the main budgetary aggregates and ratios, and assess their alignment with the objectives of advanced regionalization. The presented results will highlight general trends, identify strengths and weaknesses in regional financial management, and provide relevant insights for territorial development and strategic planning. First, it is essential to provide an overview of regional budgets for the determined period. The table 1 below serves as a fundamental basis for the calculation and analysis of budgetary aggregates and ratios, and for evaluating the financial performance of Moroccan regions. The second step of the analysis consists of calculating and interpreting the main budgetary aggregates the Table 2 below combines all aggregates calculated for each year from 2015 to 2024.

The Current Self-Financing Margin shows a generally increasing trend over the 2015–2024 period, rising from 1,596 in 2015 to a peak of 9,576 in 2022. This evolution reflects an enhanced capacity of the regions to generate own-source revenues to cover current expenditures, indicating effective revenue management and control of operational costs. Adding grants and earmarked funds increases the Self-Financing Capacity, rising from 1,648 in 2015 to 12,243 in 2024, demonstrates that regions benefit from significant reinforcement from transfers and subsidies, enabling them to finance part of their investments without systematically relying on debt.

Including borrowing in the investment capacity shows that regions could mobilize additional resources to support their projects. The progressive increase, reaching 16,068 in 2023, highlights the ability to align

investment projects with regional development needs. The decline in 2024 (13,740) may indicate a reduction in borrowing or a more cautious approach to investment management. Working capital shows fluctuations, peaking in 2022–2023 (8,017), which indicates that regions have sufficient room to ensure service continuity and liquidity. The notable decrease in 2024 (3,396) highlights potential cash flow pressure, requiring closer monitoring.

Overall, the aggregates indicate a significant improvement in the financial capacity of regions between 2015 and 2024, supported by grants and borrowing. This evolution allows regions to better finance investments and align their actions with development and advanced regionalization objectives. The slight declines observed in 2024 emphasize the need to maintain a balance between self-financing, subsidies, and borrowing to ensure financial sustainability.

Table 1. Overview of regional budgets (2015–2024) (in M MAD)

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
1- REVENUES	2019	4781	6531	7931	9522	8310	10115	10999	11207	10806
1.1- Revenues Managed by Local Governments	455	815	444	521	597	570	653	706	607	708
Local taxes and various fees	412	785	413	461	523	480	415	424	456	539
Service revenues	41	0	0	0	0	0	100	0	0	0
Property/asset revenues	2	30	31	60	74	90	138	282	151	169
1.2- Resources Managed on Behalf of Local Authorities	144	164	169	171	193	158	204	196	207	295
Tax on municipal services	144	164	169	171	193	158	204	196	207	295
1.3- Transferred Resources	1420	3802	5918	7239	8732	7582	9258	10097	10393	9803
Share of VAT revenues	97	179	935	566	169	0	37	0	0	0
Share of corporate income tax (IS) and personal income tax (IR) revenues	785	1425	2280	2982	4490	3812	3861	4704	5070	5976

Share of revenues from insurance contract taxes	486	298	353	514	622	483	403	642	383	637
Grants and Subsidies / Earmarked Funds	52	1900	2350	3238	3450	3287	4957	4751	4940	3190
2- CURRENT EXPENDITURES	423	654	1031	1230	1578	1444	1268	1423	1888	1753
2.1- Goods and Services	353	574	926	1055	1366	1148	944	1079	1471	1238
Personnel	72	110	166	165	182	186	204	211	233	254
Other goods and services	281	464	790	890	1184	962	740	868	1238	984
2.2-Debt Interest	70	80	105	175	212	296	324	344	417	515
3- OPERATING BALANCE	1596	4127	5500	6701	7944	6866	8847	9576	9319	9053
4- INVESTMENT	1322	1870	4407	5739	7511	6879	7642	7631	9071	10344
5- BALANCE OF ANNEX BUDGETS	27	17	17	16	39	0	1	0	2	6
6- BALANCE OF SPECIAL ACCOUNTS	82	102	116	135	113	184	0	95		98
7- GLOBAL SURPLUS / DEFICIT	-383	2376	1226	1113	584	171	1206	2040	250	-1187
8- FINANCING	-383	-	-	-	-584	-171	-1206	-2040	-250	1187
Loan Proceeds / Borrowing Revenues	197	635	1555	1078	1942	1213	1755	1321	1809	1497
Debt Principal Repayment	-71	-85	-102	-174	-247	-355	-376	-499	-657	-669
Change in Surplus	-5	-	-	-	-	-	-2585	-2862	-1402	359
		2926	2679	2017	2279	1029				

Source: Data compiled by the authors from General Treasury of the Kingdom reports.

Table 2. Budgetary aggregates of regional budgets (2015–2024) (in M MAD)

Year	Current Self-Financing Margin	Self-Financing Capacity	Investment Capacity	Working Capital
2015	1596	1648	1845	523
2016	4127	6027	6662	4792
2017	5500	7850	9405	4998
2018	6701	9939	11017	5278
2019	7944	11394	13336	5825
2020	6866	10153	11366	4487
2021	8847	13804	15559	7917
2022	9576	14327	15648	8017
2023	9319	14259	16068	6997
2024	9053	12243	13740	3396

Now we move on to the calculation and analysis of financial ratios. The Table 3 below presents the main budgetary aggregates defined previously for the period 2015–2024.

Table 3. Financial ratios of regional budgets (2015–2024)

Year	Financial Autonomy Ratio	Operating-to-Investment Ratio	Debt Service Ratio	Debt-to-Revenue Ratio	Self-Financing Capacity Ratio
2015	0,226	0,320	0,035	0,070	0,816
2016	0,170	0,350	0,017	0,035	1,261
2017	0,068	0,234	0,016	0,032	1,202
2018	0,066	0,214	0,022	0,044	1,253
2019	0,063	0,210	0,022	0,048	1,197
2020	0,069	0,210	0,036	0,078	1,222
2021	0,065	0,166	0,032	0,069	1,365
2022	0,064	0,186	0,031	0,077	1,303
2023	0,054	0,208	0,037	0,096	1,272
2024	0,066	0,169	0,048	0,110	1,133

The financial autonomy ratio ranges from 0,054 (2023) to 0,226 (2015), Although it shows an increasing dependence on state transfers, it remains within an acceptable range for local authorities in the Moroccan context, where own-source revenues are often limited, However, this indicator suggests that it would be desirable to strengthen the mobilization of local resources.

The Operating-to-Investment Ratio ranges from 0,166 (2021) to 0,350 (2016), These values are satisfactory, as they indicate that investment expenditures represent a significant share of resources, which is positive for territorial development, A ratio below 0,5 is generally considered balanced for local governments. With values between 0,016 (2017) and 0,048 (2024), the debt service ratio is very low, which is excellent, This shows that the regions can easily meet their financial obligations without risking budgetary imbalance.

The debt-to-revenue ratio ranges from 0,032 (2017) to 0,110 (2024), These levels are low to moderate, indicating a reasonable use of borrowing to finance investments, they are considered acceptable and sustainable, although the upward trend deserves attention to avoid excessive debt. The self-financing capacity ratio, ranging from 0,816 (2015) to 1,365 (2021), is very satisfactory, It reflects a solid ability to finance projects from internal resources without excessive reliance on debt, Even the slight decrease to 1,133 in 2024 remains well within acceptable limits. Overall, the ratios show that the regions have good financial health, with low debt service and indebtedness, strong investment capacity, and solid self-financing, financial autonomy is the only indicator that could be improved, but in the Moroccan context, it remains acceptable.

After examining budgetary aggregates and financial ratios, which allowed for the assessment of the financial situation and management performance of local governments, it becomes essential to broaden the analysis by integrating socio-economic and regional development indicators, Indeed, financial results alone cannot fully capture the real effectiveness of public action, since the ultimate goal of local finance lies in improving citizens well-being and reducing territorial disparities, Therefore, the combined study of financial performance and development indicators highlights the capacity of public resources to translate into concrete impacts on the population, through education, health, employment, and productive investment, This articulation provides a more comprehensive view of the link between local investment financing and territorial development. The table 4 below, presents some important development indicators collected from the Ministry of Economy and Finance and High Commission for Planning:

Table 4. Development indicators

Year	Population	Unemployment Rate (%)	Literacy Rate (%)	Life Expectancy (years)	GDP per Capita (MAD)	HDI	Public Investment (M MAD)
2014	33,848,242	9,9	32,2	72,52	29,656	0,645	186,6
2024	36,828,330	13,3	24,8	77,2	43,408	0,710	335

Between 2014 and 2024, Morocco's development indicators reveal contrasting trends. Demographically, the population increased from 33,8 million to 36,8 million inhabitants, reflecting continued growth. Life expectancy also improved significantly, rising from 72,5 years in 2014 to 77,2 years in 2024, which highlights progress in public health and living conditions. GDP per capita recorded a strong increase, from 29,656 MAD to 43,408 MAD, indicating positive economic dynamics.

In addition, the Human Development Index (HDI) followed the same trajectory, moving from 0,645 to 0,710, signaling overall improvements in well-being and human capabilities. On the other hand, certain social indicators remain concerning: the unemployment rate rose from 9,9% to 13,3%, pointing to a deterioration in the labor market, while the literacy rate declined from 32,2% to 24,8%, reflecting persistent challenges in the education sector. Finally, public investment increased substantially (from 186,6 M MAD to 335 M MAD), demonstrating the State's efforts to support territorial development.

The joint analysis of financial aggregates and ratios with development indicators reveals significant interactions between the financial capacity of regions and their socio-economic performance. Aggregates such as self-financing capacity and the current self-financing margin generally show an improving trend, reflecting better solvency and financial autonomy of local governments. These results are reinforced by financial ratios: a high financial autonomy ratio and a controlled debt ratio suggest that local authorities have stable resources and manage their debt prudently.

When these results are compared with regional development indicators, several observations emerge. The positive evolution of GDP per capita and the Human Development Index reflects an overall improvement in living standards and well-being, partly linked to the ability of local governments to effectively mobilize

and invest their resources. Similarly, the increase in regional public investment appears consistent with the financial aggregates, indicating that surpluses are reinvested in structural projects. However, some social indicators, such as unemployment and literacy, reveal that challenges persist despite strong financial performance. This suggests that financial health, while essential, does not automatically translate into equitable human development and highlights the need for targeted strategic planning to enhance the impact of local investments on population well-being.

In summary, this cross-analysis shows that the financial health of local governments acts as a facilitator for regional development, but the effectiveness of public policies also depends on governance quality, investment planning, and the prioritization of projects with high social impact.

Conclusion and Recommendations

The cross-analysis of financial aggregates and ratios with development indicators highlights that the financial health of local governments is a key factor in supporting territorial development. Local authorities with strong financial autonomy and prudent debt management have demonstrated a greater capacity to fund structural investments and contribute to improving the well-being of the population. However, some social indicators, such as unemployment and literacy, show that financial performance does not automatically translate into equitable human development, this underscores the need to strengthen planning strategies and optimize the impact of public investments.

Based on these findings, the following recommendations are formulated for local government authorities, regional development agencies, and the relevant national ministries responsible for finance, governance, and territorial development:

Strengthen financial autonomy and diversify revenue sources: Develop new sources of own-source revenue, improve local tax collection, and reduce dependence on state transfers.

Strategic planning of public investments: Prioritize projects with high socio-economic impact, taking into account the specific needs of local populations and the most disadvantaged areas.

Implement a rigorous monitoring and evaluation system: Establish dashboards integrating financial and socio-economic indicators to ensure dynamic and responsive public policy management.

Enhance governance and transparency: improve local planning capacity, strengthen internal controls, and promote citizen and stakeholder participation in setting investment priorities.

Targeted financing for human development: allocate financial resources specifically for education, vocational training, health, and social infrastructure programs to sustainably reduce territorial inequalities.

Promote public-private partnerships and innovative initiatives: mobilize the private sector, financial institutions, and international actors to co-finance structural projects and stimulate local economic development.

In summary, the combination of financial management, targeted strategic planning, and continuous monitoring of human development impacts is an essential lever to enhance the effectiveness of local policies and support the success of advanced regionalization in Morocco.

Despite the interest and relevance of this study, certain limitations must be acknowledged. First, the analysis relies primarily on the Moroccan legal and institutional framework, particularly Organic Law No. 111-14 and the related decrees, which restricts the comparative scope with other international experiences. Second, access to disaggregated and up-to-date financial data at the regional level remains limited, which prevents a deeper empirical assessment of the financial performance of the regions. Moreover, the research places greater emphasis on the normative and institutional approach rather than on a quantitative or econometric analysis, thereby reducing methodological diversity. Finally, it is important to emphasize that advanced regionalization in Morocco is an evolutionary and progressive process. Consequently, some of the conclusions of this research should be interpreted with caution, as they may evolve in light of future institutional and financial reforms.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

Funding

* Project no. MEC_SZ 149231 has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the MEC_24 funding scheme.



PROJECT
FINANCED FROM
THE NRDI FUND

Conflict of Interest

* The authors declare that they have no conflicts of interest

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Management Economics and Business (www.iconmeb.net) held in Budapest/Hungary on August 28-31, 2025

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AGILITY 2.0: THE IMPACT OF AI INTEGRATION ON THE OPERATION OF A FINANCIAL INSTITUTION

Abstract: In recent years, the rapid development of artificial intelligence (AI) technologies has significantly impacted various areas of corporate operations – especially those where agile methodologies are already embedded in everyday practice. This study examines how AI is transforming workflows, decision-making mechanisms, performance indicators, as well as human behavior and attitudes toward work within the agile operation of a financial institution. The research is based on a questionnaire survey completed by members of the agile team of a Hungarian financial institution, along with in-depth interviews conducted with several senior managers and professionals working in agile roles. These sources provide insights into experiences, attitudes, and organizational maturity related to the implementation of AI. The study explores how AI tools are integrated into daily routines, including task automation, predictive analytics, and more efficient collaboration. It highlights the differing perceptions of AI across various roles – from developers to product owners to executives – and sheds light on the coexistence of optimism and skepticism. Special attention is given to the challenges of aligning AI capabilities with agile principles such as flexibility, transparency, and continuous improvement. The aim of the research is to support financial institutions in developing more conscious and strategic approaches to AI adoption. The findings contribute to understanding how new technologies can become real competitive advantages in the agile environment of the future.

Keywords: workflow transformation, artificial intelligence, agile operations, decision-making, organizational maturity

Introduction

a. Artificial intelligence opens up a new dimension in the agility of financial institutions

Over the past decade, the technological evolution of financial institutions (Világgazdaság, 2020) has reached a new level: automation, data-based decision-making and digital services have become not only complements but also shapes banking operations. In this dynamically changing environment, artificial

intelligence (AI) targeting intelligent behavior (Crabtree, 2023) has emerged as not just a tool, but also a strategic factor — transforming our perception of agile development.

b. The Rise of AI in Software Engineering — A New Era in Agility

Domestic and international financial institutions are increasingly using generative AI tools, which not only automate code writing, but are also able to support backlog prioritization, help testing processes, and even participate in the production of documentation. With this, the technology affects agile roles that were previously based solely on human decision-making. Senior bank executives also agree on this (Lemák, 2025).

The introduction of AI in development teams is not only about increasing efficiency, but also about a change in culture: new skills are needed, knowledge and collaboration that support AI are becoming the norm. Very similar to learning agile operating models, a serious change of attitude must be made here (Portfolio, 2021). In addition, ethical and transparency issues arise that also affect agile decision-making mechanisms — for example, who is responsible if a strategic decision is made based on an AI proposal? AI is gradually but significantly transforming the banking sector, improving efficiency, offering personalized services, while also posing new ethical, regulatory, and technological challenges (Mirlam et al, 2023). And technological issues pose new challenges for professionals, as whether or not the solution is related to AI, it must work based on the customer's needs (Bagó, 2023).

Therefore, AI is not only a technological opportunity, but also a factor that encourages reflection on the human side of agile development. The aim of the study is to explore how this new technology is shaping the development practices of financial institutions, what challenges and opportunities it brings to agile teams, and how experts relate to it.

The emergence of artificial intelligence has created a new paradigm in software development. While agile methodologies were previously based on human cooperation, iterative learning and rapid response, with the involvement of AI, these processes are gaining a new interpretation. Generative AI that appears in development cycles can automatically generate code, suggest test cases, predict bugs, or even help understand business needs — essentially becoming a virtual team member (Kilby, 2024). Obviously, the automatic generation of codes is not flawless, it cannot be applied without thinking, programming knowledge is definitely required.

For agile teams, AI is not only a technological support, but also a system of collaboration and decision support. AI is increasingly being used in sprint planning, retrospectives, and backlog management, providing real-time data, analytics, and recommendations. I note that this type of use has not been verified by anyone during our research. At the same time, it also brings new challenges: transparency, maintaining human control, and critically evaluating AI-proposed solutions are essential for agility to maintain its principles. While it increases efficiency, it also poses serious challenges in terms of data protection, team-level knowledge development, and preserving human creativity (Ziyao, 2025).

AI does not replace agile operations — it transforms and adds new values. It encourages the development of a new approach (IVSZ, 2025). The development environment of the future will be not only fast and flexible, but also intelligently supportive.

AI can certainly support software development very effectively, but further research and analysis is needed to truly understand its impact on personality and processes (Cabrero, 2023), and it is also a serious challenge in terms of data protection, the knowledge level of team members, and the preservation of human creativity (Takács, 2019).

c. The impact of AI on the human and operational dimensions of development

In the world of software development, AI is no longer just a technological innovation — it's also a complex organizational factor, and even a strategic tool that contributes to large-scale agile transformations (Pavlic, 2024). According to our literature research, more and more AI-based tools are appearing in the development environment of financial institutions, which not only support and assist coding and testing (Bahi et al, 2024), but also participate in the definition of backlog priorities, sprint planning, and documentation processes. Let's face it, AI is gaining a foothold in all areas, not only for customers, but also for financial institution employees (Deloitte, 2024).

Technological evolution affects three fundamental areas:

- *The nature of the developer work:* Manual tasks are partially automated, while new competencies are needed to interact with AI — changing the daily workflow and the interpretation of roles.

- *Team structure and dynamics:* AI as a "virtual colleague" creates new forms of collaboration, challenging traditional models of trust, transparency, and accountability between agile teams.
- *Operational efficiency and flexibility:* While AI can lead to faster decision-making and optimized processes, it is questionable how this will affect long-term agility and the ability to innovate.

d. Regulatory environment and initiatives

The Artificial Intelligence Act is the first comprehensive, binding piece of legislation on artificial intelligence, adopted by the European Parliament in March 2024. It aims to ensure security and compliance with fundamental rights, while stimulating innovation and reinforcing Europe's leadership in AI (European Parliament, 2024).

In May 2020, the Hungarian government finalized Hungary's Artificial Intelligence Strategy, which covers the period 2020-2030. The aim of the public document is to put Hungary at the forefront of AI development, focusing on education, research and development, industrial applications and data management. The coordinating organization of the strategy is the AI Coalition, which brings together state actors, universities and tech companies into a bunch (Government of Hungary, 2020).

The Hungarian government plans to establish the Artificial Intelligence Office in the autumn of 2025, the main goal of which will be the transposition and implementation of the European Union's AI Act in Hungary. Although the specific tasks of the office are not yet known, according to the legislative plan, the bill may be submitted to parliament in September 2025, and the vote is expected in November 2025 (Government of Hungary, 2025). So this is a very recent action plan in Hungary regarding AI.

Decree No. 1301/2024 (IX.30.) Government Decree provides for the implementation of the EU AI Act 2024 in Hungary. It establishes the Hungarian Artificial Intelligence Council, which issues guidelines and positions (Government of Hungary, 2024).

The background study of the Hungarian Parliament provides a comprehensive analysis of the technological types, benefits, dangers and international regulatory trends of AI, and highlights that there is no separate AI law in Hungary yet, but adaptation to the EU regulation is in progress (Szalay, 2023).

Hungary is actively striving to keep pace with European AI regulation and to build its own institutional framework for its application in Hungary. This has already been formulated in several studies by Hungarian experts (Domokos & Sajtos, 2024). The adoption of the AI Act not only creates legal compliance, but also an opportunity for the country to become a competitive player in the field of AI developments. The strategy papers, the planned office and council, and the legislative preparations all show Hungary's long-term commitment to the safe, ethical and innovative use of AI. In addition, it can be said that there is a great need for the use of AI to take place within a regular framework. We are talking about a technology that dances on very thin ice. We know that AI devices often hallucinate and are wrong. Critical thinking is required to use it in the right way. Young people are at the greatest risk (Csiszárík-Kocsir – Tóth, 2024), as they are not always able to decide whether the information they receive is correct or even real. AI tools are known to be based on probabilistic data, and this may be the fault (Venczel et al, 2024). However, the error must be recognized. It is important to emphasize that the Adatbias characteristic of AI also refers to the importance of critical thinking, as AI already learns from data that already contains bias.

Material and Method

The aim of the study is to explore the impact of artificial intelligence in the agile development environment of a financial institution. To this end, I used a combined research methodology: I conducted qualitative in-depth interviews and carried out quantitative questionnaire data collection. With the method, I got to know the personal experiences and reflections of the experts, and on the other hand, I identified quantifiable patterns in the developer's practice. The thematic analysis of the interviews provided an opportunity to explore deeper meanings and correlations, while the statistical characteristics of the questionnaire results helped to identify generalizable trends. The combination of the two methods made it possible to examine the role of AI in an agile environment from multiple perspectives. To preserve anonymity, the participants of the in-depth interviews were identified anonymously.

Research questions:

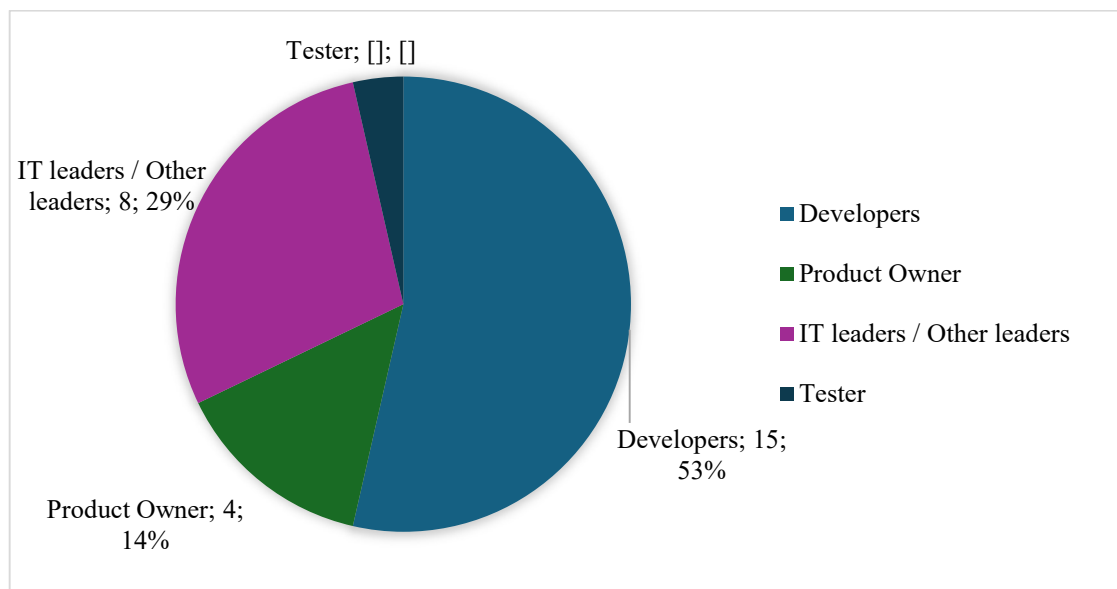
1. How and in what area do development teams use AI in agile methodology?
2. What changes has the use of AI brought to the way teams collaborate and role?

3. To what extent is the integration of artificial intelligence into decision-making mechanisms perceptible?
4. What impact does AI have on the success of the application of the agile framework in a financial institution environment?
5. To what extent do developers feel that AI is useful in their daily work?
6. Does the use of AI affect the satisfaction or performance of agile teams?

Results and Discussion

In the qualitative phase, 3 in-depth interviews were conducted with developers in different roles, who encounter AI-based solutions directly or at the management level. During the quantitative data collection, an online questionnaire was filled out by the employees of the agile teams involved. 28 responses were received, which represents a response rate of 35% compared to the targeted population of about 80 people. 64% of the respondents, 18 people, use artificial intelligence tools regularly, on a daily basis, and the remaining 10 respondents (36%) also occasionally.

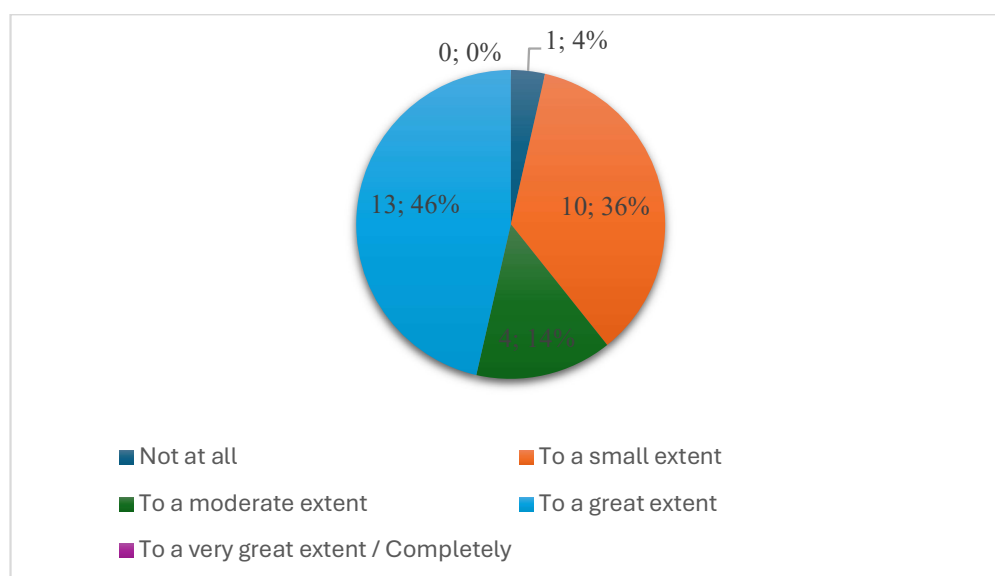
Figure 1: Role of respondents



(Source: Author's own research, 2025, n = 28)

You can see that the questionnaire was shared with about 80 people who have all the agile roles from the system organizer to the high-level Tribe Lead. Despite this, responses were typically received only at the management level (Figure 1). This may be due to the fact that system organizers do not yet use artificial intelligence at all, so they did not consider it important to fill it out, or it was negative thinking that prevented them from doing so.

Figure 2. The impact of AI on work



(Source: Author's own research, 2025, n = 28)

Figure 2 shows that 46% of respondents said that the emergence of AI has significantly changed their daily work. Over the past 12 months, the rate of use of AI in their work has changed at an average rate (Figure 2). According to the subjects of the in-depth interviews, they had already tried to use the available AI tools on an experimental basis, but since the bank provided them with a supervised device, they jumped headlong into the opportunity to a much greater extent. This can be illustrated by the fact that according to the respondents, the rate of AI use has changed only to a lesser extent in the past 12 months, depending on the role. However, the difference in productivity is much more vivid. Also role-specific, but 45% of respondents experienced a positive change in how efficiently they can perform their work.

The following statements were made during the survey research:

- AI helps you better understand customer needs.
- AI doesn't distract from real customer problems.
- AI enables faster analysis of customer data.
- AI does not diminish the role of human intuition.

Based on the in-depth interviews, it can be clearly stated that AI allows for very efficient work if it is used properly. Respondents were unable to provide clear information about the skills required, but they made it clear that critical thinking and openness are essential to properly use AI or any of its components. Regarding the motivation for the use of AI, an interesting fact emerged based on in-depth interviews and questionnaire answers.

The four faces of the AI revolution in the workplace

The rise of AI is diverse not only in terms of technology, but also in terms of human reactions. During the in-depth interviews, the subjects uniformly grouped the employees working with the AI. Based on the attitudes, I formulated the following grouping:

- *Enthusiastic Pioneers:* evangelists of the world of AI. They see the potential in it, they are happy to experiment with it, and they are always looking for new opportunities. They inspire, pull others along with them, and are not afraid to break new ground.
- *Silent Beneficiaries:* They use AI because "that's what protocol says." They acknowledge its benefits, but they have not yet ignited enthusiasm. Rather, they are observers who follow developments from the background and build on the innovations of the Enthusiastic Pioneers.
- *Silent Enemies:* They also use AI, but more out of necessity. Their focus is on difficulties and they find it difficult to open up to new opportunities. Change is a burden for them, not an opportunity.
- *Loud Resistances:* AI is a red cloth for them. They openly criticize it, actively oppose it in debates, and can even hinder or sabotage projects. They are the defenders of the status quo, who not only doubt but also fight.

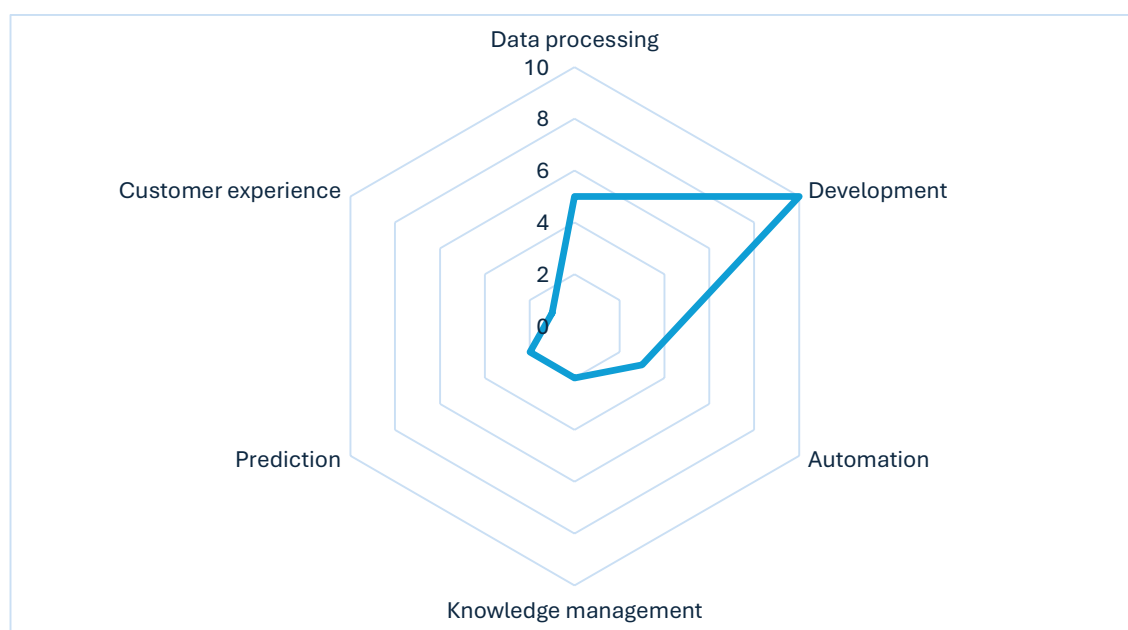
Based on the above, it can be said that just like in the case of an agile organizational transformation, it is necessary to fight for employee satisfaction and for the AI-driven tools to be used consciously and accepting the approach. They need to develop critical thinking and a sense of competition. Because it is no longer a

competitive advantage for a financial institution to use artificial intelligence. The competitive disadvantage is if you don't. To accept and understand this, the loyalty of employees is needed. They must feel that it is important for the company to maintain a competitive advantage, which is why it can stay in the market, generate profit from it, from which it pays salaries and bonuses. The employee must feel ownership of the technology. AI is the future, you can't resist. If we don't use it, we will be left behind.

Opportunities and development directions: the future of us from the perspective of agile teams

Of course, during the questionnaires and in-depth interviews, more opportunities than potential emerged for the financial institution. Out of the 27 responses, a total of 16 responses were received, which formulated clear possibilities. These are data processing, development, automation, knowledge management, prediction, customer experience.

Figure 3. Opportunities



(Source: Author's own research, 2025, n = 28)

The spider web diagram above (Figure 3) clearly shows that the potential of AI is consistently pointing in the direction of data processing and development, followed by automation. Although artificial intelligence tools are already used by employees in several companies, and let's face it, we often scramble to it for answers,

it seems that the financial institution has not yet reached the point of admitting this. Or just don't communicate it. In conclusion, as it stands, AI primarily contributes to improving work efficiency in data processing and development, and employees also see the future in this. Obviously, this is also due to the fact that IT companies providing AI tools are already providing AI tools specifically for developers, which really makes the work easier.

Risk Analysis: Concerns of the Application of AI in an Agile Development Environment

Based on the questionnaire responses, six key areas were identified where the use of AI could pose a potential risk in the decision-making process.

1. AI can simplify the interpretation of customer needs, which can distort the product version created by the Product Owner (PO).
2. AI-generated recommendations can suppress PO's intuition, which is especially important for complex or unstructured problems
3. The data that influences AI's decisions is not always transparent, which can lead to a loss of trust and erroneous decisions.
4. AI can skew business priorities by disproportionately weighting data. This can be especially dangerous if the PO does not have enough control over the directions suggested by the AI.
5. The use of AI can raise ethical and privacy concerns, especially when handling sensitive customer data.
6. The overuse of AI can lead to a decrease in the autonomy of the PO, which can result in a void of the role in the long run.

It is a well-known fact that AI often works with distorted data, and the term "black box" is also used, according to which it happens that the basis and calculation of the analysis and decision made by the AI cannot be determined. These also demonstrate that AI-generated data is not always reliable (26). It can be said that the use of AI in the PO decision-making process poses risks in several aspects, especially in the areas of transparency, the marginalization of intuition, and ethical and data protection issues. The results suggest that AI integration should be treated with caution and that the role of PO in AI-assisted decision-making situations should be strengthened. Strict regulation of the use of AI can certainly be a solution to this, not only at the national level, but also in the organizations that use it. Obviously, this must be followed

by a strict audit, because why regulate if its compliance is not controlled. We hope that this will happen soon. Based on the responses to the questionnaire, the introduction of AI in the field of agile development poses risks in several dimensions. They affect not only technological, but also organizational, legal and human factors. Based on the free-form answers, I present the most frequently mentioned risks and their possible consequences thematically.

1. Privacy and security

A significant number of respondents mentioned data security, data leakage, IT security and GDPR compliance as critical risk factors. AI systems often handle large amounts of sensitive data, so inadequate protection can have serious consequences. Of particular concern is the fact that it is difficult to guarantee stable security compliance due to the fast update cycles of AI solutions available on the market (e.g. MS Copilot).

2. Education and awareness

Several responses indicated that users do not have sufficient knowledge about the correct use of AI. Lack of education, lack of knowledge of the limitations of AI, and excessive expectations can all contribute to flawed application. Sensitization and training at the organizational level are essential to treat AI as an opportunity, not a threat.

3. Technology Limitations and Reliability

AI is not a universal solution. Several respondents highlighted that AI is not intelligent or reliable enough in all situations, especially in handling so-called "edge cases". Over-automation can lead to a decrease in developer creativity, as developers may tend to forgo deeper problem-solving in addition to mid-level AI solutions.

4. User attitude and expectations

The overuse of AI and lack of self-control are also risks. If users leave all problems to AI, it can lead to a weakening of professional competencies in the long run. It is important that AI does not become the sole source of information, but functions as a complementary tool.

5. Organizational Culture and Adaptation

The body's ability to adapt is crucial. The introduction of AI requires not only a technological but also a cultural change. Sensitizing and involving employees can help them see AI as an opportunity for development rather than as an enemy.

6. Legal and ethical issues

The unsettled legal background, ethical dilemmas (e.g. dismissals, liability issues) and lack of transparency can all be serious obstacles to the application of AI. Respondents say that clear regulation and responsible use are needed.

7. Quality and integration

Technology integration and quality control are also priority areas. AI should only be implemented with appropriate processes and controls, especially for automated decision-making.

8. Accuracy and source of information

Several respondents indicated that the accuracy of the answers given by AI is difficult to judge in business matters. In addition, the distinction between AI-generated content and human input (transparency) is also an important aspect.

The application of AI in an agile development environment therefore carries complex and multifaceted risks. Successful integration requires consideration not only of technological, but also of organizational, legal and human factors.

- Strengthen privacy and security protocols
- Introduction of educational and sensitization programs
- Consciously managing technological limitations
- Developing organizational culture
- Ensuring ethical and legal compliance

Conclusion

Based on the in-depth interviews and the questionnaire survey, it can be stated that in the case of the financial institution under review, employees in the agile area do not yet use artificial intelligence tools to support decision-making, regardless of their role. Although the agile field has already started on the path of transformation, it is in a very rudimentary phase. In addition to the AI tools available to pretty much everyone, some developers are already trying out AI tools optimized for the development environment, but this is still in its infancy. It takes longer to gain experience, not to mention that even though this solution is based on code writing and developer competencies, strict regulation and its enforcement are crucial due to the risks identified during the research. However, it has been clearly established that the use of AI tools greatly simplifies the work, and some tasks can be completed much sooner than before. This helps employees to do quality work in their remaining time or to develop their competence through further training.

Obviously, AI-generated content is not 100% reliable, so critical thinking is the most important. To put it colloquially, don't trust what the AI tells you. It needs to be checked. However, if we want to compare the content of a document with a regulatory document, for example, we may gain more information than if we rely solely on our own reading. In this case, the AI works quite well, but unfortunately we cannot be sure of the correctness of the result here either. In our further research, I plan to examine the use of AI in areas of financial institutions that do not deal with development, such as internal audit and background operations.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

Funding

* Project no. MEC_SZ 149231 has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the MEC_24 funding scheme.



PROJECT
FINANCED FROM
THE NRDI FUND

Conflict of Interest

* The authors declare that they have no conflicts of interest

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Management Economics and Business (www.iconmeb.net) held in Budapest/Hungary on August 28-31, 2025

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WHAT NEW THINGS CAN THE AGILE APPROACH BRING TO STRATEGIC MANAGEMENT?

Abstract: The turbulent market environment and technological changes pose increasingly greater challenges to corporate strategic management. Traditional, plan-driven, output-oriented, and rigid strategic approaches are proving to be less and less effective. As a result, there is growing attention directed toward integrating agile and design thinking approaches into strategic management. The purpose of this research is to examine how agile and design thinking approaches can be implemented in practice within organizations in strategic management, and what challenges arise in this regard.

The main objective of the research is to examine how agile approaches and design thinking can contribute to organizational strategic leadership. To this end, the study seeks answers to the following research questions:

1. What are the challenges of strategic leadership today?
2. What added value can we expect from integrating agile approaches and design thinking into strategic leadership?
3. What potential impacts can we expect from a project cost perspective if these methods are properly integrated?

Literature sources and research results reveal that incorporating agile and design thinking principles into strategic management brings numerous advantages, regardless of organization size, such as enhanced strategic agility, customer-centricity, user-centricity, and efficiency. However, the transition is not without challenges, such as organizational resistance to change, redefinition of roles and responsibilities, and employee mindset shifts. The key to successful transition lies in gradual implementation, leadership commitment, and conscious shaping of organizational culture. The theoretical and practical implications of the research contribute to a better understanding of strategic management and agile/design thinking integration. The identified best practices can help similar organizations more effectively apply agile and design thinking in strategic decision-making and operational improvement.

Keywords: strategic leadership, agile management, design thinking, management-mix

Introduction

Due to the acceleration of free resource flow, businesses focusing on local markets have also had to face competition visible in the international market (Balaton, 2015). These situations pose increasingly greater challenges to companies and other organizations year after year. For example, the increasingly intensive presence of eBay, Amazon, or even Kifli (Rohlik) in market segments where primarily local retailers once appeared has caused previously unimaginable challenges. These processes have been further intensified in recent years by the aggressive expansion strategy of Chinese market players, not only in technological and supplier areas but also in retail sectors. One serious challenge of this is currently Temu's aggressive expansion strategy. "The size of the Chinese company's Hungarian customer base exceeded 1.25 million people in April 2024, which was accompanied by more than 1.5 million orders sent to Hungarian customers in the first three months of 2024. The total value of their spending in the first quarter of this year was 22.5 billion forints, representing 7 percent of total online spending" (source: 168 óra).

Rapid recognition and innovative thinking are not based on traditional approaches. In Temu's case, the cause of success is naturally complex, but one significant impact is their maximally utilized direct sales model, where products go directly from the factory to the webshop. Alongside market changes, the pace of technological development has also significantly accelerated. The driving force of this in the past two years has primarily been artificial intelligence solutions accessible to anyone. The effects of this are increasingly permeating various areas of our daily lives day by day.

But why is all this important? Modern cars, which brought similar-scale changes to the world's functioning, appeared at the end of the 19th century. However, after their appearance, it took 20-25 years to reach one million cars sold. The internet, without which the world's functioning is now unimaginable and has become basic infrastructure like electricity in most of the world, needed 20 years to reach 1 million users. In contrast, ChatGPT needed only 5 days to reach one million users. It currently has more than 180 million users, and its impact could likely far exceed that of cars and the internet in the long term. Beyond ChatGPT's spread, we must not forget the "waves" created by the phenomenon, which produce even more stunning numbers today.

The acceleration of the market environment and technological development alone poses a serious challenge to businesses, and we haven't even considered the increasing pressure of other environmental impacts, such as raw material and labor shortages, climate change, etc.

All these effects pose increasingly serious challenges, which immediately ripple into education and educational services, where the market clearly expects them to train potential workforce that is open to innovations, capable of understanding and efficiently using them, with high adaptability and creativity.

What are the challenges of strategic leadership today?

It is essential that achieving all these goals occurs along clear strategy and strategic objectives. Accordingly, it can be observed that organizations strive to create short and long-term strategies and follow them (Varga et al., 2025). However, this is no longer sufficient. Rigid adherence to carefully crafted strategies can easily put companies and services at a market disadvantage. The new situation has called for new solutions and approaches.

Strategic management today faces numerous challenges:

1. Turbulent and unpredictable environment: Globalization, technological changes, and other external factors reshape market conditions in extremely short periods. Traditional long-term planning is becoming increasingly ineffective.
2. Intensified competition and market uncertainty: Industry boundaries are increasingly blurred, new competitors appear, and there is an increased presence of global players in local markets. Due to rapid changes in consumer needs and preferences, it is more difficult to predict demand patterns.
3. Increasing complexity and cross-dependency: In multiple areas, there is an observable increase in interconnectedness of companies with other players (suppliers, partners, etc.). Decision-making requires increasingly diverse perspectives and knowledge, affecting multiple areas, making management of interdependencies more difficult.

4. Resource scarcity and sustainability pressure: Raw material, energy, and labor shortages, along with environmental sustainability requirements, pose increasingly greater challenges. These affect resource allocation and other business decisions on a daily basis.
5. Digitalization and technological changes: Artificial intelligence, automation, big data, and other innovative technologies keep education/training and multiple industries under constant technological pressure. Companies must make rapid adaptability an integral part of their strategy and operations.
6. Employee expectations and organizational culture change: Workforce motivation, expectations, and organizational culture transformation are critical factors for organizational success. Traditional hierarchical structures increasingly fail to match modern employee needs.

Strategic management must find answers to these challenges, which increasingly require flexibility, rapid adaptability, and innovation from companies. One significant direction and result of these new approaches is that the relationship between strategic thinking and agile methodologies is receiving increasing attention. Among market companies today, the application of agile methodologies is no longer just an approach used in software technology areas. There is increasing research into ways and possibilities of integrating agile practices in other areas, incorporating them into strategic management processes (Ciric et al., 2019; Vrontis et al., 2022; Tóth – Csiszárík-Kocsir, 2023). This phenomenon is also observable in our country, in the service, finance, and banking sectors

Method

This study is based on a literature review, aiming to review and synthesize the relevant current knowledge. I followed the following steps during the research: Definition of research questions - I precisely formulated the questions that I sought to answer through the literature review.

When reviewing the literature, the specific investigation focused on the following areas:

1. What are the challenges of strategic management today?

2. What added value can we expect from integrating agile approaches and design thinking into strategic management?
3. What potential effects can we expect in terms of project costs if these methods are properly integrated?

Databases: I utilized the following databases to identify relevant literature: Scopus and Web of Science. During the analysis, I used content analysis to identify patterns, trends, and contradictions.

The significance of the relationship between strategic management and agile/design thinking approaches

Agile methodologies emphasize flexibility, adaptability, and rapid response to changes (Ciric., 2019). These approaches primarily place iterative short-term progress approaches in the foreground, in contrast to traditional, significantly longer-term, quasi-linear and plan-driven, often practically rigid strategic management practices. While strategic thinking typically involves long-term planning and goal setting, agile methodologies apply a continuous phased, regular feedback-based decision-making and implementation approach (Maamzi & Tawfik, 2022). The intersection of strategic thinking and agile methodologies is a complex and nuanced relationship where mutually reinforcing and more difficult to reconcile elements can be found. For the two approaches to reinforce each other, thorough knowledge of the approaches is essential. In the 1970s and 80s, the strategic approach centered on environmental adaptation. This was based on the premise that organizational strategies must adapt to existing situations and conditions. This adaptive attitude should be a key issue for the organization (Porter, 1980). In the 1990s, due to the further acceleration of the world, it became increasingly important that, beyond adaptive attitudes and developing various strategies, organizational operations also become more dynamic. Previously built or acquired capabilities can only provide market advantage for a limited time because competitors can eventually master them (Ambrosini & Bowman, 2009). Due to these effects, continuous capability development, learning, and renewal became essential for survival. However, it is important to note that, based on observations, learning potential from past events often comes at the expense of experimentation (Fejes, 2015).

In strategic management, strategy creation, decision-making, and planning function as a unified system. Strategic management is one of the key functions of today's organizations. It determines direction and guides

resource allocation to achieve desired results. Traditional strategic management approaches are typically characterized by top-down, hierarchical processes and control mechanisms. During these processes, goals are achieved based on long-term plans and well-defined steps, and their precise execution. In today's dynamic and unpredictable business environment, this rigid approach is often not effective (Ciric et al., 2019). Organizations have also recognized these factors and, therefore implemented changes to make strategy creation processes faster and more flexible.

Strategy theory progressively directs attention to internal factors through the resource- and capability-based strategy concept. In developing strategies, factors other than environmental impacts are also considered. These foundations have not been questioned today; however, environmental impacts, technological changes, and risks are far from being as predictable as before. As we can see in Temu's case, an aggressive marketing strategy and new approaches that had never been considered before can lead a company to success. Moreover, all of this turned the retail market upside down in an extremely short time. Such and similar impacts (the emergence of artificial intelligence, increasingly frequent viruses and environmental disasters, etc.) can suddenly have serious effects on a company, organization, or economy, as well as on their carefully crafted strategies. If we are not able to quickly adapt to these, we can easily become victims of the resulting situation. The following figure illustrates the 6 main tasks of strategic management.



Figure 1. The 6 key tasks of strategic management, own editing 2025

As a result of globalization and technological development, risk-taking management has become more valuable. Based on international research, this does not mean that there is no need for strategy. In fact, the need for strategy is much greater than it was under more stable conditions (Grant, 2003). However, this does not mean detailed, comprehensive, formalized plans, but rather well-thought-out concepts related to future operations and goals (Mintzberg et al., 1990).

We usually examine the effectiveness of a given organization from two main perspectives:

- human factors, such as behavior and communication
- material conditions, such as structure or technology.

Resource- and capability-based strategies have played an increasingly important role in strategic management since the turn of the millennium, especially in a changing market and technological environment (Balaton, 2019). Companies are paying more and more attention to their internal resources and capabilities, the well-being and development of their employees, and ensuring stability, as these give them the opportunity to gain a competitive advantage. The use of agile methodologies as part of strategic

management fits into this approach. If an organization is able to maintain its internal resources stably and make its operations more responsive and flexible, it can achieve efficiency gains that can contribute to its long-term survival. In addition to internal processes, it is of course also necessary to stabilize dependencies within the organization, such as industrial relationships with suppliers, etc.

Potential benefits of agile methodologies

Agile organizations are expected to be more flexible, adaptable, and customer-centric. The various approaches that have emerged as a result of the Agile Manifesto emphasize the importance of continuous learning and reflection, rapid experimentation, and quick responses to changing market conditions. From the latter point of view, it is particularly important that all this is achieved through the democratization of decision-making powers, i.e., the classic top-down decision-making mechanism and control have been replaced by a shared responsibility approach. Iterative planning, continuous feedback, and cross-functional collaboration lay the foundation for rapid information flow and faster decision-making mechanisms than before. On the other hand, the maturity of the management, the immature structure, and the level of accumulated experience require a different approach (Venczel, T. B et al., 2024)

One of the most important advantages of integrating agile principles and practices into strategic management is increased strategic agility. Strategic agility means that the organization is able to regularly adapt to an uncertain and changing environment and redesign the intermediate steps leading to its goals. Agile methods such as Scrum, Kanban, the Hoshin Kanri model, OKR frameworks, or Lean provide a framework for rapid decision-making, continuous feedback, and iterative renewal of strategic plans.

Effective solutions do not necessarily require a commitment to a single solution. In fact, the right approach likely is to be aware of the different approaches and combine them to create the "management mix" that can most effectively support the organization. For this very reason, it is not enough to think only in terms of the methodologies of recent years. From this perspective, it is not enough to be familiar with the characteristics and effects of strategic and agile management. Operational management also has its place in modern corporate management, as the achievement of strategic goals and the operation of agile units depend on execution at the operational level. The agile approach and cultural transition also have an impact on operational processes.

Table 1. Comparison of strategic, operational and agile management, own editing 2025

Strategic management	Operational management	Agile management
Complex and ambiguous situations, unique solution methods	Routine, clear decision situations, applied decision models	Problem handling and responsibility locally at the given level of responsibility
Decisions that affect the entire organization and are of fundamental importance	Isolated decisions affecting parts of the organization	Decentralized decisions made in agreement between stakeholders relevant to the given area
Long-term effects and consequences	Short-term effects and consequences	Short and long-term effects and consequences

Traditional corporate structures typically operated within a hierarchical management structure. These structures often hinder rapid response and decision-making, as management must approve every decision. The strength of agile strategic management is based on shared knowledge and lessons learned, as well as decentralized decision-making processes. This decentralization lays the foundation for greater autonomy and responsibility for teams and delegates decision-making rights. As a result of this approach, decisions can be made directly at the operational level, which increases efficiency and individual responsibility, commitment, and engagement. As a result of the introduction of agility (decentralized decision-making processes), Tripp and colleagues' study shows that agile practices can lead to higher levels of job satisfaction among employees, as they can take on greater responsibility and actively participate in decision-making processes (Ciric et al., 2019). This effect can significantly support the internal stability of the organization. However, incorporating agile principles and practices into traditional strategic management processes is not without its challenges. Resistance to change within the organization, the acceptance of new roles, responsibilities, and practices, and the shaping of employee attitudes often result in difficulties and even resistance (Embarking on a Business Agility Journey: Balancing Autonomy Versus Control, 2023) (Maamzi & Tawfik, 2022) (Annosi. et al., 2020) (Waardenburg & Vliet, 2013) (Morgan & Page, 2008). Successfully combining strategic and agile approaches, therefore requires not only determination but also careful attention, organization, and perseverance. Based on my own experience, the basis for a successful transition depends primarily on shaping the mindset of employees and the organizational culture, as well as on leadership setting an example.

Prioritizing customer-centric strategy through design thinking

Traditional strategic management approaches often ignore customer feedback or rely solely on information and data available before strategy formulation, evaluating them only after implementation and delivery. One of the fundamental principles of agile methodology is customer centricity, which is particularly important in strategic management. Agile approaches require organizations and their units and individuals to shape their goals with the involvement of customers and based on their feedback. This continuous learning and adaptation process enables organizations to move in the direction that best meets customer needs and to continuously monitor market changes. This approach has the potential to contribute to the creation of something truly new and valuable through our operations. Implementing an agile approach promotes faster and more customer-centric development, especially in the face of uncertain and changing requirements (Venczel, T. B et al., 2024). When developing an agile culture and customer-centric thinking, an important point in terms of value creation is the formation of failure avoidance. It is important to shape the mindset of individuals and teams so that mistakes are interpreted as learning points rather than failures. This kind of change in mindset can significantly improve the aforementioned dual learning opportunities (experiential learning and innovative learning), As a result, teams can experiment more boldly with new ideas and approaches without fear of the consequences, thereby increasing both competitiveness and customer experience.

Focusing on flexible strategy

As mentioned earlier, strategy development is typically a long-term approach. Organizations typically think in terms of at least a one-year timeframe. As a result, in many cases, by the time the end result reaches the target audience, it no longer meets expectations or has become obsolete. The flexibility that agility brings to an organization can be an important factor in counteracting and solving this problem. Moreover, the results of a research suggest that the chosen working approach has an impact on the perceived use of creativity, whereas learning is significant in cases where the stand-up tool of agile project management is used (Blaskovics, B. et al., 2023)

When preparing for the practical implementation of agile culture and leadership, the most important step is to transform organizational structures and processes. Agile methodology can only be truly successful if agility and decentralized decision-making are supported at all levels of the organization. To this end, they

need to rethink their processes and decision-making mechanisms. Opportunities for transparency, continuous review, and modifiability must be created. In practice, this means that strategic goals must be broken down into short-term sub-goals that can be evaluated and measured. As a result, if changes in the market or technological environment, or partial results, justify it, the organization has the opportunity to respond quickly to changes. As a result, the organization can shape and fine-tune its strategy.

Delegating responsibilities, making expert and professional decisions locally, flatter approval mechanisms, and the formation of cross-functional teams can all potentially contribute to faster and more effective responses and the rethinking of strategic steps to achieve strategic goals. In addition, when agility is properly integrated into the organizational culture, it also provides space for continuous experimentation. Experimentation can create further competitive advantages. It can support efficiency and flexibility, both in terms of processes and end results. Innovation is not only important in the area of products and services, but also in the operating models and strategy development of organizations. Agile methodology is not only about rapid adaptation and customer focus, but also about the optimal use of resources and capabilities. The rigid and slow approach of traditional management methods to resource allocation often hinders the organization's ability to adapt quickly. Agile management, on the other hand, enables faster and more efficient resource management, as management continuously monitors the functioning and efficiency of processes and adjusts the use of resources accordingly. This ability is particularly important in areas of innovation (R&D), where rapid response and efficient resource management are critical to successful market performance.

As a result, organizations can transform and reorganize their resources more quickly when new opportunities or threats arise in the market. This is especially important when planning to enter new markets, where rapid experimentation, adaptation, and iteration can play a decisive role in success. Evidence of this can be found in the research results of Conforto and his colleagues, which showed that integrating agile methodologies into traditional project management can improve project outcomes, such as faster time to market and better alignment with customer needs (Mera et al., 2012).

The impact of agile and design thinking approaches on project budgeting

Agile projects can only be effective if the project is driven by real demand or a gap in the market, and if its feasibility is based on solid foundations. During the project, these will determine the daily work of the project team and how their work achieves the business goal. The agile approach can therefore support strategic management not only in terms of project success and resource retention. When the agile approach is combined with conscious planning, concrete cost reductions and revenue increases can also be achieved. In practice, these positive effects are the result of several factors.

Cost of fixing a given error

During product and service development and operation, errors and problems inevitably occur that need to be resolved. If we are aware of this, it is important to examine how we can handle these situations as efficiently as possible. As shown in the figure below, the cost of fixing errors increases exponentially over time. There are several reasons for this, such as how many customers/users encounter the problem, dependencies affected by the problem, and in extreme cases, downtime, which can impair the product or service experience, or even cause financial or other damage. Therefore, it is crucial that we identify potential errors as early as possible, in as large a proportion as possible, preferably before development, but at least before market launch. The most common method for this is various types of post-testing, where the finished solution is subjected to subsequent tests, possibly small-scale "beta" tests. Even with regular customer presentations, none of these methods can guarantee that we will achieve a result that creates value. This risk can be mitigated primarily by conducting design thinking-based research during agile iterations launched prior to development.

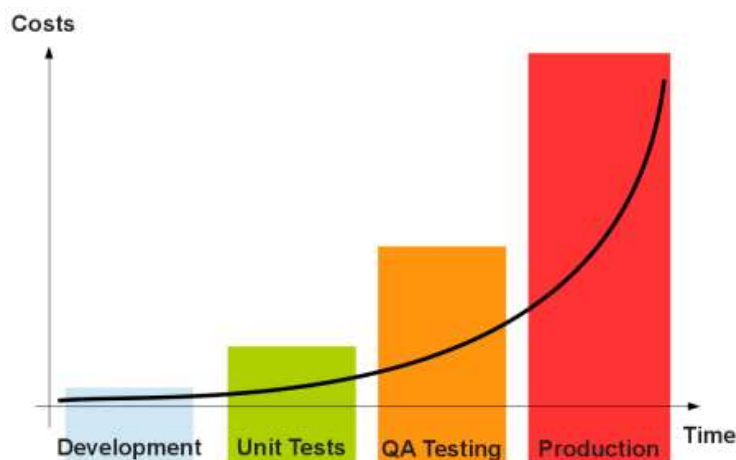


Figure 2. Relative error correction cost as a function of detection time. source:deepsources.com, Accessed: May 29, 2025

These research methods contribute effectively to understanding the root causes of real needs and problems and are also capable of validating the effectiveness of the responses to them. This not only helps us identify potential errors and create product value but also lays the foundation for teams to make good estimates. This enables them to plan the rest of the project more accurately. We usually summarize these research methods as user experience or customer experience research. Based on IBM's research, for every \$1 spent on "experience research," \$10 is saved in development and \$100 is saved in post-release maintenance activities. (Clare-Marie Karat, IBM: T. J. Watson Research Center, 2009). In addition, IBM research also shows that involving the right UX professionals while the concept is still being developed can result in a 30-50% reduction in the development cycle.

Reducing the cost of bringing a product/service to market (company example)

IBM's cost reduction results during the development cycle recently attracted interest at my current employer's parent company, so two similar projects were examined with the same team. One project used a "standard" approach to this product. A team of six worked in three-week sprints over five sprints. By the end of development, the project had cost \$292,500, after which it took four sprints to fix the bugs, generating a cost of \$230. Thus, it cost \$526,500 to bring the product to market and took a total of 27 weeks. In the other case, development was preceded by a three-week research phase involving three people. The

cost was \$34,250. After that, the development cycle with the same team was only four sprints long. The cost was \$234,000. After that, only two sprints were needed to fix the bugs. This cost \$117,000. The total cost was only \$385,250 and took only 21 weeks. Overall, compared to the traditional approach, the product was brought to market for \$141,250 less with the more modern approach and six weeks faster.

Potential revenue growth

In addition to cost reductions, the available analyses also indicate potential opportunities for revenue growth. According to research conducted by McKinsey & Company involving 300 mature partners from a design thinking perspective, improvements in user experience correlate strongly with revenue growth for the companies concerned. Their research shows that the return on investment in user experience is 9900%, and user-friendly products can increase conversion rates by up to 400%. They cite Bank of America as an example, where 24% more people registered on their website after redesigning their user interface. (McKinsey: The business value of design 2018) Based on all this, it is clear that a modern, agile approach combined with design thinking not only has a positive impact on expenses but can also result in increased revenue.

Conclusion

In the turbulent market environment, business, education, and even public administration are facing new challenges because of rapid technological changes. In practice, a rigid, long-term, output-driven strategic approach alone cannot support organizations in increasing their efficiency and achieving their market goals. The relationship between strategic management, operational management, and agile methodologies is a complex and constantly evolving process. Organizations that want to keep pace with change must carefully navigate the challenges and ensure that the combination of these approaches is consistent with the organization's culture, governance structures, and strategic goals (Hayata & Han, 2011) (Sharma et al., 2022) (Ciric. et al., 2019) (Barahma, 2021). However, agile frameworks and methodologies are not magic wands in practice, nor are they like "fast food menus." It is easy to see that it matters how the agile approach is integrated into corporate operations at both the strategic and operational levels. For example, if agile methodologies are combined with a modern approach to design thinking, then not only the customer but also the user side can potentially adapt and respond more quickly to new circumstances. The introduction

of agile practices can improve collaboration and cross-functional coordination within the organization. As a result, information flow also becomes more efficient. Further changes within the organization include increased transparency and shorter cycles of continuous learning. Through the above, a proper transition can support the elimination of organizational silos and strengthen the coordination of processes within the organization. As a result of these processes, they can have a positive impact on both expenses and revenue. Integrating agile and design thinking into strategic management can bring numerous benefits to organizational management, such as:

1. Increased strategic agility, i.e., the organization's ability to adapt and respond quickly.
2. Places greater focus on customer and user centricity, which improves the effectiveness of strategies.
3. Increases the speed of decision-making and response through changed operational processes and shorter iterations.
4. Can reduce project costs and time to market, as well as increase revenue by reducing the number of errors, the cost of fixing them, and increasing user satisfaction.

The combination of strategic management and agile approaches fundamentally changes the way organizations operate at both the strategic and operational levels, so it is not without its challenges. Previous transformations have shown that it is not necessarily sufficient (or expedient) to introduce a framework on its own. This step can only be the first step in a longer process. Successful organizational transformation is about finding the right "management mix." As a first step in the change process, it is useful and necessary to put the organizational culture on a new footing. Establishing an organizational culture based on agile core values, in which leadership by example is key, decentralized decision-making mechanisms can be implemented, and there is room to make mistakes and learn from them, thereby laying the foundation for innovation. As a result of these changes, we will have a more customer-focused, competitive organization that is better able to adapt to an accelerated world.

Recommendations

Although the study provides valuable theoretical and practical conclusions, it also has some limitations. On the one hand, the research was primarily based on theoretical literature analysis and case studies of large companies. Future research should use interviews to examine in greater depth the real challenges and effects

of transforming strategic management through agile and design thinking in organizations of different sizes, thereby highlighting the practical differences and challenges between the SME sector and large companies.

In addition, the study focused on general issues of strategic management but did not go into detail about the specific characteristics of individual industries or organizational contexts. Future research could also cover how agile and design thinking methods can be integrated into strategic management in different organizational environments.

Finally, although the study highlighted the potential impacts on project costs and revenues, the analysis of actual financial and business metrics requires further research. It would be worthwhile to collect and analyze quantitative data in the future to obtain a more accurate picture of the business implications of integrating these methods. Overall, the study lays the foundation for further research directions to gain a deeper understanding of the agile and design-driven transformation of strategic management. Practical experience, contextual specifics, and a more detailed examination of financial and business impacts can all contribute to a better understanding of the field.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

Funding

* Project no. MEC_SZ 149231 has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the MEC_24 funding scheme.



PROJECT
FINANCED FROM
THE NRDI FUND



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Conflict of Interest

* The authors declare that they have no conflicts of interest

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Management Economics and Business (www.iconmeb.net) held in Budapest/Hungary on August 28-31, 2025

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AND INNOVATION OFFICE
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PROJECT
FINANCED FROM
THE NRDI FUND

PUBLIC PERCEPTIONS AND TRUST DIMENSIONS OF MILITARY AUTONOMOUS VEHICLES IN THE AGE OF ARTIFICIAL INTELLIGENCE

Abstract: The development of autonomous vehicle technologies over the past decade has opened up new strategic, economic, and security policy opportunities for both the civilian and defense sectors. Technological innovations have also led to significant changes in the structure of warfare: unmanned aerial vehicles (drones), self-driving land vehicles, and artificial intelligence-supported systems have become increasingly prevalent in armed conflicts in recent years. These systems not only perform reconnaissance, logistical, or support functions, but are also increasingly involved in actively targeting and autonomously reaching the target area. The development and application of military autonomous systems therefore deserve special attention, as it raises a number of new types of risks and challenges in the areas of cybersecurity, ethical standards, international humanitarian law, and national security. The aim of this research is to map social attitudes and trust levels regarding the use of autonomous vehicles for military purposes. The study examines the opinions of different demographic groups on an empirical basis, paying particular attention to trust in technological developments, assessments of the safety of transport and combat systems, and legal and ethical considerations related to military applications of AI. The results show that the social acceptance of military autonomous systems is closely related to public trust in artificial intelligence and automated systems, as well as the perception of risks associated with them. The study contributes to a deeper understanding of the economic and social impacts of technological innovations for defense purposes and lays the foundation for future research examining the integration of autonomous systems into military infrastructure, taking into account regulatory, security policy, and social aspects.

Keywords: Autonomous vehicles, Artificial intelligence, Military technology, Public trust, Ethical concerns

Introduction

The Social, Legal and Ethical Challenges of Autonomous Vehicles

Self-driving vehicles represent one of the most dynamic and controversial areas of technological development. These systems are not just engineering innovations but are the bearers of complex social and regulatory dilemmas that redefine the framework of transport, responsibility and ethics. The operation of autonomous vehicles is determined by different levels of automation. The taxonomy developed by SAE International (2016) distinguishes six levels from full manual control to full autonomy. This scale indicates not only the degrees of technological progress, but also the different public attitudes towards each level (Schoettle & Sivak, 2016).

Regulatory frameworks have a significant impact on the potential for technology adoption. In the European Union, the Vienna Convention requires all vehicles to have a human driver (United Nations, 1968), which places a barrier to full autonomy. In the United States, by contrast, the National Highway Traffic Safety Administration (NHTSA) has developed safety standards that have enabled faster time to market (Atiyeh, 2021). China is also at the forefront of autonomous systems development, supported by extensive government R&D programmes.

However, social acceptance of self-driving cars depends on a number of factors. Public attitudes are influenced by age, gender, education and technological attitudes (Cavoli et al., 2017). Although a significant proportion of the public is sceptical about reliability and pricing (Howard & Dai, 2014; König & Neumayr, 2017), some research suggests that social trust can be increased if autonomous technology is initially introduced in public transport (Kyriakidis et al, A similar result was found in a Chinese study, which showed that individual differences, such as age and attitudes towards the technology, significantly affect the adoption of self-driving buses (Li et al., 2022). However, trust is fragile: users are often reticent in the initial period following adoption (Kettles & Van Belle, 2019), and many are concerned about accidents due to software failures. However, confirmation may come if evidence is available that autonomous systems reduce the risk of accidents, especially in extreme conditions.

At the heart of the ethical dilemmas are the decisions made in accident situations. The theoretical position is that the vehicle should make a decision with the least possible loss, but individuals often put their own safety first. According to Gogoll and Muller (2017), ethical operation can only be guaranteed if the principles of human decision-making are incorporated into the operation of systems. The question of liability is also

controversial: in the event of an accident, the question arises whether the manufacturer, the programmer or the driver can be held liable (Borenstein et al., 2019; Goodall, 2014; Servin, 2023; Woollard, 2023). In this context, Bo (2024) pointed out that the responsibility of programmers does not end with the completion of development but extends to the entire life cycle of the operation of the systems.

Security risks are of particular importance in the context of cyber threats. Perger (2022) has described cyberterrorism as attacks aimed at crippling infrastructures or achieving political objectives. And military drones and autonomous weapon systems raise new ethical and legal questions that require an integrated approach to the human and technological factors of defence strategies (Kumar & SM, 2019). The pace of progress is currently slowed by both technical and societal barriers. According to Viktor and Fodor (2024), the lack of vehicle-to-vehicle (V2V) communication and data security issues pose serious challenges. Kovács, Hógye-Nagy, and Kurucz (2021) point out that situational awareness and user awareness can contribute to improving security. Nevertheless, extreme weather, cyber threats and infrastructure deficiencies continue to hinder widespread deployment (Chougule et al., 2023; Gál, 2024).

The social impact of accidents may increase scepticism, particularly in Europe (Othman, 2023), while populations in developing countries are more open to new technologies (Jaradat et al, 2020). Although self-driving vehicles with their advanced sensing systems can contribute to improving road safety, lack of regulation, infrastructure and trust remain major barriers (Szatmáry & Lazányi, 2022). Overall, the development of autonomous vehicles poses not only technological but also social and ethical challenges, which need to be addressed for widespread adoption.

Military Dimensions and Social Acceptance of Autonomous Systems

The military application of autonomous systems and artificial intelligence represents one of the most significant strategic and technological turning points of the 21st century. The digitalisation of warfare and the spread of automated decision-making are fundamentally reshaping military operations, security policy and global stability. AI-based systems are capable of autonomously executing tasks, supporting decisions and complementing command in complex environments. However, technological capabilities alone do not guarantee successful military integration. The confidence of society and military personnel is key to the effective deployment of these systems.

Hagos and Rawat (2022) emphasise that although AI and machine learning offer revolutionary opportunities for tactical autonomy, the development of systems that provide full autonomy is limited by a number of technical and operational barriers. Future models must be able to handle the complexity of real-world military environments while maintaining transparency and reliability. Research by Madsen and colleagues (2024) has shown that reinforcement learning (RL) can be effective in defending against cyber attacks, but the robustness of the systems requires further development.

The quality and transparency of the decision-making process is a particularly critical issue. Neuro-symbolic AI, which combines the learning capabilities of neural networks with symbolic reasoning, could open up new horizons in military decision support (Hagos & Rawat, 2024). This hybrid model could offer faster and more meaningful decisions but can only become socially acceptable if human control is continuously ensured. Anneken and co-authors (2025) highlight that incorporating ethical frameworks, such as human-in-the-loop and human-on-the-loop models, as well as eXplainable AI (XAI), is essential in military AI development. These will not only enhance military effectiveness, but also social trust.

The ambivalent nature of AI has been pointed out by Rashid et al. (2023): while AI has the potential to significantly enhance military capabilities - from logistics to cybersecurity - its irresponsible use can destabilise the global security system. The Russo-Ukrainian war offers a practical example of how small unmanned systems (SUAS) have become a key component of reconnaissance and support operations (Kelly et al., 2023). Kula and Çelebi's (2025) studies of autonomous naval systems highlighted the importance of swarm intelligence and machine learning, while emphasising the risk of cyber threats and ethical dilemmas. Overall, the literature warns that the military application of autonomous systems can only become sustainable if the technological options are accompanied by a strengthening of societal trust and consideration of ethical requirements. The future of autonomous vehicles therefore does not depend solely on engineering solutions, but at least as much on society's ability to respond appropriately to the security, legal and ethical challenges that arise.

The social, legal, ethical and military dimensions described above clearly show that the proliferation of autonomous vehicles and AI-based systems is not just a technological issue. Public trust, regulatory frameworks and the assignment of ethical responsibilities are crucial to how and to what extent these systems can be integrated into transport and warfare. One of the key challenges for future research is to

examine how public perception and user trust influence the adoption of autonomous systems and under what conditions the technology can be safely and ethically integrated into everyday life and military strategies.

Method

Research Methodology

The methodological approach of this research was based solely on primary data, which provides a comprehensive picture of the social acceptance of self-driving vehicles through the experiences and attitudes of respondents. The data was collected using convenience sampling, which, although not allowing generalisation of the results to the whole population, provides an opportunity to explore relevant correlations. Sociodemographic variables such as age, gender and educational attainment, as well as technological affinity were given priority in the study. Analysing these will help to understand the extent to which individual differences influence the adoption of autonomous technologies, a relationship that has been highlighted in previous research (Li et al., 2022). Descriptive statistical methods, Spearman's rank correlation and independent samples t-test were used to analyse the data using the *SPSS 25* statistical software package. These procedures allowed us to examine the relationships between different background variables and attitudes towards autonomous vehicles. It is important to stress, however, that the sample is not representative, so the generalisability of the conclusions drawn from the results is limited. Nevertheless, the study provides valuable insights into the attitudes of different social groups towards self-driving technologies and the factors that shape confidence or scepticism. Several objectives underpinned the research. On the one hand, it aimed to investigate the impact of the regulatory environment and, on the other hand, to explore the role of individual attitudes and experiences of technology use in the adoption of autonomous vehicles. Mapping societal perceptions can help to guide future regulatory, industry and research directions.

Description of the Sample

Data was collected using an anonymised online questionnaire. The online format had several advantages: it facilitated honest responses, reduced the proportion of socially undesirable responses, and allowed for fast and efficient data processing. However, it also had drawbacks. A common problem with online surveys is

low response rates and bias due to voluntary participation, which can affect the sample composition. In addition, there may be inconsistencies in the interpretation of questions, which can introduce uncertainty into the results. After sample cleaning, 2312 respondents were included in the analysis. The age of respondents ranged from 10 to 90 years. Figure 1 illustrates the distribution of respondents by age. The distribution indicates relatively stronger participation from younger cohorts, but the wide age range shows that the questionnaire reached a broader span of ages, allowing for a detailed examination of different aspects of social acceptance. The results of the survey, although not representative, can provide significant insights into the evolution of public opinion and contribute to a better understanding of the social acceptance of future self-driving vehicles.

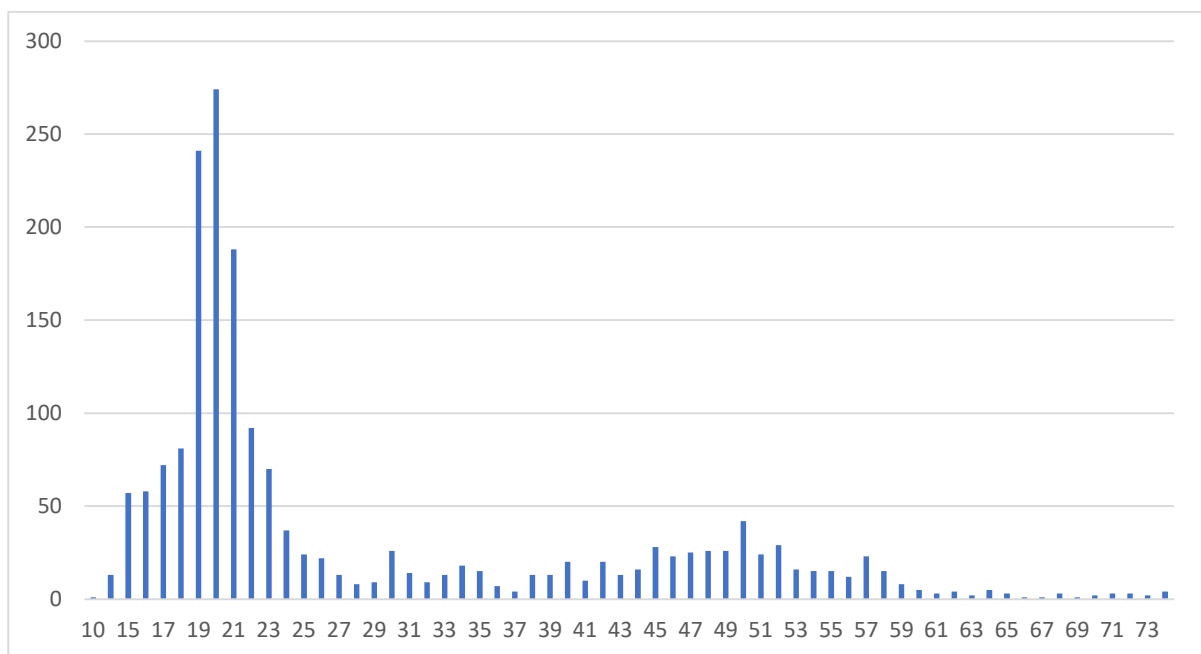


Figure 1. Distribution of respondents by age (N = 2,312)

The survey explored attitudes towards autonomous vehicles along **eight targeted questions** covering technological, social and military dimensions. The questions focused on the following main themes:

- ***Biggest technological challenge:*** The question aimed to explore what respondents perceive as the main barriers to the deployment of self-driving vehicles. The results could contribute to setting development priorities.

- **Cybersecurity risks:** This dimension looked at IT vulnerabilities and concerns about hacker attacks on autonomous vehicles. The question measured the extent to which respondents considered unauthorised use of the technology likely.
- **Communication with human road users:** This aspect is particularly important in urban transport.
- **The need for a regulatory framework:** This question asked to what extent they considered clear legislation on responsibility, ethics and safety to be essential.
- **Most challenging transport environment:** Respondents were asked whether they perceived the operation of autonomous systems in urban traffic, on motorways or in extreme weather conditions as the most challenging.
- **Military combat applications:** This question explored attitudes towards the deployment of self-driving vehicles in armed conflicts, in particular the acceptability of decision-making without human intervention.
- **Most suitable military tasks:** respondents could rate whether they considered autonomous vehicles to be most suitable for logistical, reconnaissance, surveillance or combat tasks. The results help to understand the societal perception of military technologies.
- **Likelihood of terrorist use:** This question asked how much respondents feared that self-driving vehicles would be used for malicious purposes, such as terrorist attacks.

Through these questions, the survey provided a comprehensive picture of societal perceptions of the use of self-driving vehicles in civilian and military applications. Together, these dimensions have enabled an understanding of how respondents from different demographic and attitudinal backgrounds perceive the risks and opportunities of autonomous technologies. The research provides an empirical basis that can contribute to a better understanding of the embeddedness of self-driving vehicles in society and help shape future regulatory, development and safety policy guidelines. The above methodological framework and the definition of the dimensions of investigation allowed the research to explore in detail the specificities of societal attitudes towards self-driving vehicles, the results of which are presented in the next chapter.

Results and Discussion

The Civil (Non-Military) Dimension

The civil (non-military) dimension of attitudes toward autonomous vehicles (AVs) can be read as a demand-side story about how consumers price risk, how they value safety externalities, and what institutional arrangements they require to move from curiosity to adoption. Using the survey of $N = 2,312$ respondents with English value labels applied, the evidence indicates modest baseline support, fragile cybersecurity trust, and—importantly—overwhelming demand for visible communication in mixed traffic and for clear legal rules that allocate liability. These four levers—support, trust, communication, regulation—jointly determine the speed and cost of diffusion. The narrative below integrates the observed distributions with standard economic mechanisms.

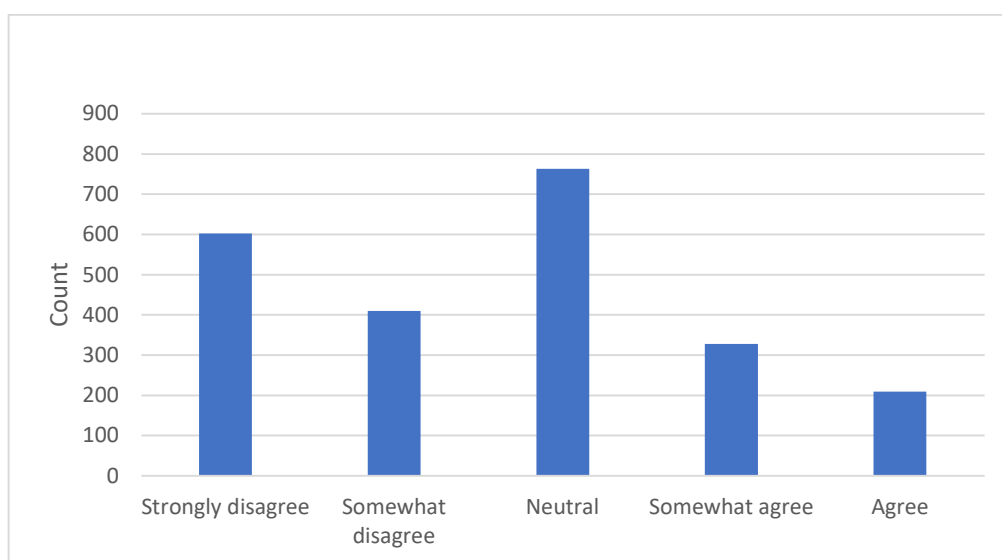


Figure 2. Support for introducing autonomous vehicles ($N = 2,312$)

The cross-section of support is not yet right-shifted toward acceptance. A combined 43.7% of respondents oppose introduction (26.0% “Strongly disagree” and 17.7% “Somewhat disagree”), 33.0% are neutral, and only 23.2% express support (14.2% “Somewhat agree” and 9.0% “Agree”). In an adoption-diffusion framework, such a distribution implies that perceived private benefits (time savings, comfort, access) are outweighed by perceived costs (safety concerns, loss of control, learning costs) for a large share of the

population. The large neutral mass is strategically pivotal because it represents relatively low switching costs if credible information reduces uncertainty; this is the segment where marginal persuasion is cheapest. For firms, the implication is higher customer acquisition costs and a slower S-curve without complementary measures that directly address risk perceptions; for policymakers, localized pilot corridors with transparent performance dashboards can convert neutrals at lower fiscal cost than broad subsidies. Trust in AV cybersecurity behaves like a credence attribute: consumers cannot verify protection *ex ante* and thus rely on signals. The distribution is skewed toward distrust: 15.0% report “Do not trust at all” and 37.0% “Rather do not trust,” while 42.7% “Rather trust, but with reservations” and only 5.3% “Fully trust.” In transaction-cost terms, low trust inflates the subjective risk premium attached to AV use, depresses willingness to pay, and raises the hurdle rate for private investment. It also creates a credibility gap that marketing alone cannot bridge because the underlying uncertainty is technical and systemic rather than merely perceptual. Two instruments mitigate this. First, verifiable disclosures—third-party penetration tests, conformity to recognized security standards, and routine update logs—reduce information asymmetry and allow both consumers and insurers to convert vague fears into assessable risk. Second, a complementary legal infrastructure that clarifies *ex post* liability converts ambiguous tail risks into insurable, priceable risks (see below). These instruments are strategic complements: disclosures persuade when paired with rules that bite, and rules are more effective when the technical evidence base is transparent.

Table 1. Trust in autonomous vehicles' cybersecurity (N = 2,312)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Do not trust at all	346	15,0	15,0	15,0
	Rather do not trust	856	37,0	37,0	52,0
	Rather trust, but with reservations	988	42,7	42,7	94,7
	Fully trust	122	5,3	5,3	100,0
	Total	2312	100,0	100,0	

If trust concerns largely unseen software defenses, the next lever—vehicle–pedestrian communication—addresses visible behavior in mixed traffic, where AVs create safety externalities for non-users (pedestrians, cyclists, conventional drivers). Here the preference signal is unambiguously strong: 62.5% rate enhanced communication as “Very important,” 30.6% as “Important, but not primary,” and only 6.8% assign low or no importance. Economically, this reveals two features. First, consumers place high marginal value on legible, standardized external human–machine interfaces (HMI): eye-contact analogues, intent signaling, crosswalk

interactions, and predictable yielding behavior reduce coordination failures and perceived risk. Second, because benefits accrue even to non-adopters, there is a public-good component that private firms may underprovide without coordination. A cost-effective policy response is standard-setting: common iconography, light colors, message timing, and acoustic cues (akin to brake-light conventions) generate coordination gains, so each new AV benefits from an installed base of expectations. For firms, early compliance with emerging HMI norms yields reputational dividends and lowers neighborhood-level opposition in dense urban markets.

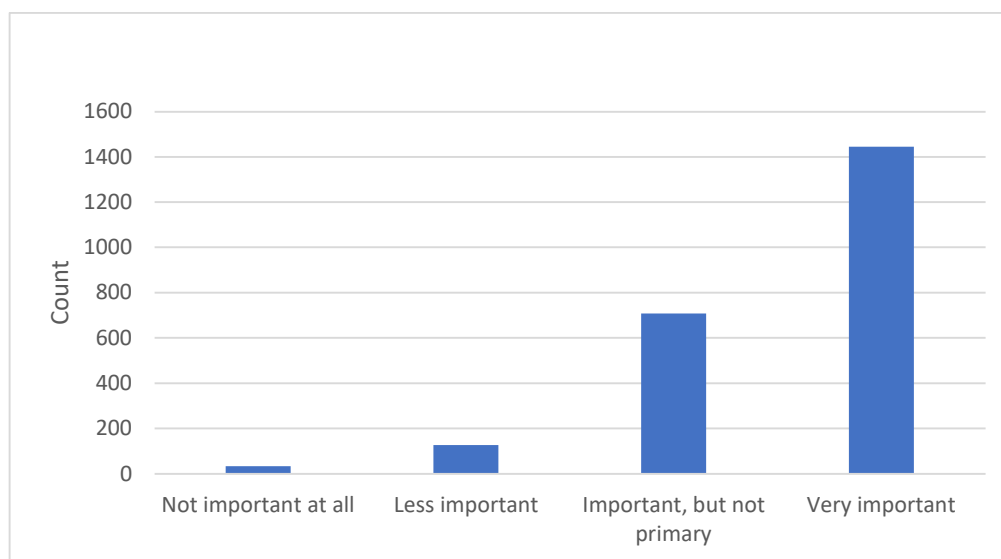


Figure 3. Importance of vehicle–pedestrian communication for safety (N = 2,312)

Legal regulation to clarify liability closes the loop by reallocating risk to the least-cost avoider and making losses contractible. The survey reveals near-consensus: 69.9% rate legal clarification “Very important,” 22.8% “Important, but not primary,” and only 7.3% assign low or no importance. In regulatory-economics language, the distribution signals high social demand for rule-based risk allocation: consumers currently price in uncertainty over who pays when things go wrong (owner, manufacturer, software provider, government, insurer), while producers face elevated cost of capital due to litigation risk and unclear compliance duties. Clarifying ex ante who bears which class of risks (design defects, software faults, misuse, maintenance neglect) reduces deadweight loss by improving insurance design, speeds claims resolution, and feeds back into trust by demonstrating credible, enforceable backstops. This is also where public and private incentives can align: an industry that invests in compliance-ready designs and documentation earns a trust

premium, while regulators gain a lever to align incentives with safety outcomes (e.g., strict liability for defects paired with safe-harbor provisions for certified software updates).

Table 2. Importance of legal regulation to clarify liability (N = 2,312)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not important at all	36	1,6	1,6	1,6
	Less important	131	5,7	5,7	7,2
	Important, but not primary	528	22,8	22,8	30,1
	Very important	1617	69,9	69,9	100,0
	Total	2312	100,0	100,0	

Taken together, the four levers point to a trust-and-rules-first path to adoption. Baseline support is modest, so price competition or advertising alone is unlikely to accelerate diffusion if fundamental uncertainties persist. Cybersecurity distrust is widespread, but the modal stance—“trust with reservations”—is elastic to credible information and enforceable guarantees. Communication standards are a low-regret, high-impact coordination fix with broad public support; they reduce everyday frictions precisely in the situations where social acceptance is formed—crossings, merges, ambiguous right-of-way cases. Legal clarity, finally, converts catastrophic tail risks from ambiguous liabilities into priced risks, unlocking insurance markets and lowering capital costs for producers. A pragmatic sequencing is therefore: (i) adopt visible communication standards in pilot areas to normalize behavior and reduce day-to-day anxiety; (ii) legislate and operationalize clear liability rules that map faults to actors; (iii) institutionalize cybersecurity disclosures and certifications tied to those rules. This order targets the large neutral middle identified in the support distribution and should shift the mass toward acceptance at the lowest marginal persuasion cost.

The Military Dimension

The military dimension of attitudes toward autonomous vehicles (AVs) speaks directly to how citizens balance operational effectiveness against ethical risk, and how they price uncertainty in life-and-death contexts. Using the survey of N = 2,312 respondents with English value labels applied, three patterns dominate the landscape: first, baseline acceptability of fully autonomous military vehicles in combat (no human intervention) is divided but leans modestly positive; second, the public clearly differentiates between missions, favoring reconnaissance and logistics over kinetic operations; third, perceived threat of terrorist

misuse is high and could act as a drag on acceptance unless mitigated by credible safeguards. These patterns interact with civil support for AVs and with demographics, creating a structured map of where legitimacy is strong and where it is fragile.

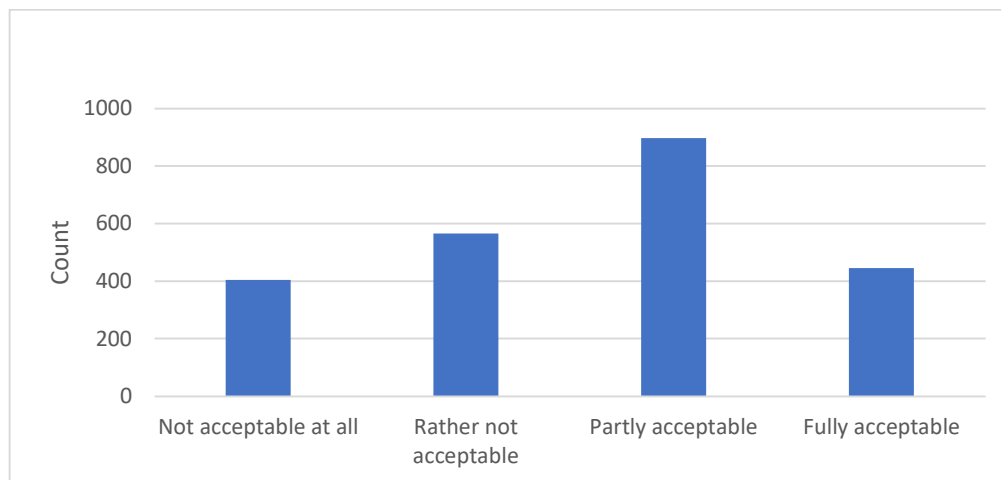


Figure 4. Acceptability of autonomous military vehicles (No human intervention) in combat (N = 2,312)

On acceptability, the distribution suggests a cautious, conditional mandate: 17.5% judge such deployment “Not acceptable at all,” 24.5% “Rather not acceptable,” 38.8% “Partly acceptable,” and 19.2% “Fully acceptable.” Aggregating the top two categories yields 58.0% who are at least partly accepting, yet the minority of full endorsement (19.2%) underscores the salience of control and accountability in lethal contexts. From a defense-economics vantage point, this profile implies that the social license is elastic to governance design: where command responsibility, auditability, and ex post review are robust, marginal acceptance is likely to rise; where these are vague, the “rather not acceptable” group will harden into outright opposition. Gender and education gradients reinforce this: acceptability differs significantly by gender ($\chi^2 = 35.4$, $p < .001$), with men more often in the “Fully acceptable” category, and varies by education ($\chi^2 = 54.2$, $p < .001$), hinting that technical familiarity and perceived capability shape risk tolerance. For capability planners, the implication is to tie autonomy to bounded mandates—clearly scoped mission envelopes, explicit fail-safe criteria, and legally codified review—so that the median voter perceives restraint rather than unfettered delegation of lethal force.

Mission preferences are sharply stratified, revealing how citizens allocate autonomy across the production function of defense. When asked which tasks are most suitable for autonomous vehicles, 48.4% choose

reconnaissance and surveillance, 36.7% logistics and transport, and only 15.0% combat operations (valid N $\approx$ 2,307 after missing). This ranking is economically coherent: the first two categories deliver high expected value per unit risk—exposure to enemy fire is reduced while information and supply resilience are increased—whereas autonomous kinetic action concentrates downside risk in the very domain where error costs are catastrophic and reputationally irreversible. The public, in effect, prices mission externalities: ISR and logistics generate positive spillovers (fewer casualties, fewer convoys) with low moral hazard, while autonomous combat concentrates moral hazard and attribution problems. Strategically, this points to a phased portfolio: scale autonomy where the social cost–benefit ratio is clearly favorable and build legitimacy through demonstrated performance, then reconsider kinetic roles only under strict human-on-the-loop constraints and transparent rules of engagement.

Table 3. Most suitable military tasks for autonomous vehicles (N = 2,312)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Reconnaissance and surveillance	1116	48,3	48,4	48,4
	Logistics and transport	846	36,6	36,7	85,0
	Combat operations	345	14,9	15,0	100,0
	Total	2307	99,8	100,0	
Missing	System	5	,2		
Total		2312	100,0		

The third pillar is perceived threat of terrorist misuse. Here the distribution is heavy on the “likely” side: 42.4% “Likely” and 27.9% “Very likely,” with only 6.1% “Not likely at all” and 23.5% “Less likely.” In risk-analysis terms, respondents are assigning a fat-tail penalty to technology: even if baseline risk is low, the perceived severity of a successful misuse inflates the expected disutility and shifts preferences toward precaution. Left unaddressed, this fear can bleed into otherwise favorable views on non-combat missions, depressing the revealed willingness to accept autonomy even where net benefits are high. The policy lever is to decouple legitimate military autonomy from the misuse narrative through concrete, auditable safeguards: hardened geofencing and remote-disable protocols; strong chain-of-custody for hardware and models; export and end-use controls; red-team exercises with public reporting; and integration of domestic counter-UAS defenses. Each instrument turns a diffuse fear into a monitored control, lowering the subjective variance that drives the high “likely” mass.

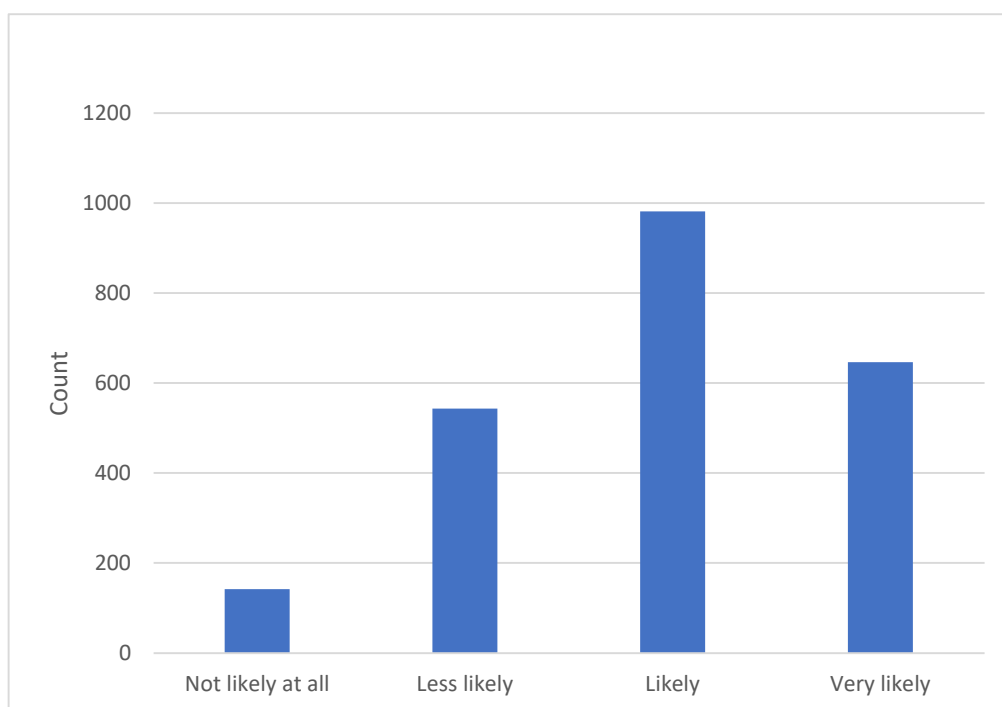


Figure 5. Likelihood terrorists use autonomous vehicles for attacks (N = 2,312)

Table 4. Support for introducing autonomous vehicles * Acceptability of autonomous military vehicles (no human intervention) in combat Crosstabulation (N = 2,312)

		Not acceptable at all	Rather not acceptable	Partly acceptable	Fully acceptable	
Support for introducing autonomous vehicles	Strongly disagree	28,7%	23,1%	32,9%	15,3%	100,0%
	Somewhat disagree	15,9%	25,9%	42,0%	16,3%	100,0%
	Neutral	13,2%	27,3%	43,5%	16,0%	100,0%
	Somewhat agree	11,3%	23,2%	40,2%	25,3%	100,0%
	Agree	13,4%	17,7%	30,1%	38,8%	100,0%
Total		17,5%	24,5%	38,8%	19,2%	100,0%

Crucially, military acceptance is not independent of the civil sphere. Cross-tabulation with civil support for introducing AVs shows a strong monotone gradient ($\chi^2 = 142.3$, $p < .001$): respondents who “Agree” with civil introduction are far more likely to find military use acceptable (e.g., 38.8% “Fully acceptable” in the “Agree” group versus 15.3% among “Strongly disagree”). At the same time, the rank-based association is modest (Spearman $\rho \approx 0.173$), indicating that a sizable minority differentiates sharply between civilian mobility and lethal military contexts. For strategy, this means two distinct trust architectures: a civil trust stack (safety performance, pedestrian communication, liability clarity) and a military trust stack (rules of engagement, human oversight, post-hoc accountability, misuse safeguards). Progress in the civil stack helps but cannot substitute for visible reassurance on the uniquely military risks of autonomy. In communications, conflating the two can backfire; instead, planners should explicitly acknowledge the difference in moral stakes and foreground the additional constraints attached to military autonomy. The association between civil support for introducing AVs and the acceptability of fully autonomous military vehicles in combat is statistically significant, Pearson’s $\chi^2(12, N = 2,312) = 142.25$, $p < .001$, with acceptance rising monotonically across support categories.

A workable sequencing emerges from these distributions. Begin by amplifying autonomy in reconnaissance and logistics, the domains with clear public support and favorable cost–risk profiles, and pair deployment with rigorous after-action transparency to build a performance record. In parallel, legislate and promulgate mission-bounded autonomy doctrines: explicit “halt/hand-off” triggers, authenticated command channels, immutable audit logs, and clearly specified human-on-the-loop duties for any operation with plausible kinetic consequences. Simultaneously, close the misuse expectation gap through visible controls—technical (geofencing, remote disable), organizational (segregated development and operations), and legal (end-use enforcement)—with periodic, public red-team reporting. Only once these layers are in place should consideration be given to expanding autonomous roles in kinetic missions, and even then under graduated oversight that makes residual risk allocations legible to both operators and the public. This sequencing aligns with revealed preferences: it respects the public’s mission ordering, addresses the salient tail-risk fears, and leverages the positive spillovers from civil AV trust without pretending they solve the uniquely military accountability problem.

Conclusion

This article reports indicative evidence from a large, well-labeled, non-probability survey of attitudes toward autonomous vehicles (AVs) in civil and military settings. The dataset comprises $N = 2,312$ completed questionnaires gathered online through convenience and snowball recruitment. As no probability frame, quotas or post-stratification weights were applied, estimates should be interpreted as patterns within the obtained sample rather than population parameters. Coverage is strongest among younger and urban respondents—typical of networked surveys—which is analytically useful for early-adoption contexts but implies selection and self-selection biases that caution against national prevalence claims. On the civil side, baseline support for introducing AVs is modest and skewed toward caution. A total of 43.7% oppose introduction (26.0% “Strongly disagree”, 17.7% “Somewhat disagree”), 33.0% are neutral, and 23.2% express support (14.2% “Somewhat agree”, 9.0% “Agree”). Trust in AV cybersecurity is fragile: 15.0% report “Do not trust at all” and 37.0% “Rather do not trust”, while 42.7% “Rather trust, but with reservations” and only 5.3% “Fully trust”. Within the sample, support and cybersecurity trust covary strongly (Spearman $\rho \approx 0.41$; Pearson $r \approx 0.40$, $p < .001$), consistent with a credence-attribute mechanism whereby security assurances raise willingness to adopt. Age correlates negatively with cybersecurity trust ($r = -0.115$, $p < .001$), suggesting systematically greater scepticism among older respondents, while the age–support association is weak and not statistically significant. Two enabling conditions command near-consensus: respondents emphasise the importance of clear vehicle–pedestrian communication (62.5% “Very important”, 30.6% “Important, but not primary”) and of clarifying legal liability (69.9% “Very important”, 22.8% “Important, but not primary”). Support differs by gender, education and residence (χ^2 tests, $p \leq .005$), indicating that segmentation matters for both policy design and market communication. On the military side, acceptance of fully autonomous military vehicles in combat (no human intervention) is cautious but non-trivial: 17.5% “Not acceptable at all”, 24.5% “Rather not acceptable”, 38.8% “Partly acceptable”, 19.2% “Fully acceptable”. Mission preferences are sharply differentiated: autonomy is judged most suitable for reconnaissance/surveillance (48.4%) and logistics/transport (36.7%), and least suitable for combat operations (15.0%; valid $N \approx 2,307$). Perceived risk of terrorist misuse is high (42.4% “Likely”, 27.9% “Very likely”), a tail-risk concern that can depress acceptance unless countered with credible safeguards. Military acceptance rises monotonically with civil support (Pearson’s $\chi^2(12, N = 2,312) = 142.25$, $p < .001$), yet the rank association is modest (Spearman $\rho \approx 0.173$), implying that many respondents distinguish sharply between civilian mobility and lethal military contexts. Gender and education relate to military acceptance (χ^2 $p < .001$), consistent with differences in perceived capability, risk and accountability. Taken together,

the evidence points to a “trust-and-rules first” pathway to adoption. In civil contexts, the large neutral middle is elastic to credible reductions in uncertainty in everyday interactions and to legible allocation of tail risks; in military contexts, legitimacy hinges on bounded mandates, human oversight and auditable safeguards. We therefore propose five actionable recommendations. First, institutionalise cybersecurity transparency and assurance: third-party penetration testing, conformance to recognised standards, publicly accessible security update logs and software bills of materials, backed by independent certification; these measures convert credence claims into verifiable signals and should be tied to procurement incentives. Second, standardise external human–machine interfaces for mixed traffic—common iconography, light patterns, message timing and acoustic cues—piloted in dense urban corridors with public performance dashboards; this coordination device reduces day-to-day frictions and accelerates social learning. Third, clarify liability *ex ante* by legislating fault allocation (owner vs. manufacturer vs. software provider vs. operator) and evidentiary rules; pair strict liability for defects with safe-harbour provisions for certified software updates to make risks insurable, shorten claims cycles and lower capital costs. Fourth, target communication and product design to the neutral segment and to older cohorts that report lower cybersecurity trust; emphasise legibility at conflict points (crossings, merges) where attitudes are formed, and report near-miss and incident metrics transparently. Fifth, sequence military autonomy where the social cost–benefit ratio is clearly favourable—reconnaissance/surveillance and logistics—while reserving kinetic roles for tightly bounded use cases under human-on-the-loop oversight; implement immutable audit logs, authenticated command channels, rigorous red-team exercises with public reporting, hardened geofencing and remote-disable functions, and chain-of-custody plus export/end-use controls to decouple legitimate military autonomy from the terrorism-misuse narrative. Monitoring should track conversion of neutrals, trust uplift, incident rates in pilot zones, and claim resolution times post-liability reform. Executed in this order—visible communication standards, liability clarity, security assurance, and scaled deployment in low-controversy military missions—the programme aligns with revealed preferences, lowers perceived risk premia, and offers the fastest route to durable social licence at the lowest marginal persuasion cost.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

Funding

* Project no. MEC_SZ 149231 has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the MEC_24 funding scheme.



PROJECT
FINANCED FROM
THE NRDI FUND

Conflict of Interest

* The authors declare that they have no conflicts of interest

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Management Economics and Business (www.iconmeb.net) held in Budapest/Hungary on August 28-31, 2025

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HUMAN-CENTERED FUTURE: THE RISE OF INDUSTRY 5.0 IN CORPORATE SUSTAINABILITY LITERATURE

Abstract: In the second quarter of the 21st century, Industry 5.0 is considered as the most advanced stage of the industrial revolution, where the interaction between people and smart technologies has reached a new level. This assessment is not limited to the digital transformation of production processes, but also shaped by multidimensional sustainability elements such as environmental sensitivity, social benefit and ethical responsibility. The concept of Industry 5.0 seeks to build a manufacturing ecosystem grounded in sustainability and human-centric principles. The aim of this study is to reveal the current research trends in the international academic literature within the framework of the keywords “Industry 5.0” and “Sustainability” and to analyze the areas in which this conceptual framework is concentrated through bibliometric data. Building on this context, a total of 664 English-language scientific publications published between 2020 and 2025 in the Web of Science (WoS) Core Collection database were included in the scope of the analysis. The retrieved data were processed using RStudio Biblioshiny and VOSviewer software, and the publications were systematically evaluated according to their distribution across research fields, open access status, funding institutions, ongoing projects, influential conferences, leading journals, and prolific authors. The findings reveal that engineering, computer-related fields, and environmental sciences stand out as the disciplines contributing most to this area, while the fact that 71% of the publications are open access has gained particular attention. Furthermore, it was identified that funding bodies originating from the European Union and China provide the majority of financial support for this research domain. International conferences and publishers such as IFIP, IEEE, and ACM are among the most prominent platforms where the research is disseminated. As a result of the research, it is seen that the themes of Industry 5.0 and sustainability are met with increasing interest in the scientific literature; this interest is supported by multidisciplinary collaborations, global research funds and open access policies. This study contributes to identifying gaps in the literature and possible future research directions by revealing how Industry 5.0 is positioned in the context of sustainability.

Keywords: Industry 5.0, Sustainability, Bibliometric analysis

Introduction

Since the industrial revolution, technological advances have not only transformed production processes, but also radically affected social structures, labor relations, and understanding of sustainable development (Schwab, 2016). Today, the concept of Industry 5.0 aims to develop more resilient and sustainable production systems by bringing together human creativity and the capabilities of advanced technologies (Machado & Davim, 2023). The transition to Industry 5.0 has become possible with the deepening of cooperation between humans and smart technologies (Xu et al., 2021). While Industry 4.0 is basically shaped around automation, the internet of things, and digital integration, Industry 5.0 emphasizes a harmonious cooperation between artificial intelligence and human skills (Machado & Davim, 2023).

At the same time, unlike Industry 4.0, Industry 5.0 does not only focus on production efficiency; It contributes to the construction of a sustainable and human-centered future by adopting a human-centered approach that prioritizes ethical values, social inclusiveness, environmental responsibility and the well-being of employees (Güdek, 2023). While this transformation takes human-machine collaboration to a further level, it also requires a radical change in the strategic orientations of institutions. Especially when considered within the framework of "corporate sustainability"; Industry 5.0 requires businesses to integrate their economic gain goals with social responsibility and environmental ethics (Elkington, 1998; Carroll & Shabana, 2010).

Corporate sustainability requires addressing economic, environmental and social dimensions with a holistic approach in line with the United Nations Sustainable Development Goals (UN SDGs) (UN, 2015). In this context, it is argued that Industry 5.0 is not only a technological evolution but also a structural paradigm that will contribute to sustainable development. Although the number of academic publications addressing these two concepts - Industry 5.0 and corporate sustainability- has increased in recent years, it is seen that the current literature has some limitations in terms of thematic diversity, theoretical depth and empirical basis (Palumbo et al., 2022; Dacre et al., 2024).

In this context, the main purpose of the study is to examine the academic accumulation developing on the axis of Industry 5.0 and corporate sustainability with a systematic and bibliometric analysis method, to map the existing knowledge clusters and to reveal the intersection points of these two concepts in the literature. In this context, the analyses will be based on the Web of Science database and conceptual clusters,

publication trends and author collaborations will be analyzed using bibliometric analysis tools such as VOSviewer and CiteSpace (van Eck & Waltman, 2010; Chen, 2006).

The originality of the study lies in its interdisciplinary approach to evaluating the complementary and sometimes tense relationship between Industry 5.0 and sustainability issues. In addition, this literature mapping study aims to direct scientific knowledge production by defining thematic focus areas that will form the basis of future qualitative and quantitative research (Small, 1973; Aria & Cuccurullo, 2017).

On the other hand, recent systematic reviews in the literature show that the relationship between Industry 5.0 and sustainability is still at an early stage and has methodological limitations. For example, in their systematic review analyzing studies published between 2019 and 2022, Baig and Yadegaridehkordi (2024) emphasized that Industry 5.0 has a great potential to contribute to sustainability goals; however, this potential has not yet been addressed in a fully holistic and systematic manner in the scientific literature. Studies show that technologies such as the Internet of Things, artificial intelligence, and collaborative robots stand out in sustainability-oriented applications; however, human-centered production systems are the most common research theme. These findings support the analytical basis on which our study is based and indicate that Industry 5.0 should be investigated more comprehensively in the context of corporate sustainability (Baig & Yadegaridehkordi, 2024).

Conceptual Framework

Paradigm Shift in Industry 5.0

The distinctive aspect of Industry 5.0 is that it aims to balance the high automation capacity offered by machines and artificial intelligence with human creativity and values. In this context, Industry 5.0 represents not only a technological evolution, but also a paradigm shift that prioritizes ethical, environmental and social responsibilities (Javaid et al., 2022). Especially in terms of its relationship with sustainability, Industry 5.0 is evaluated with a holistic approach that includes goals such as reducing the carbon footprint in production processes, adopting circular economy principles and using resources more efficiently (Santos et al., 2023). However, it is stated in the literature that this relationship has not yet fully matured and the scope of the research is limited. In fact, the systematic review conducted by Baig and Yadegaridehkordi (2024) shows

that the studies on Industry 5.0 and sustainability remain largely at the conceptual level and that data for practice are insufficient. Most of the studies emphasize human-centered technological developments, but a significant portion of these studies are based on limited sample groups and lack long-term impact analyses. In this context, the need for empirical findings on how sustainable development goals can be more effectively integrated with Industry 5.0 technologies is increasing. When the thematic distribution of the studies is examined, it is seen that four main headings such as robotic advancement, sustainability in higher education, human-centeredness and ecosystem development stand out. These research axes are of critical importance in terms of making sense of the multidimensional structure of Industry 5.0 (Baig & Yadegaridehkordi, 2024).

Industry 5.0 aims to go beyond the Industry 4.0 paradigm, which is based on digitalization and automation, and restructure technology with a human-centered approach. This new approach prioritizes not only production efficiency, but also human values such as ethical responsibility, social inclusiveness and environmental awareness (European Commission, 2021). In the literature, Industry 5.0 is defined as a production model that focuses on people, integrating with individuals' creativity, decision-making competencies and problem-solving skills (Güdek, 2023).

Technologies such as cyber-physical systems, artificial intelligence, the internet of things (IoT) and big data, which came to the fore in the Industry 4.0 era, are also used in Industry 5.0, but the purpose of application of these technologies is different. In this context, technology is no longer considered only as a productivity tool, but as a tool that serves to increase social welfare. The concept of “social benefit-oriented technology” stands out as the basic structure of this transformation and is directly associated with sustainable development goals (Yıldız & Alan, 2025).

Industry 5.0 is not only considered as a digital transformation but also as a comprehensive socio-technical evolution. In this approach, technology is designed and implemented in a way that is sensitive to the needs of the individual and society. As stated in the framework report published by the European Commission (2021), the three basic principles of Industry 5.0 are resilience, sustainability and human-centeredness. Similarly, Palumbo et al. (2022) argue that this new industrial era should not be limited to industrial production alone, but that social justice, environmental responsibility and individual well-being should be integrated into a holistic production system.

This paradigm shift requires businesses to abandon their traditional strategies based solely on profit maximization and adopt multi-dimensional strategies that also take into account social, environmental, and governance impacts. Carroll and Shabana's (2010) corporate social responsibility theory and Elkington's (1998) "triple bottom line" model are frequently used theoretical frameworks to explain this transformation. Accordingly, Industry 5.0 is not considered a technology-based transformation; it is considered a value-based restructuring process.

Corporate Sustainability Approaches

Corporate sustainability is a holistic management approach that aims to create long-term value by considering not only the economic interests of businesses but also their environmental responsibilities and social impacts (Dyllick & Hockerts, 2002). This approach, which goes beyond traditional corporate performance measures, requires evaluating economic, environmental and social dimensions simultaneously with the Triple Bottom Line (TBL) model (Elkington, 1998). The concept of corporate sustainability has gained importance since the 1990s with the increase in environmental crises, social inequalities and demands for corporate transparency. This paradigm, which is the reflection of sustainable development principles in the business world, has ceased to be an approach focused solely on environmental or social responsibility; it has transformed into a corporate strategy integrated with risk management, strategic management, stakeholder relations and innovation (Bansal & DesJardine, 2014).

The United Nations Global Compact and the Sustainable Development Goals (SDGs) are among the important frameworks that encourage the global adoption of corporate sustainability (United Nations, 2015). In this context, a governance approach has emerged in which companies are accountable not only to their shareholders but also to all stakeholders – employees, customers, suppliers, local communities and environmental systems (Freeman et al., 2007).

In the literature, sustainability approaches have been conceptualized across different dimensions. Rame et al. (2024) emphasize that Industry 5.0 embodies both reactive and proactive characteristics, thereby focusing industrial development on two fundamental axes. This perspective highlights that Industry 5.0 is not merely a structure responding to existing problems but also one that provides a forward-looking and strategic vision. Similarly, Ghobakhloo (2022) draws attention to the importance of reactive and proactive decision-making processes in supply chains, noting that these processes play a critical role in enhancing firms' flexibility,

adaptability, and sustainability capacities. Indeed, these findings suggest that considering proactive and reactive approaches together within Industry 5.0 research offers significant contributions at both theoretical and practical levels. In addition, Hahn et al. (2015) analyze the effects of sustainability practices on organizational tensions and decision-making processes, indicating that corporate sustainability is a multidimensional art of balance.

Corporate sustainability is directly related not only to environmental performance but also to long-term competitive advantage and business model transformation. In this direction, developing conceptual structures are being re-evaluated together with transformational technological paradigms such as Industry 5.0, and an increasing intersection between these two areas is observed (Palumbo et al., 2022).

Therefore, the human-centered vision of Industry 5.0 can be redefined in harmony with the ethical, inclusive and participatory principles of corporate sustainability. Institutional structures that minimize the social and environmental impacts of technological developments, while at the same time prioritizing human well-being and ethical sensitivity, will play a key role in achieving sustainable development goals (Carroll & Shabana, 2010; Gudek, 2023)

The Intersection of Industry 5.0 and Sustainability: A Critical Review of the Literature

The intersection of Industry 5.0 and sustainability requires that today's production paradigms be restructured not only on the basis of technological efficiency, but also within the framework of ethical responsibility, environmental awareness and social inclusiveness. In this context, Industry 5.0 offers an approach that aims to integrate technological advances with social benefit, environmental balance and long-term resilience by addressing production processes with a human-centered approach (European Commission, 2021). There is a growing interest in the literature on the extent to which Industry 5.0 overlaps with sustainability principles. In particular, themes such as human-centeredness, flexibility, durability, and environmental sustainability are considered among the basic components of Industry 5.0, and many studies have been conducted in line with these elements (Bonilla et al., 2018; Xu et al., 2021). However, existing research is mainly concentrated on limited conceptual or technology-focused areas; and has deficiencies in terms of interdisciplinary approach, applied sample diversity, and methodological diversity (Palumbo et al., 2022).

These shortcomings make it difficult to evaluate the relationship between Industry 5.0 and sustainable development goals holistically; they clearly reveal the need for the concept to be addressed with more systematic and empirical foundations at both theoretical and practical levels. For example, in a recent systematic review conducted by Baig and Yadegaridehkordi (2024), it was stated that although human-centered technological developments are frequently addressed in the literature, a significant portion of these studies are limited to limited samples, single sectors, and conceptual repetitions.

When the literature is examined, Industry 5.0 is defined as a period in which advanced technologies such as artificial intelligence, the internet of things (IoT), cobots (collaborative robots) and big data are redesigned in line with human well-being (European Commission, 2021), while some other studies take a critical stance on the extent to which these technologies are integrated with corporate sustainability goals (Jarrahi, 2018). Indeed, Baig and Yadegaridehkordi's (2024) systematic review emphasizes the potential of Industry 5.0 for application in sustainability, but shows that the existing literature is not yet mature in terms of quantity and quality. The authors state that human-centered technological developments stand out in the 46 studies they analyzed, but a significant portion of these studies were conducted with limited samples and did not produce concrete outputs based on applied studies. It was also revealed that the research themes in the literature can be grouped under four main headings, which are robotic progress, sustainability in higher education, human-centeredness and ecosystem development, respectively. These findings clearly reveal the need for more in-depth, thematically categorized and systematic approaches to the relationship between Industry 5.0 and sustainability (Baig & Yadegaridehkordi, 2024).

While current studies on sustainability focus on the opportunities offered by Industry 5.0 for environmental sustainability, the ecological risks brought about by this transformation are not addressed comprehensively enough. In particular, issues such as carbon footprint, increase in energy consumption, and environmental impacts of digital waste are discussed at a secondary level in the current literature (Le, 2022). This situation shows that not only Industry 5.0 is directed towards environmentally friendly technologies, but also the environmental side effects of these technologies should be analyzed more deeply.

Similarly, some structural gaps stand out in the social sustainability dimension. In particular, issues such as the effects of digitalization on the workforce, employee well-being, digital inequality and psychosocial health are still relatively neglected; empirical and theoretical analyses on the consequences of technological

advances on humans remain limited (Ford, 2021). In this context, Industry 5.0 must not only be a tool that increases production efficiency, but also a carrier of policies sensitive to social justice and human dignity.

From a corporate sustainability perspective, it is seen that Industry 5.0 is mostly defined with technology-centered strategies and is designed with the assumption that these strategies will directly serve sustainable development goals. However, these approaches often lack ethical dimensions. It is observed that normative concepts such as digital rights, justice, privacy, transparency and human dignity are not systematically integrated into the literature (Zamany et al., 2024). Therefore, holistic approaches are needed that evaluate sustainability and technology not only through technical tools but also in the context of ethical and human values.

Finally, the bibliometric analyses conducted reveal that thematic integrity and interdisciplinary transition are still weak in the Industry 5.0 and sustainability literature (Yan, 2023). The concentration of conceptual clusters in a limited number of focuses shows that this field is an immature research area. In this direction, future academic studies should be designed not only at the level of technological applicability, but also to take into account ethical, socio-ecological and cultural dimensions. This multi-dimensional approach will contribute to the human-centered and sustainable transformation envisaged by Industry 5.0 being established on a more realistic and effective basis.

Method

In this study, the bibliometric analysis method was preferred to examine the trends of scientific publications on Industry 5.0 and sustainability and to reveal the structural features of the literature. Bibliometric analysis is a systematic approach that allows the quantitative evaluation of scientific production in a specific research field and is a frequently used method in identifying developments, gaps and trends in the literature (Donthu et al., 2021). The Web of Science (WoS) Core Collection database was selected as the data source in the study. The “topic” field was searched using the keywords “Industry 5.0” and “Sustainability” together, and the resulting publications consisted of 664 scientific publications published between 2020 and 2025. Research articles, review articles, book chapters and conference proceedings were included in the scope of the analysis. In the analysis process, variables such as publication types, annual publication trends, number of authors, citation amounts, keyword frequencies, journals published, funding organizations, productive

authors and countries were systematically examined. In addition, structural indicators such as keyword clusters, author collaboration networks, country and institution-based distributions were also comprehensively evaluated.

Two main tools were used for data analysis and visualization: the Bibliometrix R package (Aria & Cuccurullo, 2017) and the VOSviewer software (van Eck & Waltman, 2010). Annual production trends, basic bibliometric indicators and keyword analyses were performed with Bibliometrix, while collaboration networks between authors, countries and institutions, keyword matches and citation clusters were visualized with VOSviewer. Thanks to this methodological approach, scientific production in the field of Industry 5.0 and sustainability was analyzed from an interdisciplinary perspective, supported by both quantitative data and visual maps.

Results

In this bibliometric study prepared with the theme of Industry 5.0 and sustainability, 664 articles belonging to the years 2020–2025 were obtained from the Web of Science (WoS) database. 582 of these articles were research articles, 41 were reviews, 12 were book chapters, and It was published in the form of 29 conference papers. The publications were published from 402 different sources and were created by a total of 1961 different authors. The average number of publications per author in the studies was 0.331, and the average number of authors per publication was determined as 4.15. The total number of citations to the publications was 8032, which shows that the average citation per article was 15.41. These data clearly reveal the interdisciplinary nature and increasing scientific interest in Industry 5.0 and sustainability in Table 1.

Between 2020 and 2025, a total of 664 articles were retrieved from the Web of Science database using the keywords “Industry 5.0” and “Sustainability.” Among these, the top 20 most-cited studies are listed in Table 2. The article entitled “*Industry 5.0: Prospect and Retrospect*” by Uzun et al. (2022) ranks first with 446 citations. This study provides a comprehensive discussion of the human-centered nature of Industry 5.0 in relation to technological transformation. Lu et al. (2022), in their work “*A Perspective on Human-Centered Production: Industry 5.0*,” examined how human well-being can be prioritized in production systems and ranked second with 321 citations. The study “*The Industry 5.0 Framework: Sustainability and Integration*” authored by Ivanov (2023) focuses on the integration of Industry 5.0 into sustainability and resilience policies, receiving 290

citations and ranking third. Adel's (2022) publication "*Solutions and Challenges in the Industry 5.0 Society of the Future*" made significant contributions in terms of societal impacts and ethics-oriented transformation, with 273 citations, ranking fourth. Collectively, these studies demonstrate that Industry 5.0 should be regarded not merely as a technological revolution but also as an instrument of social, ethical, and sustainable transformation.

Table 1. General characteristics of articles on "industry 5.0 and sustainability"

Examined Years	2020- 2025
Publication Type	Number (% of Total)
Research Articles	582 (57.8%)
Reviews	41 (15.6%)
Book Chapters	12 (0.4%)
Conference Papers	29 (2.0 %)
Total Publications	664 (100%)
Publication Source	529
Number of Authors' Keywords	2061
Average Citations per Article	15.41
Average Annual Citations	1.71
Single-Author Articles	38 (5.7%)
Multi-Author Articles	630 (94.3%)
Total Number of Authors	2019 (100%)
Articles per Author	0.331
Co-authors per Article	4.15
Collaboration Index	3.42

Table 2. The 20 most cited articles on "industry 5.0 and sustainability"

Author(S), Year	Article Title	Journal Name	Citation
Uzun et al. (2022)	Industry 5.0: Prospect And Retrospect	Journal Of Production Systems	446
Lu et al. (2022)	A Perspective On Human-Centered Production	Journal Of Production Systems	321
Ivanov (2023)	The Industry 5.0 Framework: Sustainability And Integration	International Journal Of Production Research	290
Adel (2022)	Solutions And Challenges In The Future Industry 5.0 Society	Journal Of Cloud Computing	273
Bednar and Welch (2020)	Socio-Technical Perspectives: Sustainable Systems	Frontiers In Information Systems	183

Ghobakhloo and Iranmanesh (2022)	Contributions Of Industry 5.0 To Sustainable Development	Sustainable Production And Consumption	177
Mourtzis and Angelopoulos (2022)	Transition Opportunities From Industry 4.0 To Society 5.0	Energies	172
Carayannis Eg., Morawska-Jancelewicz (2022)	The Future Of Europe: Society 5.0 And Industry 5.0	Journal Of Knowledge Economy	167
Grabowska et al. (2022)	Industry 5.0: Enhancing Humanization And Sustainability	Scientific Measurement	165
Hasun and Ait-Kaddour (2023)	Industry 4.0 Technologies In Food	Critical Reviews In Food Science And Nutrition	159
Fraga-Lamas and Lopes (2021)	Green Iot And Its Use In Industry 5.0	Sensors	156
Zizic Mc., Mladineo Mc., 2022	The Paradigm Shift From Industry 4.0 To Industry 5.0	Energies	153
Kardesim and Kaynak (2022)	Rethinking Engineering Education	Journal Of Industrial Information Integration	145
Sindhwani and Afridi (2022)	Revolutionizing The Resilience Wave	Technology In Society	127
Santhi and Muthuswamy (2023)	Industry 5.0 Or Industry 4.0?	IJIDEM	115
Zhang et al. (2023)	Toward Smart Manufacturing With Industry 5.0	Advanced Engineering Informatics	109
Destouet and Tlahig (2023)	Flexible Workplace Planning Problem And Industry 5.0	Journal of Production Systems	106
Saniuk and Grabowska (2022)	The Shift From Industry 4.0 To The Concept Of Industry 5.0	Sustainability	105
Rojas & Penafiel (2021)	The Japanese Concept For Society 5.0	Sustainability	96
Sindhwani and Afridi (2022)	Social Value Creation Through Multi-Criteria Analysis	Technology in Society	90

The distribution of a total of 664 publications published in the Web of Science database on the themes of Industry 5.0 and sustainability within the scope of the 2020–2025 period is presented in Figure 1. While a limited number of publications were encountered in the first years of this period, it is seen that academic interest increased significantly especially after 2020. For example, while there were only 16 publications in 2020, this number increased to 24 in 2021 and reached 87 in 2022 with a significant increase. The number of publications peaked at 153 in 2023 and reached its highest level with 269 publications in 2024. This trend reveals that the concepts of Industry 5.0 and sustainability are gaining momentum at an interdisciplinary

level and have a wide resonance in the scientific community. The number of publications decreased to 147 in 2025, and only 1 publication could be accessed for 2026. It is considered that this situation is related to the fact that the year 2026 has not yet been completed. When evaluated in general, the intensity between 2022-2024 indicates the period in which these themes attracted the most attention from researchers.

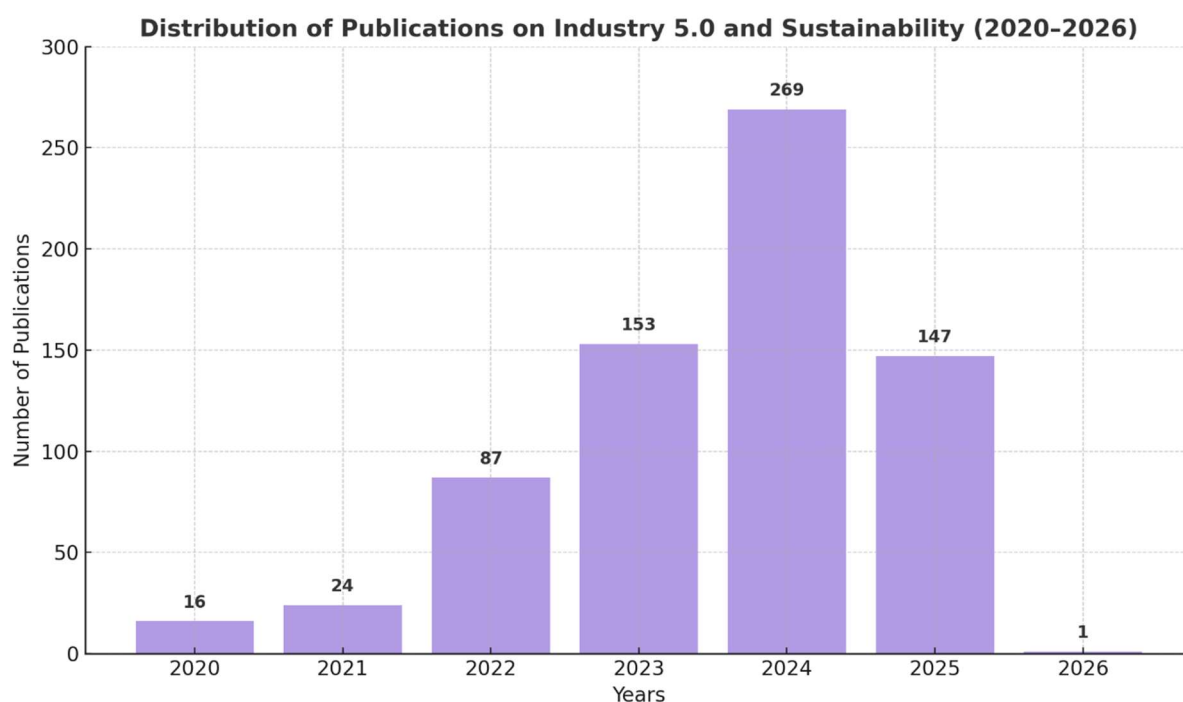


Figure 1. Annual publication number of articles on “industry 5.0 and sustainability”

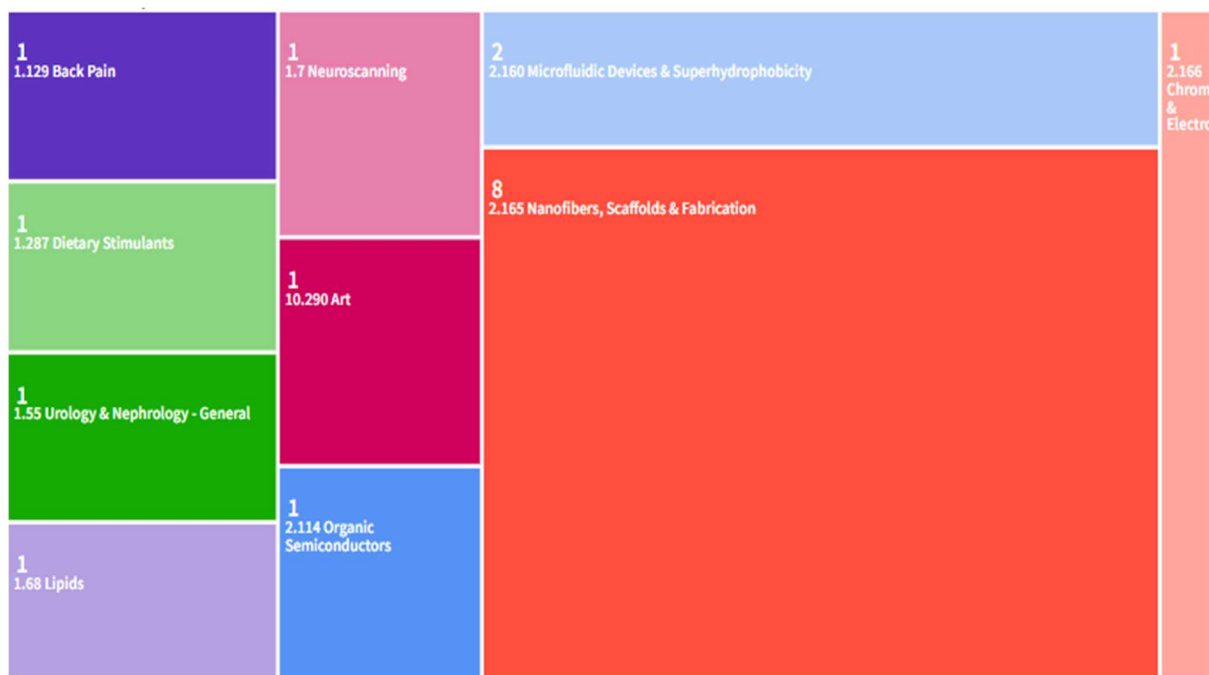


Figure 2. Thematic distribution: Citation topics meso analysis

When 664 articles published between 2020 and 2025 in the Web of Science database with the keywords "Industry 5.0 and Sustainability" are analyzed, it is seen that the prominent themes within the scope of the Citation Topics Meso classification reflect the interdisciplinary structure and technological focal points of the field (Figure 2). In this analysis, the topic "Nanofibers, Scaffolds Fabrication" ($n = 8$) was determined as the field with the highest thematic density. This situation points to the close relationship between sustainable material development and advanced manufacturing technologies and Industry 5.0. The increasing literature interest, especially in biomaterials, tissue engineering and nano-manufacturing, can be considered as a fundamental axis of the transformation in this field. However, among the analyzed data, topics such as "Microfluidic Devices & Superhydrophobicity", "Organic Semiconductors", "Back Pain", "Dietary Stimulants" and "Urology & Nephrology – General" are represented by a limited number of studies. This shows that Industry 5.0 research is not limited to production technologies, but also spreads to very different disciplines such as health, food, electronics and biophysical applications.

In Citation Topics Micro level analyses, more specific themes stand out. Particularly, topics such as "Stretchable Electronics", "Brain-Computer Interface", "Superhydrophobicity" and "Calcium Carbonate

Crystallization" reflect the leading application areas of Industry 5.0 in terms of human-machine interaction, flexible electronic systems and sustainable environmental technologies. In addition, the existence of areas such as "Diuretic Medication", "Virgin Olive Oil", "Coffee and Caffeine", "Low Back Pain" and "Museum Evolution" reveal that technological transformation is not limited to industrial production; it has a multidisciplinary structure that includes cultural, medical and social dimensions.

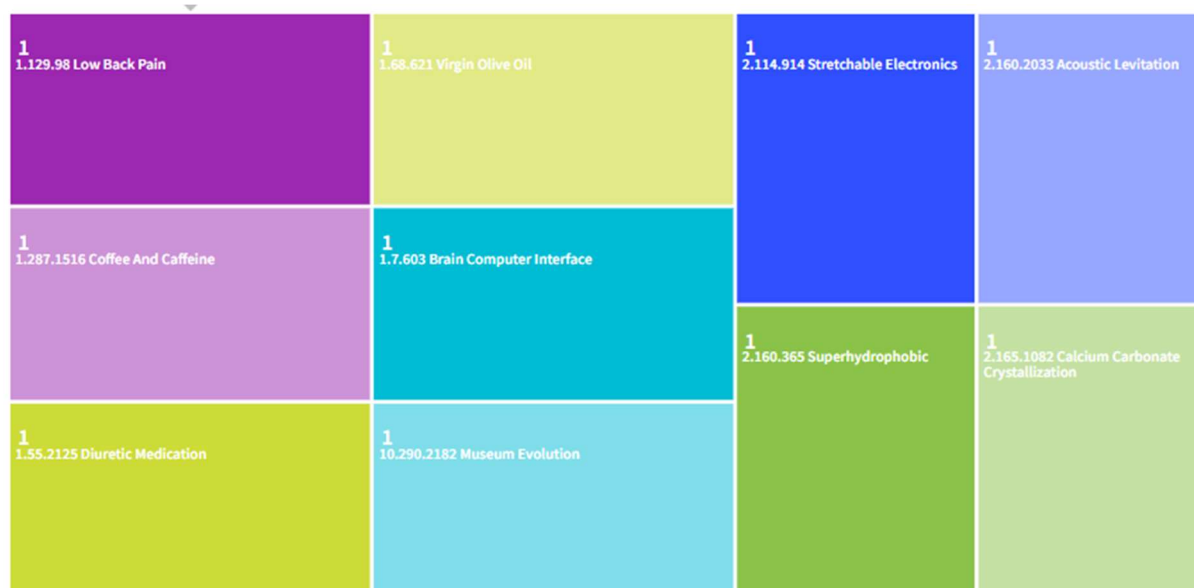


Figure 3. Thematic distribution: Citation topics micro analysis

According to the meso and micro level thematic analysis findings in Table 2 and Table 3, both meso and micro level analyses reveal that the themes of Industry 5.0 and sustainability are not limited to engineering or production; they present a multi-layered literature structure from health sciences to environmental technologies, from cultural studies to advanced physics applications. This thematic diversity is guiding in both creating a theoretical framework and determining application areas in future research.

Keywords Plus is an indexing system specific to Web of Science and is automatically generated from the words or expressions in the titles of the cited articles. The analyses made through this system in the table in Figure 4 provide important clues about the basic conceptual framework of the research field. When the Keywords Plus data of the publications included in the study are examined, it is seen that terms such as "industry 5.0", "sustainability", "smart manufacturing", "digital transformation", "artificial intelligence", "human-centric",

“resilience”, “future”, “technology”, and “automation” stand out. These key concepts reveal that the Industry 5.0 and sustainability literature is not limited to technical or production processes only; it also has a strong interaction with multidimensional areas such as digitalization, human-centeredness, artificial intelligence, and sustainable development. Therefore, this thematic density based on Keywords Plus data clearly reflects the interdisciplinary nature of the subject and the research trends on the developing technology-sustainability axis.

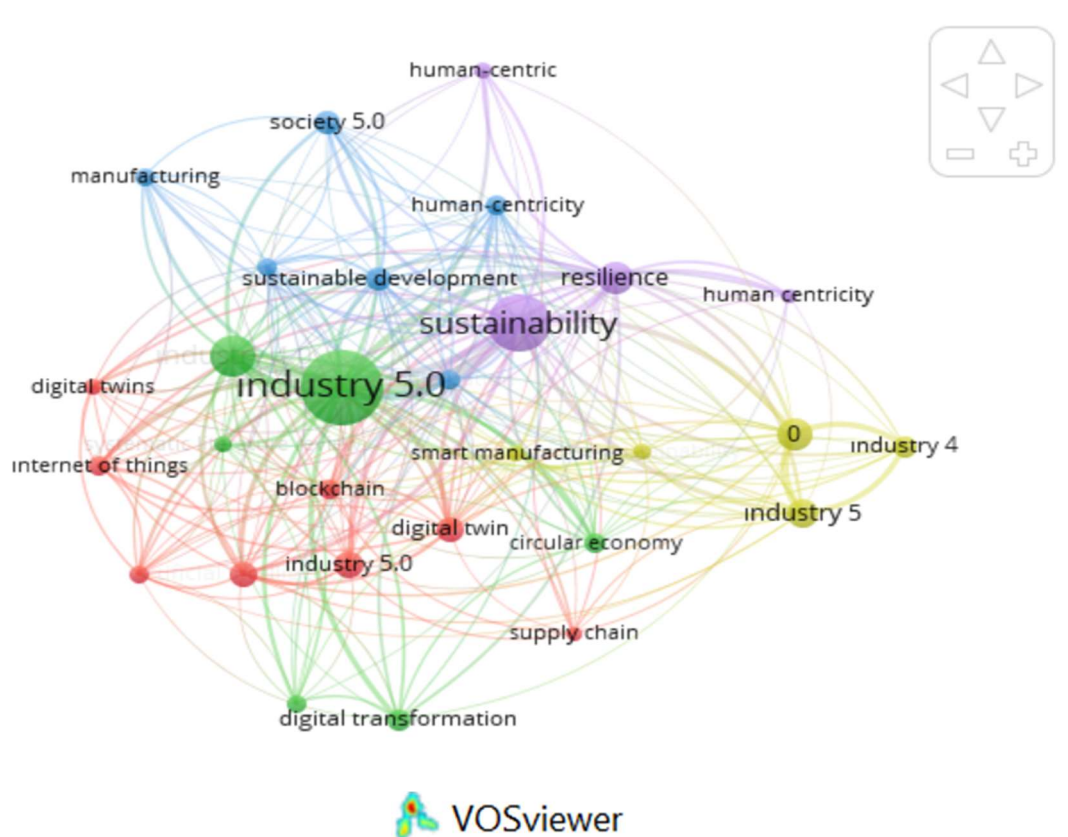


Figure 4. Keyword analysis: Frequency distribution

The distribution of publications on Industry 5.0 and sustainability has been examined according to Web of Science categories (Figure 5). The thematic analysis reveals that the area with the largest share is *Nanofibers, Scaffolds & Fabrication* (25.0%). This finding indicates that a substantial portion of the studies in the dataset are shaped around nanotechnology, advanced materials engineering, and biomedical applications. The second most prominent theme, *Microfluidic Devices & Superhydrophobicity* (18.0%), points to a strong research interest particularly in microfluidic systems and superhydrophobic surface technologies.

This is followed by *Organic Semiconductors* (12.0%), a field that has gained particular significance in the context of flexible electronics and sustainable energy systems. The themes of *Back Pain* (10.0%) and *Urology & Nephrology* (8.0%) indicate a strong connection between Industry 5.0 applications and health technologies. The themes of *Neuroscanning* (7.0%) and *Art* (6.0%) reflect the diversity of interdisciplinary approaches.

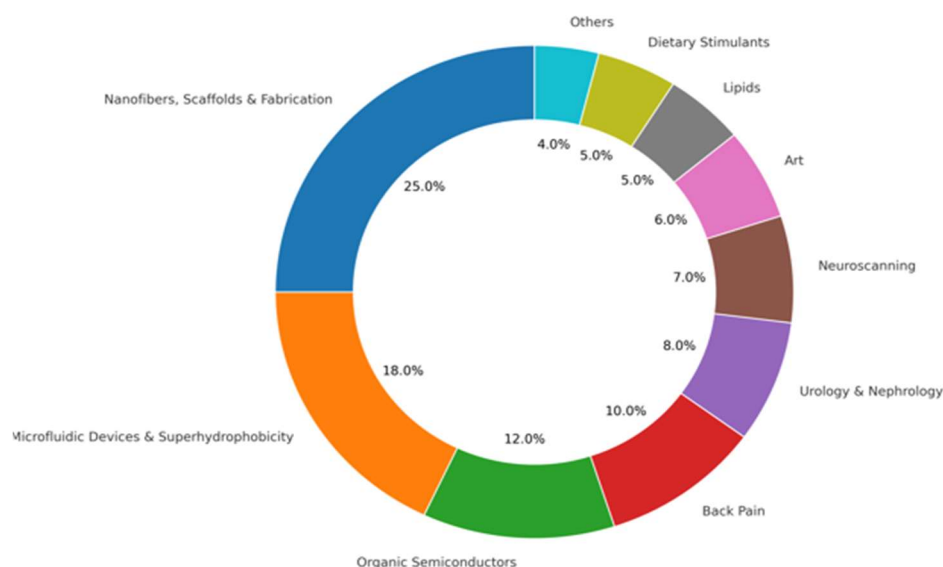


Figure 5. Publication areas covering industry 5.0 and sustainability by type

Themes with lower proportions, such as *Lipids* (5.0%), *Dietary Stimulants* (5.0%), and *Others* (4.0%), represent relatively limited but still contributive research areas that enhance the holistic structure of the field. Overall, the thematic distribution demonstrates that the Industry 5.0 and sustainability literature extends beyond production and engineering technologies to encompass health, biotechnology, and interdisciplinary domains. This indicates that the field possesses a highly diverse and integrated research ecosystem.

The analysis of publication outlets on Industry 5.0 reveals that the *Journal of Intelligent Manufacturing* ranks first, hosting the highest number of articles ($n = 42$). It is followed by *Procedia CIRP* ($n = 38$) and *Robotics and Computer-Integrated Manufacturing* ($n = 36$). The *Journal of Manufacturing Systems* occupies the fourth position with 33 articles. Other prominent journals in this domain include the *International Journal of Production Research* ($n = 30$), *Sustainability* ($n = 28$), *Journal of Cleaner Production* ($n = 27$), *Procedia Manufacturing* ($n = 25$), *IEEE Access* ($n = 22$), and *Computers in Industry* ($n = 20$). This distribution underscores the central role of journals

focusing on manufacturing systems, robotics, computer-integrated manufacturing, sustainability, and clean production in shaping the scholarly discourse on Industry 5.0. Data related to the field are given in Figure 6.

This distribution offers valuable insights into the core thematic orientations of Industry 5.0 scholarship. The prominence of research areas such as manufacturing systems, robotics and computer-integrated manufacturing, sustainability, and clean production reflects an integrated approach that simultaneously addresses technological transformation and environmental responsibility. Such a distribution resonates with the prevailing scholarly discourse, positioning Industry 5.0 as a human-centric paradigm that embeds flexible manufacturing systems within a broader conceptual framework grounded in sustainability principles.

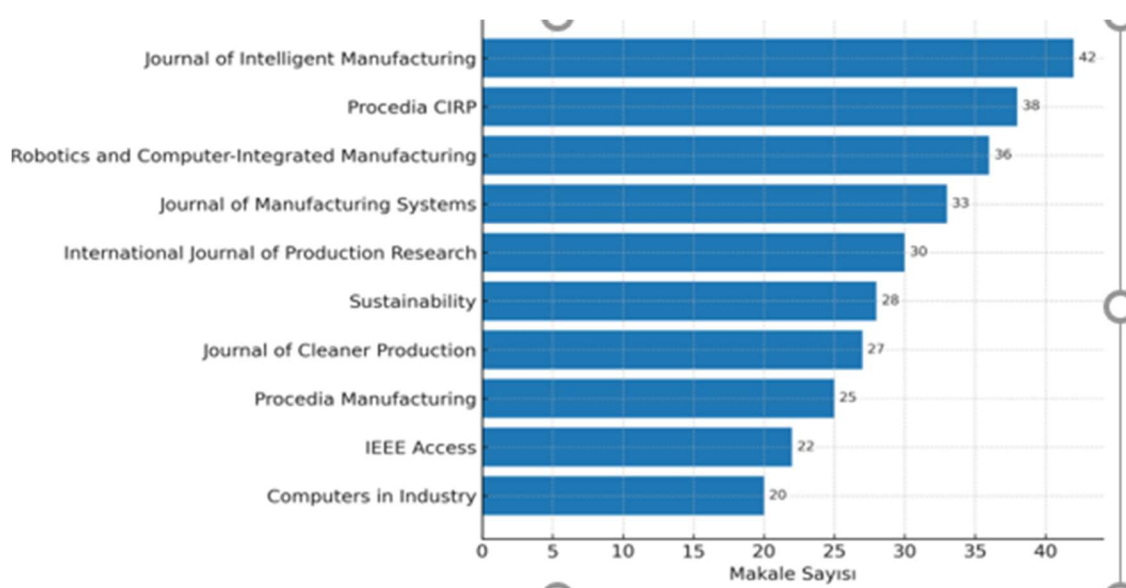


Figure 6. Journals where articles on “industry 5.0 and sustainability” are most published

An examination of the country-level distribution of studies on Industry 5.0 and sustainability reveals that the United States (USA) produces the highest number of publications, followed by China, Australia, Canada, and Italy. However, not only the total number of publications but also the extent to which these publications are produced through international collaboration serves as an important indicator. In this context, SCP (Single Country Publications) refers to publications authored solely by researchers from a single country, whereas MCP (Multiple Country Publications) denotes publications co-authored by researchers from different countries.

The data reveal an inverse relationship between the total number of publications and the MCP ratio in some countries. For instance, while the United States has a high number of publications, its MCP ratio is relatively low; conversely, China, despite having a lower total number of publications, exhibits a higher level of international collaboration (MCP ratio), with approximately 30% of its publications falling into this category. Similarly, countries such as Jordan, Ireland, France, and Italy also display notably high MCP ratios. Turkey, on the other hand, has a total of 42 publications, with an MCP ratio of 9.5%, indicating that its level of international collaboration in the field of Industry 5.0 remains limited. These findings indicate that academic output in the field of Industry 5.0 and sustainability is increasingly being produced by multinational teams; however, the extent of this trend varies across countries. Therefore, research policies should focus not only on the total number of publications but also on the rate of international collaboration.

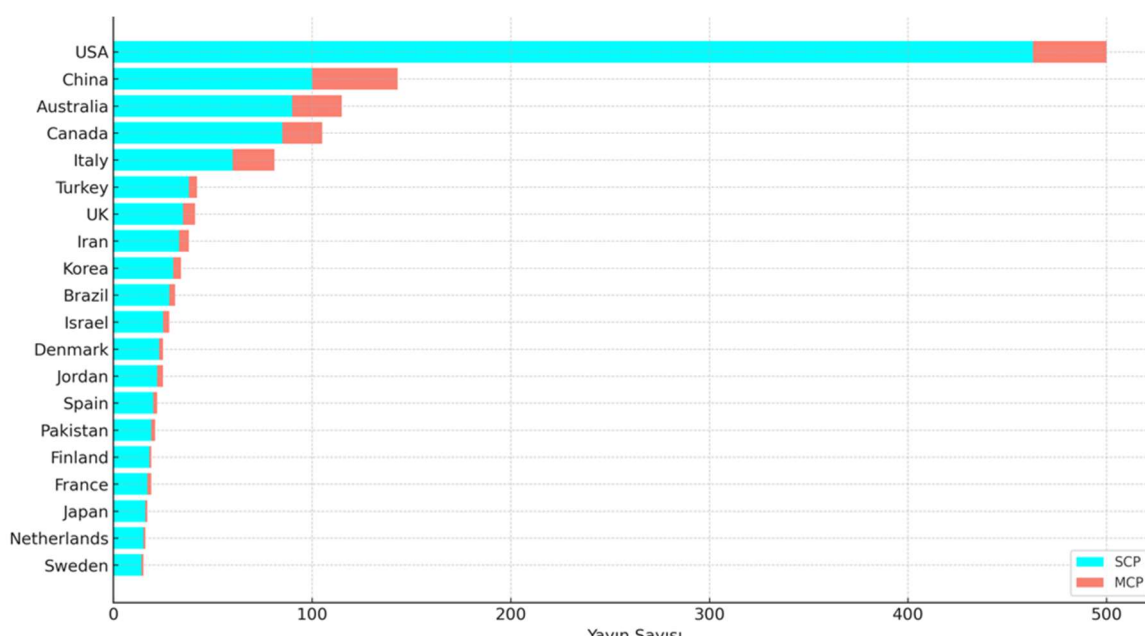


Figure 7. Degree of international cooperation in articles on “industry 5.0 and sustainability”

An examination of the countries contributing to the body of literature on Industry 5.0 and sustainability shows that a total of 75 countries have made contributions to this field. However, only 27 countries with five or more publications were included in the analysis (Figure 8). Within this scope, country-level citation analysis and collaboration networks were visualized using VOSviewer, revealing the presence of four distinct clusters of countries that interact with one another. The relationships among the countries within each

cluster are represented by blue, red, green, and yellow colors. The red cluster, consisting of 10 countries, is led by the Republic of China, followed by Iran, Norway, Denmark, Austria, Mexico, Portugal, Sweden, the USA, and Serbia. This cluster demonstrates a high level of activity in terms of publication output and regional collaboration. The green cluster, comprising 9 countries, is led by India. This cluster is characterized by effective regional partnerships, particularly in the areas of sustainability, human-centric manufacturing, and digital transformation.

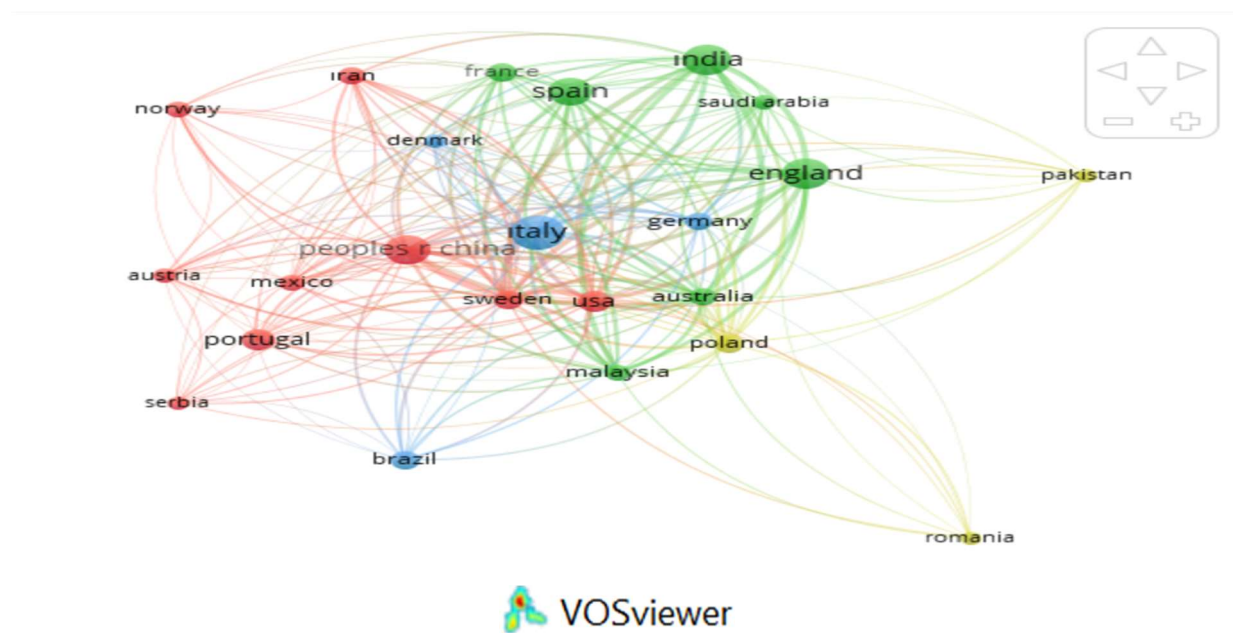


Figure 8. Citation power and citation network by country

In the blue cluster, which consists of three countries, Italy emerges as the leading nation. Specifically, this small cluster—comprising Italy, Germany, and Brazil—represents Europe–Latin America–oriented collaborations. Within this cluster, research predominantly focuses on engineering, production systems, and Industry 5.0 applications. Finally, in the yellow cluster, where Pakistan holds the leading position, Romania and France are included. Among all countries, China has recorded the highest total citation count and link strength values. China is followed by the United States and the United Kingdom. China’s total citation count was identified as 3,961 with a link strength of 1,824; the United States had 3,175 citations and a link strength of 1,620; while the United Kingdom recorded 2,582 citations and a link strength of 1,387. These findings indicate that research in the field of Industry 5.0 is shaped by international interaction and scientific collaboration.

An examination of authors' productivity over time reveals that scholars such as Ghobakhloo, M. and Fraga-Lamas, P. began publishing in the field of Industry 5.0 at an early stage (Figure 9). In particular, Ghobakhloo's record of 12 publications indicates a profile that has shaped the research domain and established a strong position within the literature. In contrast, authors such as Amirkhizi, P.J., Al Amin, M., Guerrero, B., Rejeb, A., Hsu, C.H., Slavic, D., Ivanov, D., Trstenjak, M., and Rios, A.J., despite not attaining high citation counts, have consistently contributed to the literature by publishing at regular intervals over the years. This finding underscores that, in Industry 5.0 research, not only high citation impact but also sustained scholarly productivity holds significant importance.

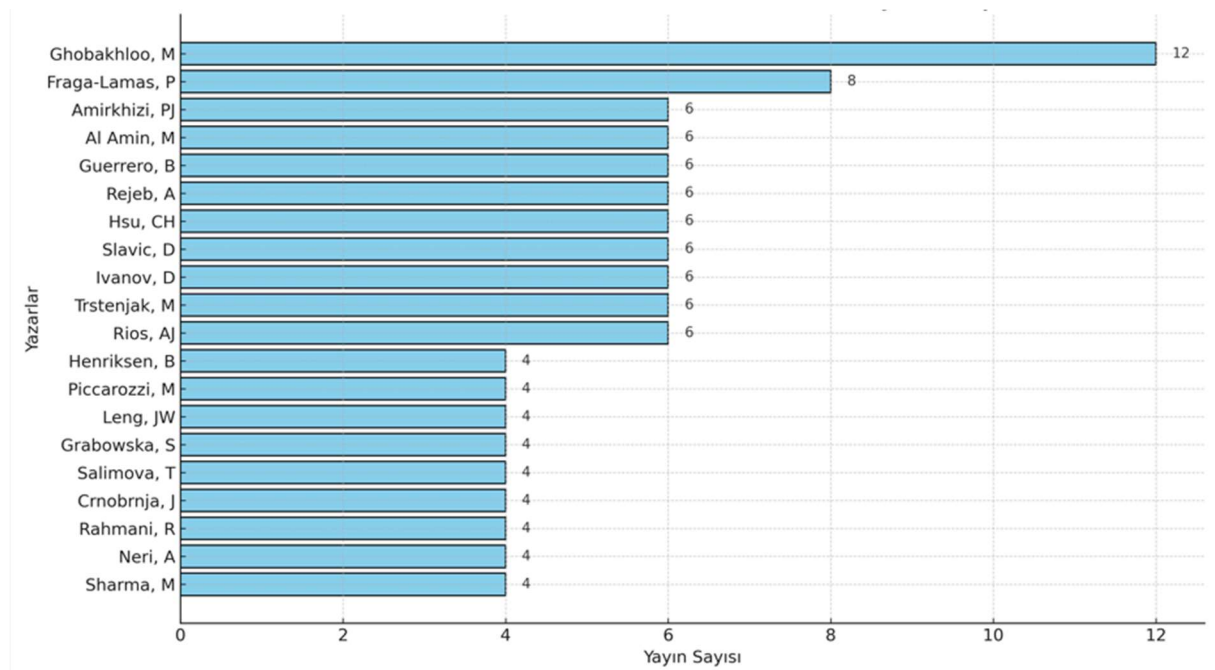


Figure 9. Production of authors over time

Conclusion

Industry 5.0 stands out as a new paradigm that prioritizes human-centered approaches in the evolutionary process of industrial revolutions and aims for sustainable technological transformation. This approach, which goes beyond digitalization and integrates human creativity with technologies such as artificial intelligence, the internet of things (IoT), collaborative robots and big data, brings sustainability elements

such as ethical values, social inclusiveness and environmental awareness to the center of production systems. For this reason, Industry 5.0 is considered not only as a technical transformation but also as a multi-dimensional social and economic restructuring process.

In recent years, there has been a significant increase in the number of academic publications that address the concepts of Industry 5.0 and sustainability together. This increase shows that the relevant concepts are increasingly attracting the attention of researchers in an interdisciplinary context and that new thematic areas are emerging in the literature. However, studies on the systematic evaluation of existing publications from a holistic perspective are still limited.

In this study, English language scientific publications published between 2020 and 2025 and containing the keywords “Industry 5.0” and “Sustainability” were examined. A total of 664 academic publications were identified based on the data obtained from the Web of Science (WoS) database. Only English publications in the form of articles, reviews, book chapters, and conference proceedings were evaluated in the bibliometric analysis. A total of 37 publications included in the WoS records but published in German, Chinese, French, Japanese, Spanish, Polish, Italian, Portuguese, and other languages were excluded from the analysis due to linguistic incompatibility.

This diversity demonstrates that the topics of Industry 5.0 and sustainability have been addressed at the global level by many countries, and that academic production in different languages has reached a remarkable level of dissemination. However, in order to ensure terminological consistency within the scope of systematic bibliometric analysis, only English-language content was considered, thereby maintaining conceptual coherence and comparability. It was determined that the 664 publications analyzed were produced by 88 different countries, which reveals the extent of international scientific interest and research diversity within the axis of Industry 5.0 and sustainability.

From the perspective of research methods, it is observed that scholars in publications on Industry 5.0 and sustainability predominantly prefer quantitative approaches. A substantial portion of the 664 studies was conducted using descriptive statistics, bibliometric indicators, and scientific mapping techniques. Among the most commonly employed data analysis tools are VOSviewer, Bibliometrix (R packages), CiteSpace, and Gephi. These publications were evaluated through these software programs based on criteria such as keyword co-occurrences, citation relationships, collaboration networks, and thematic clusters.

In line with the prevailing trends in the literature, this study also adopted the bibliometric analysis method, through which large-scale data were systematically classified and presented in a visualized form. Bibliometric analyses are regarded as an effective approach for uncovering the structural characteristics of a research field, identifying its developmental trajectories, and detecting gaps in the literature (Aria & Cuccurullo, 2017). This quantitative approach is considered particularly suitable for mapping the academic profile of emerging and rapidly evolving domains such as Industry 5.0.

Based on the findings of the analysis, a total of 664 publications addressing Industry 5.0 and sustainability were produced between 2020 and 2025. Of these, 582 were research articles, 41 were reviews, 12 were book chapters, and 29 were conference papers. The involvement of 1961 distinct authors indicates that the topic has captured the attention of a broad and diverse scientific community. On average, each author contributed 0.338 publications, while each study included an average of 3.57 authors, reflecting the prominence of collaborative and team-based research practices in this area. In addition, the corpus has accumulated 8,032 citations overall, corresponding to an average of 12.09 citations per paper. Collectively, these results suggest that scholarship on Industry 5.0 and sustainability has achieved a notable degree of academic influence in a relatively short time span.

When examining the most highly cited contributions, the article titled *“Industry 5.0: Prospect and Retrospect”* by Uzun et al. (2022), which has received 446 citations, emerges as the most influential work in the field. Similarly, the study *“A Human-Centered Perspective on Production: Industry 5.0”* by Lu et al. (2022) has made a significant impact by foregrounding human well-being within production systems. These early publications can be regarded as foundational works, serving as methodological and conceptual reference points for subsequent research.

The temporal distribution of publications also reveals a striking upward trend. While only 16 studies were published in 2020, the number rose to 24 in 2021 and then to 87 in 2022. By 2023, the output had grown to 153 publications, peaking at 269 in 2024. Although the count decreased to 147 in 2025, this decline appears to be temporary, as the dataset for 2026 remained incomplete due to mid-year data collection. Taken together, these findings indicate that the period between 2022 and 2024 represents the most prolific phase of academic production in the domain of Industry 5.0 and sustainability.

An examination of the publication outlets shows that the *Journal of Intelligent Manufacturing* (n=42), *Procedia CIRP* (n=38), and *Robotics and Computer-Integrated Manufacturing* (n=36) stand out as the most prolific journals in this field. These are followed by the *Journal of Manufacturing Systems* (n=33), the *International Journal of Production Research* (n=30), and *Sustainability* (n=28). This distribution indicates that the Industry 5.0 literature has been shaped primarily around production systems, computer-integrated technologies, and the sustainability agenda. With respect to core concepts, the terms “industry 5.0”, “sustainability”, “smart manufacturing”, “digital transformation”, “artificial intelligence”, “human-centric”, and “resilience” emerge as the most salient. These findings highlight that the field is not limited to technical production processes but also encompasses broader dimensions such as human-centered approaches, digital transformation, and sustainable development.

At the country level, China occupies the leading position with 177 publications and also achieves the highest citation impact, totaling 3,961 citations. It is followed by India (n=75), the United Kingdom (n=67), the United States (n=54), Italy (n=40), and Turkey (n=30). These figures demonstrate China’s clear dominance in terms of scientific productivity within the Industry 5.0 domain, while also highlighting Turkey’s rising contribution at the regional level, placing it among the top ten countries. Moreover, a strong correspondence is observed between the number of publications and citation performance, a pattern that is closely linked to the extent of international research collaborations.

Regarding author productivity, Ghobakhloo emerges as one of the pioneers with 12 publications, while Fraga-Lamas stands out for his high level of output. In addition, scholars such as Amirkhizi, Al Amin, Rejeb, and Ivanov have consistently contributed to the field, thereby sustaining the continuity of research. This suggests that the development of the Industry 5.0 literature is shaped not only by highly cited studies but also by steady and ongoing scholarly contributions.

This bibliometric analysis has certain limitations. First, the study focused exclusively on English-language publications indexed in the Web of Science (WoS) database between 2020 and 2025 that contained the keywords “Industry 5.0” and “Sustainability.” As a result, research published in other databases or in different languages was excluded, which restricts access to the broader body of literature. In addition, only journal articles were included in the analysis, while book chapters, reports, reviews, and editorial pieces were left out. Such a narrow scope implies that the identified trends in Industry 5.0 reflect only a specific type of publication and language focus. Furthermore, since citation data are subject to change over time, the findings

of this study should be viewed as provisional. Future bibliometric research, based on expanded datasets or alternative indexing sources, may therefore produce different outcomes.

For future research, it is recommended to expand the scope by incorporating additional databases (such as Scopus, IEEE Xplore, and Dimensions), including literature published in different languages, and diversifying the types of publications analyzed. Such an approach would enable broader and more multidimensional assessments of the field. Moreover, given the interdisciplinary character of Industry 5.0, conducting comparative analyses across diverse sectors—such as agriculture, education, culture, energy, healthcare, social sciences, and public policy—could provide valuable insights and significantly enrich the multidimensional development of the domain.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

Funding

* Project no. MEC_SZ 149231 has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the MEC_24 funding scheme.



Conflict of Interest

* The authors declare that they have no conflicts of interest

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Management Economics and Business (www.iconmeb.net) held in Budapest/Hungary on August 28-31, 2025

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EXAMINING THE RELATIONSHIP OF HUNGARIAN STUDENTS WITH AGILE APPROACHES

Abstract: A number of abilities and skills may be required to perform the tasks of a given job efficiently, effectively, and successfully. However, there is one trait that has been appearing in more and more job advertisements in recent years, and across a wider spectrum, as a requirement or at least an advantage: agility. Whether a job applicant is truly agile - and not just claiming to be - usually only becomes apparent later, when they have proven themselves through their work and attitude. However, whether someone is familiar with the basics of the agile approach, or is able to identify with them without specific knowledge, can be determined relatively quickly. In the research that forms the basis of this study, we attempted the latter: we examined Hungarian university students' identification with the four pillars and values of the Agile Manifesto, which was originally created in the world of software development in 2001 but is now much more widely known. Our main goal was to gain a better understanding of the relationship between future employees and the agile approach, and to gain insight into whether agility is rather distant from them or whether working according to the agile approach is unlikely to cause them any particular difficulty.

Keywords: Agility, Agile approaches, Agile Manifesto, Hungarian students

Introduction

Effective change management, flexibility, and adaptability have become more important than ever before in today's customer-centric world and in the age of digitalization, both for organizations and individuals. This is what the software developers who drafted the Agile Manifesto in 2001 wanted to find a solution for, and today it is a widely accepted basis for the agile approach worldwide. Its authors and first signatories defined four pillars and values: individuals and personal communication between them, working software, customer collaboration, and effective change management (Beck et al., 2001). Nowadays, science, business, and society are all interested in minimizing the negative consequences of unexpected events, which is why organizational agility is becoming increasingly popular (Sahoo et al., 2023). Research has shown that agile

projects are four times more likely to succeed and one-third less likely to fail than projects implemented using the classic waterfall model (Serrador & Pinto, 2015), (Mergel et al., 2020).

Agility must be integrated into the mindset, structure, and culture of the entire organization. This will enable them to understand their environment and identify opportunities, thereby enabling them to adapt and respond to unexpected situations and difficult circumstances (Dalcher, 2021). The introduction of an agile approach requires significant preparation on the part of organizations (Abidin, 2017): the possibilities and necessity of transforming strategy, organizational structure, and organizational culture must be considered in advance (Dang et al., 2024). It may well be that rather than considering a large-scale agile transformation, it would be more practical to implement it in stages (Kucharska et al., 2024). There is no single recipe: different methods and tools may be appropriate for different organizational structures and cultures (Bunyakiati & Surachaikulwattana, 2016). Blaskovics and his co-authors examine how the use of agile tools affects team collaboration, innovation capabilities and efficiency. According to them, agile methodology supports continuous development and promotes the successful implementation of projects in the Hungarian IT environment (Blaskovics et al., 2023). Mészáros (2024) examines the impact of agile methodology on competitiveness, particularly in an economic and technological environment characterised by rapid change. The application of an agile approach enables organisations to be flexible and adapt more effectively to market demands. Agility promotes the acceleration of innovation and improves internal operational efficiency, thereby supporting competitive performance.

A supportive, accepting environment is extremely important when applying agile values: if this is lacking, it can cause tension (Horlach & Drechsler, 2020). Leaders who possess agile characteristics – such as adaptability, flexibility, and effective decision-making – contribute significantly to increasing the agility of an organization (Arifin & Purwanti, 2023). Among other things, the agile approach helps individuals take responsibility and facilitates the integration of new team members (Wayant, 2022). However, developing an agile mindset in individuals often encounters difficulties (Ozkan et al., 2023). Therefore, it matters whether someone is receptive to learning this mindset or not. Agility briefly means nimbleness, flexibility, versatility, adaptability, and resilience (Dalcher, 2021). Some say it is a concept of how companies should operate in today's world in order to be successful (Denning, 2018). It is a new type of management model in which companies focus on exploring opportunities and finding solutions as quickly as possible through rapid experimentation (Denning, 2017). Agile operation and thinking now extend beyond the classic IT framework. Balogh and Varga's (2024) article examines the development of modern digital services, known

as superapps, through an agile lens, which take user experience and innovation management to a new level. Agility plays a key role in integrating customer focus and innovation, which are sources of competitive advantage in the digital age.

In our study, we focus on today's university students, who, according to generational theory, are members of Generation Z, as they were born in the late 1990s or early 2000s (Törőcsik et al., 2014). They are the "digital natives" (Prensky, 2001), who have access to computers, mobile phones, and the internet from an early age (Tar, 2011), and they are the ones who generally prefer podcasts and streaming services over television, radio, and print media. At the same time, their shopping habits are also completely different: they do most of their shopping online, which they consider safer than the real world (Csiszárík-Kocsir et al., 2021). In addition, they are the ones who are now approaching the labor market.

Method

We conducted a non-representative survey using questionnaires to examine Hungarian university students' attitudes toward agile thinking. The survey was conducted online using a pre-tested, complex, standardized questionnaire. The sample consisted of Hungarian university students who were studying at Óbuda University in the spring of 2025. A total of 144 students participated in the research: we filtered out those who belonged to Generation Z based on their date of birth, resulting in a total of 137 valid responses. The questions examined the presence of certain competencies, skills, and abilities related to the values of the Agile Manifesto: respondents could choose on a Lickert scale from 1 to 6 how much a given trait characterized them, where 1 was not at all and 6 was completely. We examined a total of seventeen characteristics that, in our opinion and based on our experience to date, are or may be related to the agile approach. These are summarized in Figure 1.

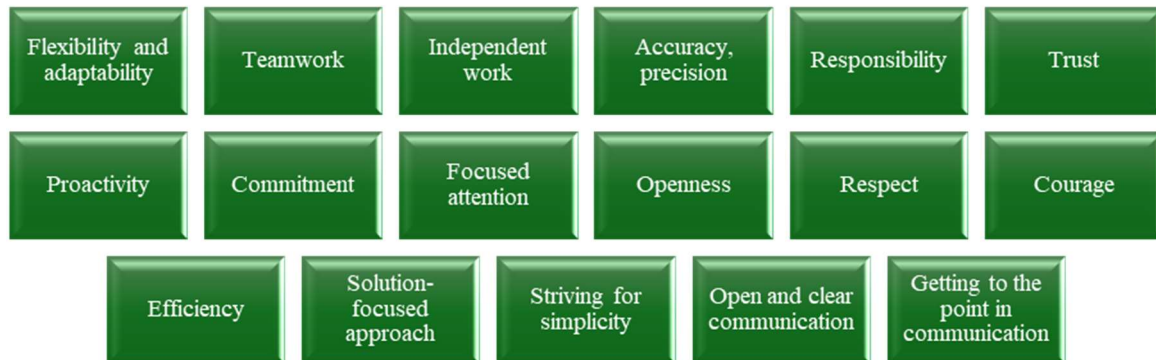


Figure 1. Competencies, skills, and abilities examined in the study

In this study, we focus on the four characteristics that, in our opinion, best cover the four values listed in the Agile Manifesto:

- open and honest communication – as a manifestation of the value of individuals and personal communication between them;
- solution-oriented thinking – as one of the most important characteristics necessary to achieve the goal of working software (or, more generally, a working end result);
- teamwork – as the key to cooperation with the customer;
- flexibility and adaptability – as the hallmarks of effective change management.

Results and Discussion

Regarding open and clear communication – as a manifestation of the value of individuals and personal communication between them – 87% of respondents (119 people) chose a value of 5 or 6 on a scale of 1 to 6, meaning that they agreed somewhat or completely, and 58% (80 people) considered it to be completely true for themselves, i.e., they chose the maximum value. This is shown in Figure 2.

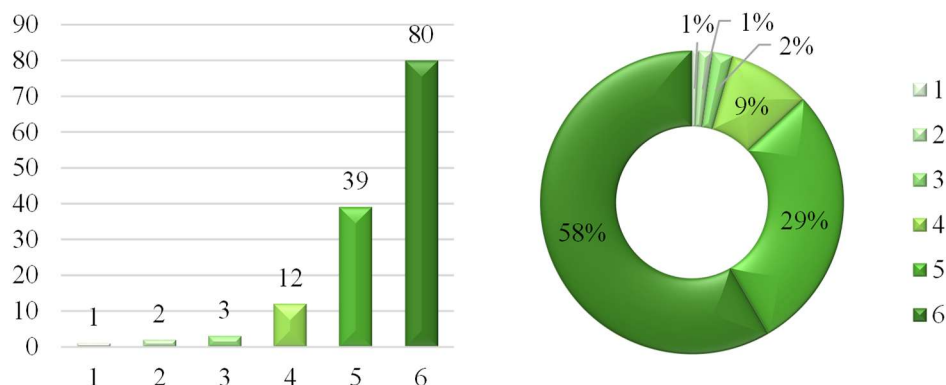


Figure 2. Distribution of responses to open and honest communication

The average value of the responses was 5.38, with a standard deviation of 0.93.

As Figure 3 shows, solution-focusedness – which we considered to be one of the most important characteristics for achieving a successful end result – was considered even more characteristic by the respondents: 64% (87 people) considered themselves to be completely solution-oriented, i.e., they gave themselves the maximum score, and a total of 91% (125 people) chose a score of 5 or 6, i.e., they felt it was somewhat or completely characteristic of them.

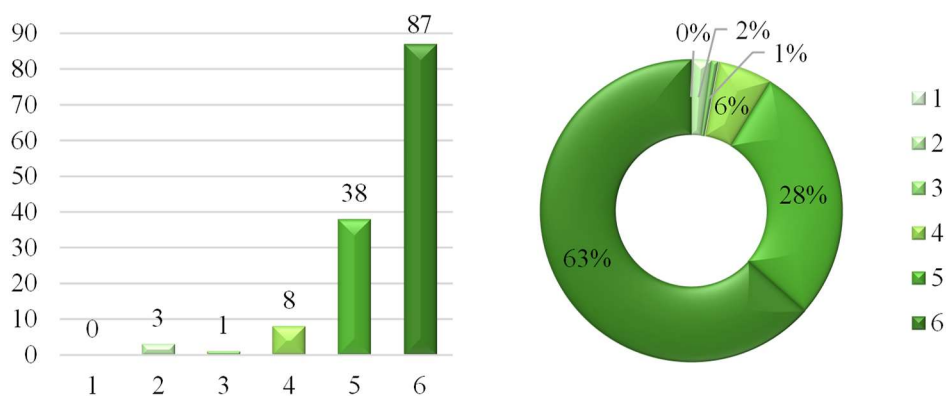


Figure 3. Distribution of responses regarding solution-focusedness

Here, the average was 5.5, with a standard deviation of 0.82.

In teamwork, the responses were slightly more evenly distributed, as shown in Figure 4. Only 37% (51 people) felt they were complete team players, i.e., they marked the maximum value, and a total of 73% (100 people) felt they were rather or completely strong in this area, i.e., they chose at least a value of 5.

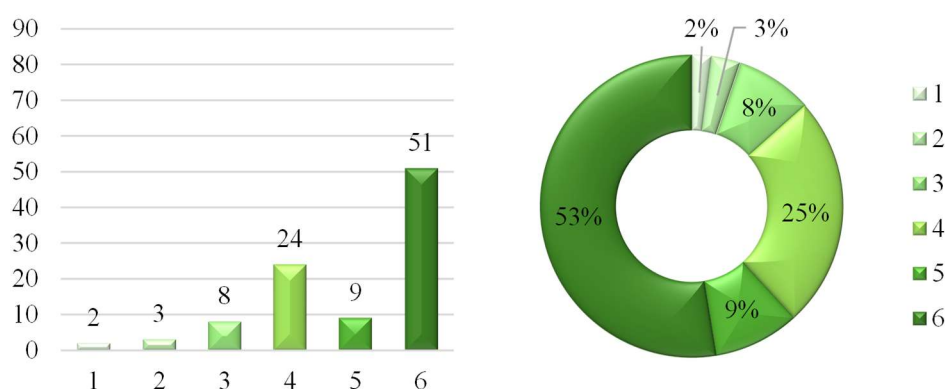


Figure 4. Distribution of responses regarding teamwork

The average value assigned to the responses was 4.96, with a standard deviation of 1.1.

Finally, perhaps the most important characteristic of all, flexibility and adaptability, was considered to be completely true by 41% of respondents (56 people), while a total of 84% (115 people) considered it to be somewhat or completely true. This is shown in Figure 5.

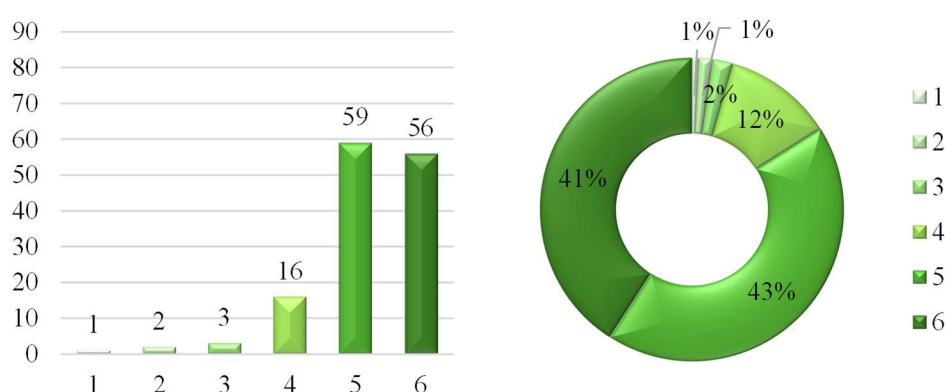


Figure 5. Distribution of responses regarding flexibility and adaptability

Here, the average was 5.18, with a standard deviation of 0.91.

Comparing the responses to the four characteristics above, it can be seen that solution-focusedness received the highest average (5.5) and had the lowest standard deviation (0.82). This is illustrated in Figure 6.

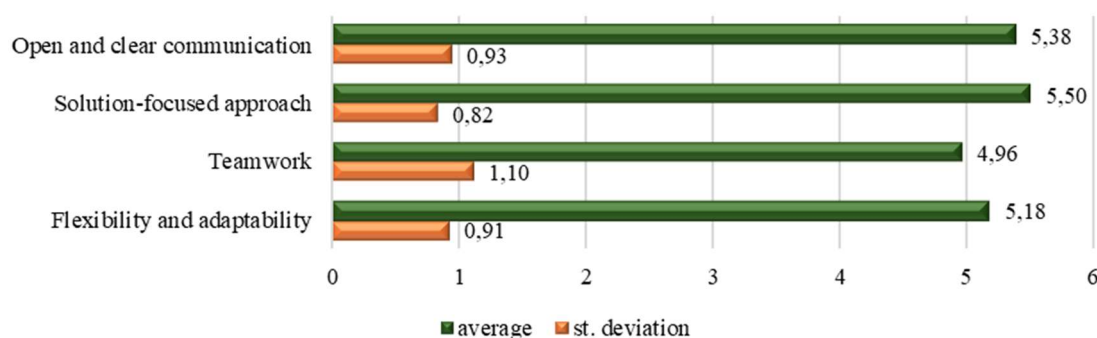


Figure 6. Averages and standard deviations of responses to the four attributes examined based on the Agile Manifesto

If we examine these four characteristics among all seventeen characteristics examined, we can say that solution-focusedness received the second highest average score (5.5), with only respect receiving a higher average score (5.61). Solution-focusedness had one of the lowest standard deviations, meaning that respondents relatively uniformly identified themselves as having a high level of this trait. The third highest average (5.42) (and the lowest standard deviation) was given to striving for clarity in communication, which, although less directly related to the Agile Manifesto, can often be important in agile operations. This was followed by open and clear communication (5.38), which was also examined.

All of these are illustrated in Figure 7 (the values of the four separately examined characteristics are marked in red).

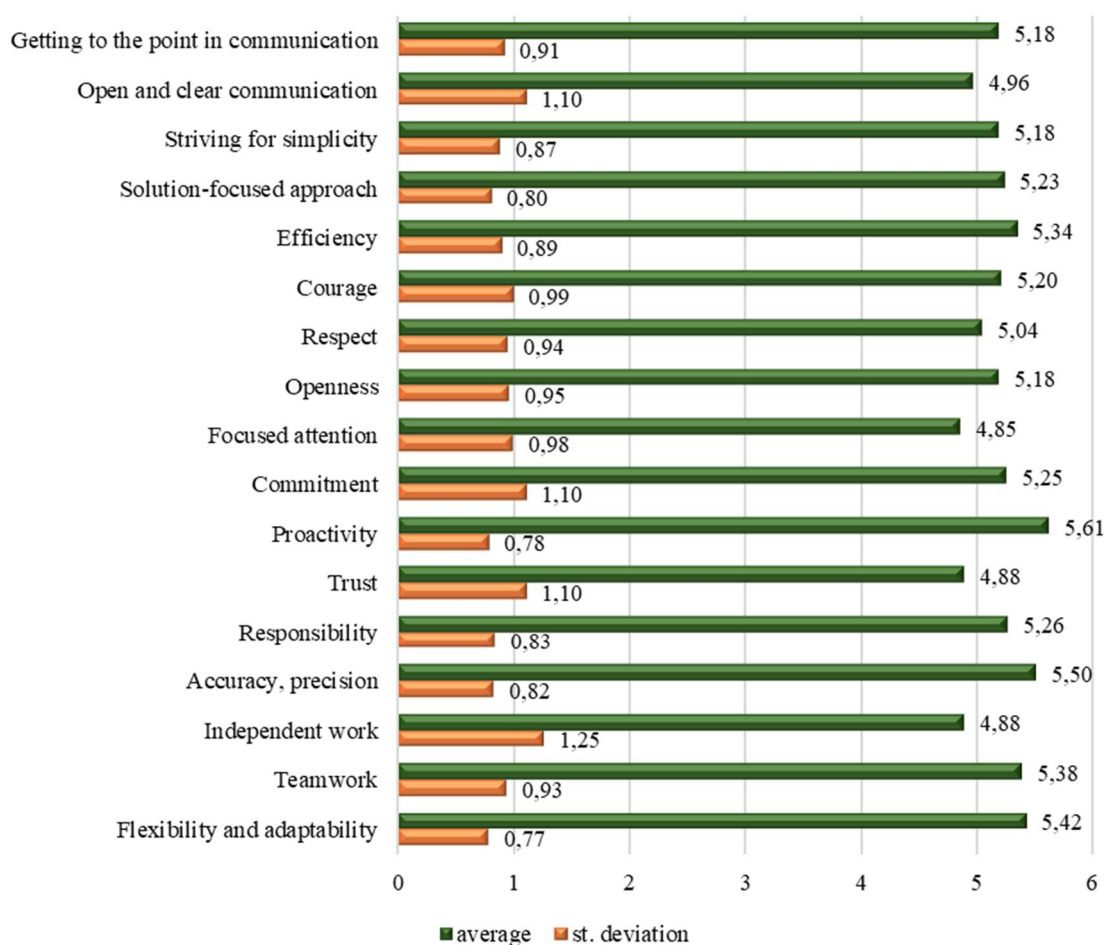


Figure 7. Means and standard deviations of responses for all characteristics examined

Conclusion

Based on the responses received and their evaluation, we concluded that the Hungarian university students surveyed are generally not far removed from the qualities required for the values set out in the agile manifesto. This was confirmed by the fact that the responses for the four main characteristics examined were clearly concentrated at the top of the scale, resulting in high average scores (around 5 or above 6 out of 6). Respondents considered solution-orientedness to be particularly true of themselves: it received one of the highest averages with one of the smallest standard deviations. Perhaps somewhat surprisingly,

teamwork received one of the lowest averages and one of the highest standard deviations. This is probably due to the fact that they have not had much opportunity to practice this, or perhaps they do not have good experiences with it.

From all this, we conclude that the majority of future employees will be able to apply an agile approach to their work, thanks to their open and clear communication, solution-oriented mindset, teamwork, flexibility, and adaptability. Since the survey is not representative, no general conclusions can be drawn, but it may provide some insight into the attitude of future employees towards agile thinking and could form the basis for a later, more extensive study.

Scientific Ethics Declaration

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Funding

* Project no. MEC_SZ 149231 has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the MEC_24 funding scheme.



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Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Management Economics and Business (www.iconmeb.net) held in Budapest/Hungary on August 28-31, 2025

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THE RELATIONSHIP BETWEEN ESG AND GREENWASHING

Abstract: ESG is playing an increasingly important role in companies' sustainability and social responsibility strategies, but the practical implementation of ESG principles poses a number of challenges, including measurability, transparency, and credibility. Companies need to strike a balance between financial performance and sustainability goals, while meeting investor and regulatory expectations. ESG reporting encourages companies to make more sustainable and ethical decisions, which can lead to long-term profitability and success.

One of the biggest problems is greenwashing, or the misleading use of sustainability claims. Companies often make exaggerated or false claims about their environmental performance to appear more appealing to consumers and investors. One reason for this is the lack of strict regulations, which currently allows for arbitrary ESG ratings and unverifiable sustainability reports. Greenwashing not only violates ethical standards, but also reduces consumer and investor confidence in ESG reporting in the long term. As a result, there is a growing demand for transparent, credible reporting systems and methods for objectively measuring sustainability performance. The EU and other regulatory bodies are continuously developing ESG regulations to curb misleading practices.

This research examines the relationship between ESG reporting and greenwashing, focusing on factors such as regulatory pressure, stakeholder expectations, and industry competition. Drawing on recent research, I examine how companies can selectively disclose favorable information about themselves and emphasize environmental initiatives to enhance their reputation. The solution for companies may lie in implementing genuine sustainability measures and communicating openly. A transparent ESG strategy and committed corporate governance not only reduce the risk of greenwashing, but can also provide a long-term competitive advantage.

Keywords: ESG, greenwashing, CSRD, Taxonomy, sustainability report

Introduction

Over the last decade, sustainability and corporate social responsibility (CSR) have played an increasingly important role in the operations and strategic decisions of companies. Global climate change, social inequalities and governance difficulties have led to increased attention from investors, consumers and regulators alike to the extent to which companies contribute to the SDGs. This process is supported by the ESG (Environmental, Social, Governance) framework, which provides a comprehensive assessment of companies' environmental, social and governance performance. ESG is now not just a corporate trend, but a global benchmark that is increasingly shaping the direction of capital markets and consumer choices.

ESG reports aim to provide transparent information on companies' sustainability performance. However, these reports often face problems of measurability, transparency and credibility (Eccles et al, 2019). Given the current lack of a uniform and binding set of standards in many countries, although the regulatory framework is becoming stronger in the European Union and is questionable to remain so, companies often produce ESG reports based on their own interpretation. This creates many opportunities for greenwashing, where companies use exaggerated or misleading claims to portray themselves as more environmentally friendly and ethical than they really are (Delmas & Burbano, 2011).

Greenwashing is one of the most serious challenges in the ESG field, as it undermines the credibility of sustainability efforts. On the one hand, it can enhance a company's reputation in the short term, and on the other hand, it can erode consumer and investor confidence in the long term, which can lead to a decline in the company's value and market position (Marquis, Toffel, & Zhou, 2016). In recent years, a number of scandals have shown that companies tend to selectively highlight their environmental or social initiatives while de-emphasizing activities that negatively impact sustainability performance.

One of the main reasons for the spread of greenwashing is the lack of a regulatory environment. Although the European Union has made significant steps in recent years to introduce ESG-related regulations, for example through the Corporate Sustainability Reporting Directive (CSRD) and the EU Taxonomy Regulation, the potential for arbitrary reporting persists in many areas (European Commission, 2021). This situation is particularly worrying as some companies focus on communication rather than improving actual performance.

The aim of this research is to explore the links between ESG and greenwashing and to show what factors encourage companies to mislead. Particular attention will be paid to the impact of regulatory pressure, stakeholder expectations and industry competition. The research will examine not only the regulatory and market environment, but also specific corporate examples that highlight the risks and consequences of greenwashing.

The aim of the research is to highlight how ESG can become a true compass for sustainability and ethical corporate governance and how greenwashing can be curbed. A transparent ESG strategy and credible communication can not only boost consumer and investor confidence, but can also provide companies with a long-term competitive advantage.

1. The emergence and evolution of the ESG framework

With regard to sustainability and future ESG, efforts to address emerging issues have been ongoing since the 1960s, but no definitive solution has been found to date. Numerous programs, strategies, conferences, and world summits have contributed to mapping the process, and attempts have been made to address the difficulties that arise, with varying degrees of success (Kozma, 2018). The roots of the ESG concept also date back to the 1960s, when the idea of social responsibility first appeared in corporate governance and investment decisions. The first initiatives can be linked to religious communities, which sought to exclude certain industries from their investment portfolios on ethical grounds, such as the tobacco industry or arms manufacturing. In the 1980s and 1990s, as the discourse on sustainable development grew, more and more investors began to pay attention to social and environmental considerations in addition to financial returns (Málovics, 2011).

The term ESG was formally introduced into the literature in the early 2000s with the UN's Who Cares Wins report (UN Global Compact, 2004), which emphasised that integrating environmental, social and governance considerations into investment decisions would enhance the long-term stability and sustainability of markets. Since then, ESG has become a global benchmark, providing key guidance for companies and investors alike. The shift in the economic system towards long-term sustainability has resulted in the creation of a novel social agreement for all economic participants. The European Union is

taking steps in this direction and passing legislation to alter how businesses engage with sustainability (Delova-Jolevska et al. 2024).

The ESG framework encompasses three dimensions which together provide a complex assessment of sustainable performance.

Environmental: This includes the assessment of companies' impact on the environment: carbon emissions, energy efficiency, water and waste management, use of renewable energy sources. Combating climate change is a high priority, as investors and regulatory bodies are setting increasingly stringent expectations in this area (Friede, Busch, & Bassen, 2015).

Social: This pillar focuses on the relationship with employees, consumers and the wider community. It includes diversity and inclusion in the workplace, working conditions, respect for human rights, and the company's contribution to the development of local communities.

Governance: The third pillar relates to the quality of corporate governance. It includes transparency, anti-corruption measures, board independence and respect for shareholders' rights (Gillan, Koch, & Starks, 2021).

Together, these three dimensions ensure that corporate performance is assessed not only on the basis of financial indicators, but also on the basis of a more complex framework that integrates sustainability considerations.

1.1 Investor, consumer and company perspectives

The role of ESG has increased dramatically over the last decade, as investors, consumers and companies have different but interrelated expectations.

A growing body of research demonstrates a positive correlation between ESG performance and financial results. Friede, Busch and Bassen (2015), based on a meta-analysis of more than 2000 empirical studies, conclude that ESG performance has a generally positive impact on a company's financial performance. For investors, ESG is therefore not only an ethical issue, but also a risk management and value creation factor.

From a consumer perspective, conscious consumers increasingly favour companies that engage in sustainable practices. The demand for transparency and ethical operations is growing, especially among younger generations (Nielsen, 2015).

The importance of ESG for companies is twofold: for reputation and competitive advantage in the marketplace, and for regulatory compliance. Companies that integrate ESG considerations into their strategies are better able to adapt to market and regulatory challenges in the long term.

1.2 Issues in measuring and evaluating ESG

Although ESG is playing an increasingly important role in the decisions of companies and investors, its measurability remains a major challenge.

One of the biggest problems is the lack of uniform standards. Different ESG-measurers use different methodologies, so the same company may perform outstandingly well according to one assessment and mediocre according to another (Berg, Kölbel, & Rigobon, 2022). This divergence makes it difficult for investors to make decisions and increases the risk of greenwashing.

A further problem is that many companies self-report their ESG reports, which often contain selective information. In this context, the lack of transparency and lack of verifiability makes it difficult to assess true sustainability performance.

In the future, it is expected that the regulatory environment, especially in the EU, will progressively standardise and tighten the requirements for ESG reporting.

The ESG framework has become a key benchmark for sustainability and corporate governance over the last two decades. While it has fundamentally positive impacts on financial performance, consumer confidence and regulatory compliance, its measurement and evaluation poses a number of problems, some of which contribute directly to the spread of greenwashing.

2. The concept and forms of greenwashing

The term "greenwashing" was first used by environmental activist Jay Westerveld in 1986 when he criticised the practices of a hotel chain: hotel guests were encouraged to reuse their towels on environmental grounds, when in fact the company had not taken any comprehensive sustainability measures (Westerveld, 1986). Since then, the term has been used to describe the practice of companies making misleading, exaggerated or false environmental claims in order to make themselves look better to consumers and investors (Delmas & Burbano, 2011).

Greenwashing is thus a communication strategy that often contradicts the actual operations of the company. In essence, it is an attempt by companies to exploit the growing consumer and investor interest in sustainability to improve their reputation through selective communication or misleading messages, without taking real and measurable steps to improve environmental performance.

2.1 Typical greenwashing strategies

Greenwashing can take several forms, the most common of which are:

Exaggerated claims: companies often exaggerate their environmental performance, for example by claiming that their products are "100% green" or "fully sustainable" without backing this up with credible data.

Misleading labels and certifications: some companies create their own logos or symbols that bear a deceptive resemblance to independent certifications. This is particularly common in the food and textile industries (TerraChoice, 2010).

Selective disclosure: Companies often highlight positive initiatives (e.g. recycled packaging) while hiding environmentally damaging activities (e.g. polluting manufacturing processes).

Use of vague terms: terms such as 'green', 'eco', 'natural' or 'environmentally friendly' are often used in communications without concrete evidence.

Irrelevant claims: some companies emphasise environmental performance that has no real relevance. For example, a "CFC-free" label on a product where CFC use has long been banned.

Misleading visual communication: green colours and natural motifs (leaves, water drops, trees) are used on packaging to create the illusion of sustainability, regardless of the actual content.

2.2 Famous international and Hungarian examples

The phenomenon of greenwashing has led to a number of scandals around the world that highlight the seriousness of the problem. The company installed software in its diesel cars that showed low emissions in official tests, while in real-world road conditions emissions were several times higher than allowed. This case is a classic example of a company systematically deceiving consumers and regulators (Hotten, 2015).

In the fashion industry, greenwashing can be linked to H&M's 'Conscious' collection. The fashion giant advertised its collection as sustainable, but tests showed that the use of materials and manufacturing processes did not meet the advertised green standards. According to several critics, the company was conducting a PR campaign rather than a real green transition (Sierra, 2025).

In the early 2000s, British Petroleum rebranded itself as BP's 'Beyond Petroleum' campaign, emphasising its investment in renewable energy while the majority of its business continued to be fossil fuel-based (Matejek 2013).

Hungarian examples. In particular in the case of products labelled "eco" and "organic", the consumer protection authority has investigated the authenticity of products on several occasions and found several cases where the claims were insufficiently substantiated (GVH, 2022).

2.3 Effects of greenwashing

Greenwashing can increase a company's market attractiveness in the short term, but in the long term it has serious negative consequences. In 2015, Nielsen research shows that consumer confidence is already starting to deteriorate, with consumers becoming increasingly sceptical of sustainability claims. According to the research, more than 40% of consumers have encountered a product misleadingly advertised as 'green'

(Nielsen, 2015). Investor confidence is also declining in the capital markets as a result of greenwashing. When it is discovered that a company has provided misleading information, it can cause significant stock price losses and reputational damage.

In the wake of these scandals, governments and international organisations are introducing increasingly stringent standards for sustainability reporting. For example, the EU is also seeking to regulate the use of green labels to discourage misleading practices (European Commission, 2023). Firms that adopt genuine sustainability measures may be disadvantaged if their competitors gain a cheaper and faster reputation through greenwashing. This distorts market competition and reduces incentives for a genuine green switch (Lyon & Montgomery, 2015).

Greenwashing is a major challenge in the sustainability discourse. While it can improve a company's image in the short term, in the long term it erodes trust, distorts the market and hinders a genuine green transition. Tackling the problem requires a complex approach: stricter regulation, more transparent reporting systems and a more critical approach from consumers and investors.

3. Regulatory environment and ESG reporting

3.1 The EU regulatory framework

The European Union has taken a leading role in regulating sustainability reporting in recent years. The aim is to present companies' sustainability performance in a comparable, reliable and verifiable way. One of the key milestones is the Corporate Sustainability Reporting Directive (CSRD), which came into force in 2022 and will gradually replace the former Non-Financial Reporting Directive (NFRD) from 2024 (European Commission, 2022a).

The CSRD requires large companies - and in the medium term listed SMEs - to produce a comprehensive sustainability report detailing their environmental, social and governance performance. The reports must be based on the European Sustainability Reporting Standards (ESRS) framework developed by the European Financial Reporting Advisory Group (EFRAG) (EFRAG, 2022). An important innovation of the CSRD is that sustainability reports must be verified by independent auditors, thus ensuring the credibility of the

reports. This step is particularly important in the fight against greenwashing, as it relies on objective, audited data rather than a self-reporting system. In parallel, the EU has developed the EU Taxonomy Regulation, which defines which economic activities are considered sustainable (European Commission, 2020). The taxonomy aims to provide a single set of criteria for green investments, thus helping investors to avoid greenwashing.

Another important regulation is the Sustainable Finance Disclosure Regulation (SFDR), which obliges financial market participants to transparently disclose the extent to which their investment products meet sustainability criteria (European Commission, 2022b). The SFDR aims to prevent the misuse of 'sustainable' or 'green' labels and to help investors make informed decisions.

A more recent EU initiative is the Green Claims Directive (2023), which aims specifically to protect consumers against misleading sustainability claims. The Directive requires all environmental claims to be supported by independent evidence and to be clearly worded, verifiable and comparable (European Commission, 2023). This is directly aimed at curbing greenwashing practices.

Overall, the EU's regulatory framework is becoming more stringent and is moving towards transparency, credibility and consumer protection.

3.2 Hungarian regulatory environment and the role of consumer protection

In Hungary, ESG reporting obligations closely follow the EU directives, as the CSRD and SFDR are directly applicable in the domestic legal system. The Hungarian legal framework is based on Act CLV of 1997 on Consumer Protection, which covers the prohibition of unfair commercial practices. This also includes misleading green claims, which are regularly investigated by the Hungarian Competition Authority (GVH) (GVH, 2022). For example, in 2022, the GVH investigated the conformity of products with "eco" and "organic" labels in several cases and found that certain companies could not credibly substantiate their sustainability claims. These practices were clearly greenwashing and resulted in heavy fines (GVH, 2022). The Magyar Nemzeti Bank (MNB) also plays an active role in promoting sustainable finance. In 2021, the MNB launched the Green Programme, which promotes sustainable lending and investment practices and sets expectations for financial institutions (MNB, 2021).

The Hungarian regulatory environment is therefore not only transposing EU standards, but is also taking initiatives of its own to strengthen the fight against greenwashing.

3.3 International regulatory trends

ESG reporting is also increasingly regulated at international level. In the United States, for example, the Securities and Exchange Commission (SEC) has proposed mandatory disclosure of climate risks in 2022, which would require companies to disclose emissions data and climate strategy plans (SEC, 2022). Although regulation is subject to political debate, it shows that there are similar efforts in the transatlantic region. Globally, the International Sustainability Standards Board (ISSB) was established in 2021 with the aim of developing a single set of sustainability reporting standards (IFRS, 2021). The IFRS S1 and IFRS S2 standards introduced by the ISSB aim to make sustainability reporting globally comparable, thereby reducing the risk of greenwashing.

Similar initiatives have also emerged in the Asian region: in Japan, the financial regulator is strictly monitoring sustainability investment funds, while in China, the government is strongly promoting the green bond market and has also developed its own taxonomy (OECD, 2022).

These examples show that sustainability reporting and the fight against greenwashing is gaining momentum at the global level. While regulations may vary from country to country, the common goal is to enhance transparency and credibility.

3.4 The relationship between regulation and greenwashing

One of the most effective ways of tackling greenwashing is to tighten and harmonise the regulatory environment. The EU example shows that mandatory reporting, standardised indicators and independent auditing can significantly reduce the spread of misleading claims.

At the same time, it is important to stress that overly complex or costly regulations can hinder smaller companies, which may find it harder to comply. For this reason, regulators need to strike a balance between ensuring transparency and managing the administrative burden on companies. Regulations are not only intended to discourage greenwashing, but also to provide incentives for companies. Companies that

introduce genuine sustainability measures can gain a competitive advantage in the long run thanks to regulations. Indeed, transparency and credible ESG communication increase investor confidence, strengthen consumer loyalty and contribute to a company's reputation (Eccles et al, 2019).

The regulatory environment plays a key role in understanding the link between ESG and greenwashing. EU regulations, led by the CSRD and the EU Taxonomy, clearly show that enhancing transparency and credibility is essential to achieve sustainability goals. In Hungary, the active action of the GVH, the MNB and other institutions proves that the fight against greenwashing is important not only at EU level but also at national level. At the international level, the regulatory efforts of the SEC and the ISSB show that the problem of greenwashing is a global challenge that can only be tackled through a unified, credible and independent system.

4. Challenges to the credibility of ESG reporting

4.1 Measurement issues and problems with self-reporting

One of the main challenges for ESG reporting is the lack of a consistent measurement and evaluation framework. Companies use different methodologies, often based on their own indicators to measure their environmental, social and governance performance (Eccles et al, 2019). This voluntary and often self-reporting-based system creates opportunities for selective information disclosure, which is directly linked to the phenomenon of greenwashing.

For example, a company may highlight its energy efficiency improvements, but conceal labour abuses in its supply chain. As there is no mandatory and uniform standard for all ESG factors, it is easy for companies to present data that reinforces their own narrative while ignoring problem areas.

Another problem with self-reporting is that the data published often cannot be independently verified. This is a particular problem with emissions data, where companies often use estimates rather than actual measurement. This makes comparability difficult and undermines the credibility of the reports.

4.2 Role of external audit and independent verification

Independent audit is one of the most important tools to enhance credibility. The CSRD requires ESG reports to be audited by an auditor to ensure that the information disclosed by companies is fair and reliable (European Commission, 2022).

The role of the audit is twofold: on the one hand, it reduces the risk of deliberate manipulation and greenwashing, and on the other, it increases investor and consumer confidence in the reports. At the same time, it is important to underline that sustainability auditing is a relatively new field, often with a lack of expertise or different methodologies (Accountancy Europe, 2020). Some critics argue that external audits do not provide full assurance either, as auditors are often engaged by the same companies they audit. This raises conflict of interest risks, especially when the auditor prepares or audits both financial and sustainability reports. One of the keys to future progress could be the development of professional standards for sustainability auditing and the strengthening of the role of independent audit organisations.

4.3 Different methodologies of ESG verifiers

One of the main sources of ESG data is provided by various rating agencies such as MSCI, Sustainalytics or Refinitiv. These agencies provide comprehensive assessments of companies' ESG performance, which are widely used by investors to inform their decisions.

However, research has shown that there is considerable variation between ESG ratings. According to a study by Berg, Kölbel and Rigobon (2022), the average inter-agency correlation is only 0.54, meaning that the same company is rated as outstanding by some and mediocre by others. This divergence is due to several factors:

- different indicators and weighting schemes,
- different sources of data (company reports, news, sector analyses),
- subjective assessment of qualitative aspects.

This situation not only creates uncertainty for investors, but also gives companies the opportunity to be selective in their assessments and to omit from their communications only those ratings that are unfavourable to them.

To address this problem, there is a growing need for greater transparency in ESG rating agencies' methodologies and the development of international standards.

4.4 Lack of transparency and its consequences

Transparency is one of the keys to credible ESG reporting. Currently, however, sustainability data published by companies is often incomplete, selective or difficult to access. This has several consequences:

Consumer and investor scepticism: lack of data or lack of transparency reduces trust in reporting, which in the long run can also damage a company's reputation.

Lack of comparability: As companies use different indicators, it is difficult to compare their performance objectively, thus market participants cannot make informed decisions.

Risk of greenwashing: incomplete data allow companies to selectively communicate their positive results while hiding the negative ones.

Digital technologies such as blockchain-based registries could help improve transparency by ensuring that data is immutable and traceable

The credibility of ESG reporting is key to achieving sustainability goals and reducing greenwashing. Measurement problems, self-reporting systems, external audit gaps, different ESG-rating methodologies and lack of transparency in data reporting are all factors that weaken the reliability of reports.

The solution can come from several directions: the development of common international standards, independent and professionally strengthened auditing, and the inclusion of digital technologies in data verification. If these are implemented, ESG reporting can become a truly reliable tool for measuring sustainability and reducing greenwashing.

5. The impact of greenwashing

5.1 Corporate reputation and market competition

One of the most powerful drivers of greenwashing is the protection and enhancement of corporate reputation. In consumer societies, there is an increasing value of a 'green' image: consumers are often willing to pay higher prices for products that are presented as environmentally friendly (Nielsen, 2015). This gives companies a strong incentive to communicate their products or services as sustainable - even if this is only partly true in reality.

The competitive landscape further reinforces this incentive. Firms that cannot adapt quickly to consumer expectations can suffer reputational disadvantage. This is particularly true in industries where sustainability is a key issue (e.g. fashion, food, energy). If a company's competitor launches a sustainability campaign, the company may feel under pressure to communicate similar messages - even if its actual actions fall short of this (Walker & Wan, 2012).

5.2 Investor pressure and short-term financial goals

The role of investors is also key to understanding the motivations for greenwashing. An increasing number of institutional investors, such as pension funds or insurance companies, are integrating ESG considerations into their decisions (Friede, Busch, & Bassen, 2015). Companies are therefore trying to present their ESG performance in a positive light in order to be more attractive in the capital market. However, short-term financial interests often conflict with long-term sustainability goals. A real green transition is often costly and time-consuming, while greenwashing offers a quick and cost-effective solution to make a company appear more sustainable. As a consequence, some managers tend to spend more on communication campaigns than on actual environmental investments (Lyon & Montgomery, 2015).

This problem is related to the phenomenon of so-called "quartiles capitalism", where companies focus on short-term quarterly results and focus less on long-term sustainability performance (Asker et al., 2015).

5.3 Consumer expectations and marketing strategies

Consumers are increasingly aware of sustainability issues. Younger generations, especially Generation Z, are regularly informed about companies' environmental and social responsibility and often base their purchasing decisions on this information (Williams & Page, 2011). Varga's 2024 research highlights that members of Generation Z are, in absolute and measurable terms, more sensitive to environmental issues (Varga & Csiszárík 2024). 202Companies are trying to cater to these expectations in their marketing strategies. Sustainability messages are integrated into advertising, packaging and brand positioning. However, actual performance often falls short of the communicated promises. In the food industry, for example, the labels 'organic' or 'eco' often appear on products that meet sustainability criteria only to a minimal extent (TerraChoice, 2010). The sustainability narratives conveyed by marketing often rely on consumers being confronted with information asymmetries: they do not have all the relevant data and thus have difficulty in judging whether a claim is true (Delmas & Burbano, 2011). This situation provides an ideal setting for greenwashing.

5.4 The role of ESG communication and PR

Companies are devoting increasing resources to ESG communication and PR activities. Sustainability reports, press releases and CSR campaigns all aim to present the company as a responsible, ethical and environmentally friendly actor (Lock & Seele, 2017). The problem starts when communication is not matched with real action. According to some research, companies often practice 'selective publicity': they disclose data that portray them in a positive light, while hiding the negative (Marquis, Toffel, & Zhou, 2016). Communication strategies also often feature the phenomenon of 'showcase projects': companies present spectacular sustainability projects with marginal impact that do not represent a real change in the business model. This is a typical greenwashing mechanism as it serves to divert attention from deeper problems in organisational structures and processes (Bowen & Aragon-Correa, 2014).

The motivations for greenwashing are complex and multifaceted. Corporate reputational pressures, market competition, investor pressure, short-term financial goals, consumer expectations and marketing communications all contribute to the tendency of companies to make exaggerated or misleading sustainability claims. A common feature of these mechanisms is that they provide short-term benefits - reputation, consumer confidence, investor resources - but undermine confidence in the long term and

increase the need for regulatory intervention. In the next section, we will illustrate how these motives play out in practice, using concrete examples.

6. Examples and empirical experience

A major thrust of research on greenwashing is how it affects consumer and investor decisions. According to Delmas and Burbano (2011), greenwashing has a dual effect: in the short term it can increase consumer confidence and willingness to buy, but in the long term it can trigger scepticism that can spread to the entire industry. For example, if consumers are disappointed by a large company's sustainability claims, they tend to become more distrustful of other companies in general.

Another study (Walker & Wan, 2012) has shown that greenwashing has a direct negative impact on brand loyalty: if a company is found to have provided misleading information, consumers tend to turn away from it and look for alternative brands.

Empirical studies on investor reactions show that investors are increasingly sensitive to the signs of greenwashing. Kruger (2015) found that when a company is embroiled in a CSR or ESG scandal, its share price immediately and significantly falls. This shows that market participants punish companies that engage in misleading sustainability communication.

A meta-analysis by Friede, Busch and Bassen (2015), based on more than 2000 studies, concludes that credible ESG performance has a positive impact on a company's financial results in the long run, while the risk of greenwashing has the opposite effect.

Hungarian research also confirms the presence of greenwashing. According to Törőcsik (2021), Hungarian consumers are increasingly demanding sustainable products, but many have been disappointed by products that contain false claims. This reinforces scepticism and in the longer term undermines the credibility of sustainability narratives.

The studies and research to date clearly show that greenwashing is not an isolated phenomenon, but a global problem that affects a wide range of industries and countries. The examples of Volkswagen, H&M

and BP illustrate that misleading sustainability communication can be beneficial in the short term, but in the long term it leads to serious reputational and financial losses. Experience in Hungary shows that greenwashing is also a dominant phenomenon in the domestic market, raising serious consumer and regulatory challenges. Empirical research confirms that greenwashing erodes trust and has a negative impact on both consumer behaviour and investor decisions.

7. Results and Discussion - Policy options and future directions

7.1 Strengthening transparency and objective measurement frameworks

Increasing transparency is one of the most important conditions for curbing greenwashing. Data published in ESG reports are often fragmented, selective and difficult to compare. As a result, investors and consumers are often unable to distinguish real sustainability performance from marketing claims. The development of objective measurement frameworks is therefore crucial. The EU's European Sustainability Reporting Standards (ESRS) and the EU Taxonomy point in the direction of standardising sustainability indicators. Similar efforts are also underway globally, for example through the IFRS S1 and S2 standards issued by the International Sustainability Standards Board (ISSB) (IFRS, 2023). A future solution for comparability could be the mandatory digitisation of ESG data and the creation of public databases. This would allow investors and researchers to access the data in real time, reducing the possibility of selective disclosure.

7.2 Independent audits and ratings

Another important pillar to enhance credibility is independent audit. The audit requirement imposed by the CSRD strengthens transparency, but further improvements are needed. Sustainability auditing is currently in its infancy: the experience and methodology of auditors is not always suited to verify complex ESG data (Accountancy Europe, 2020).

In the future, there may be a need to train specialised sustainability auditors who are experts in environmental, social and governance issues. In addition, independent rating systems accredited by public or international organisations should be introduced to validate companies' sustainability performance. These

ratings can play a similar role to financial audits in the accounting world: they ensure the reliability of data and reduce the risk of greenwashing.

7.3 Stakeholder engagement and social pressure

The active involvement of stakeholders - consumers, NGOs, media, workers - is key in the fight against greenwashing. Holding companies accountable only works if they are under constant scrutiny by society. According to stakeholder theory, companies are accountable not only to their shareholders but to all their stakeholders (Freeman, 1984). If civil society and the media actively monitor sustainability performance, this can put strong pressure on companies to communicate transparently.

In the future, it can be expected that consumers will be even more aware of holding companies to account, especially through digital platforms and social media. A single greenwashing scandal could go global in no time, creating a significant reputational risk. It is therefore advisable for companies to manage social pressure proactively: through honest communication, stakeholder dialogue and real sustainability measures.

7.4 Digital solutions and technological innovation

Digitalisation offers many opportunities to enhance the credibility of ESG data.

Blockchain technology allows ESG data to be captured in an immutable way, thus eliminating the possibility of post-manipulation. For example, a company's emissions data can be automatically captured and audited through the blockchain, significantly increasing transparency.

With Big Data and artificial intelligence, AI-based systems can analyse large amounts of data - for example from news, social media and corporate reports - to filter out suspected cases of greenwashing. This can provide valuable information not only to regulators, but also to investors and consumers.

Open data platforms, such as open ESG data platforms, can also help researchers, journalists and NGOs to verify companies' claims. This increases social control and reduces the spread of greenwashing.

7.5 Transforming corporate governance

The fight against greenwashing cannot be achieved by technical means or regulation alone. It requires fundamental organisational and cultural changes in corporate governance. The application of good corporate governance principles - such as board independence, codes of ethics, anti-corruption measures - can help companies to strive for real performance rather than just the appearance of sustainability (Gillan, Koch, & Starks, 2021). In the future, it is likely that ESG integration will be embedded at all levels of corporate governance: from strategic decisions to day-to-day operations. This will reduce the risk that sustainability issues remain at a purely communicative level.

7.6 Future directions and outlook

In the long term, the fight against greenwashing can develop in three main directions:

In terms of regulatory harmonisation, reducing the differences between regulations in the EU, the US and other regions is necessary to ensure that companies meet globally consistent expectations. In the case of integrated reporting, the integration of financial and sustainability data can provide a more comprehensive picture of company performance. This can help to embed sustainability considerations into mainstream business practices (Eccles et al, 2019).

With the rise of corporate social responsibility, companies will in future not only have to comply with legal requirements, but also with societal expectations. Operating ethically and transparently can become a competitive advantage in the long run, while greenwashing can easily lead to corporate failure.

The fight against greenwashing requires a multi-dimensional approach: stricter regulation, independent audits, social control, technological innovation and a change in corporate culture. The key to the future is a credible ESG strategy that not only ensures regulatory compliance but also creates sustainable long-term value for companies, investors and society.

Conclusions

An examination of the links between ESG and greenwashing has highlighted that sustainability and social responsibility have become central to business in the 21st century. For companies, ESG is not just an ethical framework, but a strategic tool that directly affects their reputation, consumer and investor confidence and long-term competitiveness. However, putting ESG principles into practice poses a number of challenges, one of the most critical of which is the phenomenon of greenwashing.

The three pillars of ESG – environmental, social and governance – provide a complex framework for assessing the performance of companies. It has become clear from analysis that a true integration of ESG can contribute to improving financial performance, reducing risks and enhancing customer loyalty in the long run (Friede, Busch, & Bassen, 2015). However, the measurability of ESG remains problematic. Diverging methodologies, self-reporting and divergence between ESG raters all weaken the credibility of the system (Berg, Kölbel, & Rigobon, 2022). These problems directly contribute to the proliferation of greenwashing, as they give companies the opportunity to pick and choose between favourable indicators and assessments.

The examples of greenwashing -Volkswagen, H&M or BP - have clearly shown that misleading sustainability communication can be beneficial in the short term, but can cause severe reputational and financial losses in the long term (Hotten, 2015). Empirical research also confirms that greenwashing erodes trust: consumers' disappointment with sustainability claims leads to general scepticism, while investors turn away from companies that communicate misinformation (Delmas & Burbano, 2011; Krüger, 2015).

In Hungary, investigations by the GVH and other authorities show that greenwashing is also a serious problem at the domestic level, especially in the food and chemical industries (GVH, 2022), demonstrating that the phenomenon is not limited to multinational companies but is also present in local markets.

The research has shown that one of the most effective ways to curb greenwashing is to tighten and harmonise the regulatory environment. The CSRD, , CSDDD, SFDR and EU Taxonomy are tools introduced by the EU to create comparable, verifiable and credible ESG reporting (European Commission, 2022a, 2022b). In addition, the Green Claims Directive takes consumer protection to a new level by requiring sustainability claims to be substantiated by evidence (European Commission, 2023). At the

international level, the efforts of the ISSB and the US SEC show that strengthening transparency is a global trend. Although regulations differ, they share the common goal of preserving market transparency and discouraging greenwashing.

The research has highlighted that the fight against greenwashing is taking place at several levels:

Transparency: consistent, comparable and publicly available ESG data is needed to enable market actors to make informed decisions.

Independent audit: professional development of sustainability auditing is essential to increase the credibility of reports.

Stakeholder engagement: consumer, NGO and media scrutiny strengthens corporate accountability.

Digital innovation: blockchain, big data and artificial intelligence tools offer new opportunities to monitor data in real time and detect greenwashing.

Corporate culture change: long-term sustainability can only be achieved if ESG integration becomes part of corporate governance, not just a communication tool.

Examining the links between ESG and greenwashing has made it clear that credible sustainability performance is not only a social and environmental concern, but also a business imperative. For companies, greenwashing is a tempting opportunity in the short term, but has serious long-term consequences. The key to the future is a transparent ESG strategy and committed corporate governance that can balance financial results with sustainability objectives. If can do this, companies will not only avoid the trap of greenwashing, but also create real value for shareholders, consumers and society.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

Funding

* Project no. MEC_SZ 149231 has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the MEC_24 funding scheme.



PROJECT
FINANCED FROM
THE NRDI FUND

Conflict of Interest

* The authors declare that they have no conflicts of interest

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Management Economics and Business (www.iconmeb.net) held in Budapest/Hungary on August 28-31, 2025

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THE ROLE OF INNOVATION AND HUMAN CREATIVITY IN THE LIFE OF ECONOMIC ACTORS

Abstract: Our aim is to present the contribution of human creativity to the innovation of economic actors based on opinion of regional market players. In this study we wanted to review the connection between human creativity and innovation. This topic appears periodically during research activities; its processing can be seen as significant. Therefore, we are going to think through and focus attention on innovation's human side, and the ability of creativity without a full literature review. Furthermore, we briefly touched on the sources of creativity, how imagination and different mindsets can help to create innovation, how creativity can be improved, how proper environment might be nurtured and what the leaders and organisations can do to support that. We conducted a 22-question survey among regional market players and used the results to provide evidence of how creativity plays a role in life of the economic actors and gained insight into their innovation management processes. Our study contributes to the expansion of understanding the literature in this topic and provides an opportunity for economic actors to improve the connection of creativity and innovation in their organisation. The study may draw the attention of local higher education institutions to how they can support economic actors in this area through their third mission activities.

Keywords: creativity, innovation, leadership style, organisational culture, innovation management

Introduction

Innovation and human creativity are inseparable. Although we have entered the era of AI, we still feel that the human side of innovation is becoming more valuable. Our assumption is that the source of all innovation is people, their ability to think creatively, use their imagination with which they can envision something that does not exist yet, but it will emerge during the creative process. Perhaps we can say that the whole process starts with openness and curiosity about our environment. Take the example of a small child who approaches everything with curiosity at the beginning of their life driven by a desire to discover. The imagination of a child allows them to use an object/toy differently from its specified method of use. They

are not bound by user manuals; they can invent any function for it and naturally start playing with the object as if it were created for that purpose. The adult parent is amazed at their child's imagination, as they approach that object with a different way of thinking, probably this way of using it would not have even occurred to them. This kind of thinking ability, which a person is capable of in childhood, is increasingly valued in the present. We do not have to fear that we have lost this ability during the process of becoming an adult, or because we feel that we are not the creative type. According to John Cleese, the world-famous co-founder of Monty Python: „It's a myth that creativity is something we're born with. It's not. Anyone can be creative.” (Cleese, 2021). So, creativity can be developed, and we need it in the present and will certainly need it in the future. In its Future of Jobs Report 2025, the World Economic Forum (WEF) ranked creative thinking fourth on its list of 10 core skills for 2025, indicating the importance of this cognitive ability in today's workplaces (Weforum.org, 2025). Creative thinking also ranked fourth on the WEF's list of the Top 10 fastest-growing skills by 2030. This clearly shows that, according to the respondents, creativity will still be one of the most important skills for future employees in 2030, which they will need to use in the era of working with AI and widespread digitalization. The European Union has recognized that its competitiveness also depends on the development of future-oriented skills, which is why the European Commission, in its Skills Union document created in 2025, aims to promote the process of creative thinking, among other things, by promoting STEAM fields (European Commission, 2025). According to the document, the role of people, their skills, and their way of thinking, among other things, come to the fore in developing Europe's competitiveness, and we should add that this is very right, because investing in people always pays off in the long term and supports the reduction of social inequalities, with which we could build a more sustainable and stable future.

On the relationship between creativity and innovation

Numerous studies have already addressed the concept of creativity. In their literature review, the authors searched for the appropriate definition from an economic perspective, and based on their research results, they concluded that “innovation is the market realization (implementation) of creativity, but both phenomena can occur without the other” (Derecskei et al., 2012.). In our opinion, the basis of innovation can always be a creative idea. In relation to creativity, the author highlights the creation of novelty and draws attention to the joy of discovery during the process (Csíkszentmihályi, 2022). Creativity is about generating ideas or results that are new and useful for achieving a goal (Amabile, 2011). According to the author, for a creative response to arise in a situation, four components are necessary. Three of these must be present at

the level of the individual: specialist skills, internal creative processes, and motivation. The fourth component is the social environment in which the individual exerts its influence. If the internal components at the level of the individual come together fortunately, it is much easier to realize the creative idea in a supportive environment than without it. Creativity, as defined by the OECD (The Organisation for Economic Co-operation and Development), is “the ability to generate diverse and original ideas and to evaluate and develop the ideas of others” (OECD.org, 2025). Among the requirements placed on students is the need for creative thinking, as was also stated in the WEF report based on feedback from labour market players. The author highlights this in his article “The Transformation of Higher Education,” in which he refers to the PWC Hungary CEO Survey and names the importance of creativity and innovation, which appears as a demand from the labour market (Kadocsa, 2024). The OECD Oslo Manual sets out the internationally accepted definition of innovation: “a new or improved product or process (or combination of these) that is significantly different from the unit’s previous products or processes and that is made available to potential users (product) or used by the unit (process)” (Oslo Manual, 2018). The two definitions can almost complement each other, in which creativity, as the “ability to generate diverse and original ideas,” is embodied in “a new or improved product or process” as innovation. ű

In their book, *Innovative Intelligence*, Weiss and Legrand distinguish between creativity and innovation in that creativity are about new ideas, which can be relevant, useful, feasible, or none of these, while the outcome of innovation represents value for the organization. Based on this, their definition, which can be interpreted in a business context, is that „innovation is applied creativity that creates value for economy” (Weiss et al., 2011). While examining the relationship between the creativity and the innovation, Nakano and its fellow researcher concluded that both are skills of the 21st century, in order to spread which, they called attention to the need for creative education, from primary school to higher education, with the main goal of motivating students to have a desire to learn and to discover new subjects, which goes hand in hand with the need to rethink educational strategies and methods (Nakano et al., 2018). Castillo-Vergara and its co-authors undertook a bibliometric analysis of creativity in the field of economics and found that it is an important topic on a global level, as evidenced by the fact that most research is conducted in the USA, followed by Europe in second place. Regarding the development of the research topic, they highlighted that the foundations related to creativity have already been laid, and that the analysis of the relationship with organizations and the environment is currently emphasized. The creativity is the driving force of the process of knowledge production that influences economic performance, for which the innovation is key, to develop competitiveness. They highlighted that there are two main directions, the first is that the study of the

creativity should play a role in the training of professionals, the second is that it is necessary to develop a process evaluation system within organisations for measuring organisational creativity (Castillo-Vergara, et al., 2018).

On the sources of creativity

How can imagination, problem-solving thinking, and different thinking styles help create innovation? In his PhD dissertation, Galla discussed the ten factors of the creativity, which she summarized based on the results of two researchers (Guilford, 1950, Torrance, 1974): general problem sensitivity, originality, fluency, elaboration, flexibility, analysis, synthesis, complexity, redefinition, evaluation. She stated that these characteristics differ for everyone (Galla, 2021). Based on these characteristics, a creative person emerges with the ability to identify the problem and originality, and the role of imagination can also be highlighted. Imagination, the power of intellectual creativity, can be considered a form of manifestation of creative thinking. Based on the interpretation of Galla, problem-solving thinking and thinking creatively can be characteristic of a creative personality. For imagination to fly, it is necessary to break away from thinking in patterns. In contrast, the thinking that enables a series of routine actions and plays a role in our everyday lives, using patterns, holds our processes together, points us in one direction, and helps us solve our everyday, simple problems. In contrast to convergent thinking, divergent thinking branches out, diverges, and considers multiple options when solving a problem. Edward De Bono contributed to the understanding of creative thinking by introducing lateral thinking. „Lateral thinking is not limited to merely problem solving; we can look at the same things from a new perspective, or we can use it to generate new ideas on any topic” (De Bono, 2015). It evokes the ability to associate, which allows us to step out of thought patterns and fly freely through imagination. Imagination thus becomes a source of creativity, depending on whether we create something or recreate something. The authors draw attention to the nature of creativity experimentation, which is based on trial and failure and requires a willingness to transform efforts into learning processes (Santosoa et al., 2019).

On the development of creativity

The author highlighted the human factor in the creation of innovation, among the factors influencing the competitiveness of nations. Human capital, or, as the author mentioned, human wealth, which includes, among other things, the creativity and innovativeness of the available labour force, greatly influences the

economic performance and social well-being of a country (Csath M., 2021). The study by Dobos and Csiszárík-Kocsir (2025) discusses not only creativity but also the importance of a project-based approach, examining how it affects the intensity of corporate innovation and competitiveness, with particular regard to regional characteristics and the economic environment. The author examined the role of the individual within the organization from the perspective of the development of innovation (Véghné, 2022.). For the author, creativity appears at the beginning of the process of knowledge generation, arising from human presence, which is embodied in the creation of new ideas and the innovation. The author drew attention to the time perspective of people, which can reduce the activity of innovation. As she mentioned in her study, based on research of Zimbardo-Boyd, the present-hedonic time profile supports the development of innovation on the part of people. Among her own findings, she emphasised that time orientation is a learned process and therefore can be modified. The internal drive of individuals to innovation can be stimulated by the appropriate organizational culture and leadership support. Sterczl and Csiszárík-Kocsir (2025) highlight the importance of creativity in qualitative data analysis through a comparative analysis of AI models. They examine how the combined use of human creativity and AI technology promotes deeper and more nuanced interpretation in analyses. Aigner reviewed the OECD Educational Working Paper (No. 280.), Saroyan's work on „Fostering creativity and critical thinking in university teaching and learning”. He praised, among other things, the fact that the document summarized the educational methods that can enable effective skill development and presented the elements of an environment that nurtures creative thinking (Aigner, 2024). The study suggests that these CCT skills are essential the area of misinformation and disinformation.

On the relationship between the leader, leadership style and creativity

Knowledge, creativity and the ability to create new things appear among the requirements of value creation as a source of innovation (Varga, 2015). Karacsony and his co-authors, in their studies among students of business higher education institutions, drew attention to cultural diversity, which contributes to people being more open, innovative and creative, transforming their thinking. They emphasised that the quality and consequences of cooperation depend on the issue of individual attitude (Karácsny et al., 2022). The willingness to cooperate is important for the creation of innovation.

Why the creative environment is important? How can leaders promote creativity through their leadership style and influence the creation of a supportive environment? Jiang et al. found in their study that if there is a higher expectation for creativity from the leader, this supports the creative self-efficacy of employees

within the organization. Leaders must provide a supportive environment where employees have the time and opportunity to experiment and feel that what they do matters. This allows them to be more involved in their work, formulate ideas, and contribute to organisational innovations (Jiang et al., 2017). The authors examined the role of entrepreneurial leadership style in the relationship between creative self-efficacy and innovative behaviour among employees. In their study, they used data from large Chinese multinational companies and found that creative self-efficacy had a greater impact on innovative behaviour when employees were led by a strong entrepreneurial leader. Entrepreneurial leadership style had a stronger mediating effect on the relationship between creative self-efficacy and innovative behaviour than transformational and participative leadership styles (Newman et al., 2018). The example set by a leader who uses an entrepreneurial leadership style encourages employees. The authors stated that organisations must be innovative, and the role of organisational creativity in this is unquestionable. In their study, they focus on organisational structure, processes, the role of leadership style, and understanding organisational creativity. To manage creativity, they came up practical recommendations regarding the design of organisational structure and job requirements by ensuring a high degree of autonomy, the ability to reuse knowledge, the incorporation of feedback, the diverse expertise of expert team members, and the introduction of idea management (Fetrati et al., 2022). Their study highlights leadership with emotional intelligence and the management of creativity. They also mention the transformational leadership style as a leadership style that influences creativity, which influences both the individual and organizational levels. The role of emotionally intelligent, high-level communication in corporate management and its impact on value creation were highlighted by the authors as the main employee motivation (Farkas et al., 2021). The authors examined the importance of human factors in service innovation and performance among Japanese tourism service companies. In their study, they identified four contributing factors: leadership, employee engagement, trust, knowledge management, and creativity management. The creativity management emerged as a complement to effective human resource management. They saw the role of leaders as developing a strategy that, when implemented, can ensure increased employee engagement and development opportunities, thereby influencing service innovation and business performance. (Tajeddini et al., 2020). The authors concluded a surprising finding regarding the strength of the relationship between creativity and innovation and the relationship between firms with different levels of technological development. They found that the relationship between creativity and innovation is stronger in “low-tech” industries than in “high-tech” industries. Furthermore, the relationship examined is relatively stronger for service innovation than for product innovation (Sarooghi et al., 2015).

The authors concluded that the formal context of organisations, the HR system, influences the interactions between the originally interconnected processes of idea generation and idea implementation and employees' perceptions of leadership styles (Černe et al., 2018). They pointed out that it is probably not possible to provide an organization's competitive advantage in the long term by generating ideas without implementation, furthermore they also highlighted that there may not be a perfect solution for organisations to choose which leadership style. They emphasised that context is crucial in the successful innovation process, and they also suggested a holistic approach, that an organisation can be led to achieve the best results by a single HR system. Nguyen et al. found that among the different leadership styles (transformational, transactional, creative) creative leadership has the strongest impact on online knowledge sharing. They found that the influence of leadership is significant in creating a knowledge sharing culture that contributes to increasing the level of employee creativity, which is related to personal development through organisational learning, which can be based on the effective exchange of knowledge. The authors highlighted that creative leadership encourages employees to transfer and collect knowledge, while transactional leadership plays a key role in the spread of "lurking" and "active lurking" "behaviours". They found that during their research "lurking" and "active lurking" "behaviours" are the ones that contribute the most to employee creativity (Nguyen et al., 2024). The authors found that the creative skills of employees are not equally important at each stage of the innovation process and suggested the importance of reorganising the organisational structure so that the optimal creative potential of the organisation can be fulfilled. The effect of individual creativity can be seen at every stage of the innovation process, and the development of innovation across stages contributes to increasing the production efficiency of economic organisations. They highlighted that previous innovation experiences serve as a good basis for generating new ideas and play a role in transforming them into successful innovations. They recommended hiring employees with creative skills as steps to develop the innovation potential of companies, and they emphasised the ability of managers to create a favourable atmosphere and choose appropriate methods to stimulate creativity to support the idea generation of individuals (Stojic et al., 2018).

The authors examined the relationship between employee creativity and innovation in the public sector in Indonesia by examining leadership styles (transformational, transactional, servant leadership, authentic leadership, authoritarian leadership) and public service employee motivation. The authors highlighted the positive and significant influence of authoritarian leadership on creativity and innovation, while transformational and servant leadership can also have an impact. The authors drew attention to the importance of public service motivation, which is an essential aspect in facilitating employee creativity and

innovation (Ganeva et al., 2024). The authors examined the creative processes of entrepreneurs and innovators. Analysing the range and relationships of factors influencing market success, they indicated that the interpretation of creativity as a prominent factor of entrepreneurial activity is questionable. Pure, raw creativity is not enough, it must be combined with general business sense (Barnard et al., 2019.).

If the organisational goals include achieving innovation, examining the connections between creativity and leadership styles, it can be stated that the role of leaders is unquestionable in creating a workplace environment and culture where individuals are given the freedom and autonomy to come up with creative ideas, and clear communication helps channel them into decision-making mechanisms with continuous feedback. There are many playful methods and opportunities for developing creativity and organizational creativity, as Deak summarizes in his work (Deák, 2021).

Method and Material

We conducted a survey (22-question online google questionnaire) targeting 50 market players in Szekesfehervar and in its region (Hungary). A small number of the questions are open-ended, we wanted to get completely subjective answers from the respondents to get to know their thoughts on the topic, but most of the questions are closed-ended. Only 10 companies responded within 1 week thus the sample was unfortunately smaller than we had hoped. This is one of the limitations of our study. We classified the companies based on the thresholds set out in the “User Guide to the SME Definition” published by the European Commission in 2020. 40% of respondents are large companies, 40% of respondents are medium-sized enterprises and 20% are small enterprises. The other limitations of our study, there are no respondents from microenterprises.

Based on general questions, distribution of economic organisation according to their activities are the following: 20% of the respondents are engaged in IT services, another 20% in the production of plastic products, 10% in the production of computer, electronic, optical products, 10% in the production of electrical equipment, 10% in the production of metal processing products, 10% in the production of vehicle parts and accessories. 10% of the companies operate in the areas of Human Health Care and Electricity Production and Supply.

The responders are in senior manager positions, 9 with university degree and 1 with secondary degree of which: three of them are managing directors, and the others are a plant manager, an education manager, a strategy manager, a quality management manager, an HR manager, an IT manager, and an operational manager. Among the respondents, 60% had a technical degree, 40% an economic degree, 20% an IT degree, 10% an agricultural degree and 10% a human arts degree (Four respondents had two higher education degrees).

State or local governments have no direct or indirect ownership stake in these organisations.

Results and Discussion

When asked *“What do you think of when you hear the word creativity?”*, 40% of respondents associated the concept with some kind of thinking ability ("out of the box", "problem solving", "outstanding thinking", "questioning dogmas"), while 60% associated the concept with the ability to create something new ("invention", "intellectual freedom", "creation", "idea", "value", etc.). When asked *“What do you think of when you hear the word innovation?”*, 60% of respondents associated the concept with some level of advancement and development (using the words “development”, “evolution”, “modernization”, “innovation”). Other responses included one mention each of “competitiveness”, “the need for change”, “the ability to create new things”, and “AI and science”. In 90% of the responses to our question *“How would you describe the relationship between innovation and creativity?”*, a close relationship between creativity and innovation can be discovered. In 30% of the responses, it is specifically stated that “without creativity there is no innovation”; in another 20%, the word “necessary” is used to describe the creation of innovation; the idea that the two go together is present in 30% of the responses. Creativity and innovation, as development/value realized from an idea, appeared in 20% of the responses.

To our closed question *“Do you think your company can provide employees at any level of the organization with opportunities to use their creativity during their daily workflow?”* 60% of the responses answered “partly, depending on the job”, 20% “yes, for almost all employees”, another 10% answered “at management levels”, and 10% answered “yes” in general. In the case of a “positive” answer to the previous question, we asked *“please mention in which area of your organization and at what levels this is typical?”* The areas mentioned by the respondents where it is possible to use creativity during their daily workflow were: “technical solutions/engineering areas”

in 50% of the answers, “project/organisational development/processes” in 20%, and human resource development areas (“education/training/specific HR areas/customer relations”) in another 30%. *The organisational level mentioned where it is possible to use creativity* (6 responses): “managerial level” (1 respondent from a medium-sized enterprises), “middle management and technology level” (1 respondent from a medium-sized enterprises), “at all levels”, “for everyone” (1 respondent from a large company and 1 respondent from a medium-sized enterprises), “job-related” (1 respondent from a large company). According to the respondent from the organisation operating in human healthcare (small enterprises), creativity is expected from those in direct contact with customers, as well as from IT, economists, and marketing specialists.

“Please indicate on a four-point scale how important it is for your company to be innovative (1 is not at all important, 4 is very important)?” 70% of respondents (30% large companies, 30% medium-sized enterprises, 10% small enterprises) answered “very important”, and another 30% (10% large companies, 10% medium-sized enterprises, 10% small enterprises) answered “important”. There were no respondents who indicated “not at all important” or “not important” on the scale. *“Do you think your company’s organisational culture promotes innovation?”* 40% of respondents (20% large companies, 10% medium-sized enterprises, 10% small enterprises) answered “yes”, and another 60% (20% large companies, 30% medium-sized enterprises, 10% small enterprises) answered “partly”. There were no respondents who would have marked the “no” answer. In the case of a “positive” answer to the previous question, we asked them to *“mention which elements of the corporate organisational culture support the emergence of innovation?”* Six responses were received to this question, of which 30% came from large company respondents, who mentioned “Kaizen”, “inclusion of innovation among the company’s core values”, and “recognition, innovation competitions, rewarding implemented ideas”. Another 20% of responses came from the medium-sized enterprise sector (“Competency-based transition between jobs, agile leaders” and “fast approval process, management open to change”), while small entrepreneurs (10%) answered “both”.

To our question *“Do you think that those employed in managerial positions can play a role in enabling creativity to emerge in the work of employees?”* 70% of the respondents indicated “yes”, another 20% indicated “it depends on the style of the manager”, and 10% indicated “this is only true for certain management levels”. Of the respondents from large companies (4), three indicated “yes”, and one indicated “it depends on the style of the manager”. Of the respondents from medium-sized enterprises (4), two indicated “yes”, and one

indicated “it depends on the style of the manager” and “this is only true for certain management levels”. Respondents from small enterprises (2) indicated “yes”.

To our open question *“How do you think the manager (senior, middle) can support innovation to emerge in the life of the organisation?”* the answers included the “leaders should serve as a role model”, “communication”, and the opportunity to “share ideas” three times. The idea of providing “space” and “time” for the employee, “openness” and “joint developments, problem solving” appeared twice in the responses. The idea of “rewarding”, the possibility of “making mistakes”, the creation of a “forum”, “liberal regulation of jobs”, and “acquiring resources for implementation” appeared in one response each. When asked *“If an employee comes up with an idea that offers a novel solution to a workplace problem, does the information reach the relevant manager?”* 40% of respondents answered “yes”, 50% answered “usually yes” and 10% answered “rarely”. In the case of a “positive” answer to the previous question, we asked, *“indicate how many management levels can an employee’s idea reach the decision-maker through?”* 78% of respondents indicated “two management levels”, another 11% each indicated “one management level” and “three management levels”. Several answers could be selected for our question *“In what form can an employee’s idea or innovation reach management?”*. Of the 30 nominations received by respondents, 30% indicated “personal conversation”, 27% indicated “email”, 20% indicated “idea box”, 10% indicated “presentation”, 7% indicated “upload to a designated location in the cloud”, and 6% indicated “online conversation”. To our question *“Is there a designated colleague who coordinates these initiatives?”* 50% of respondents answered “yes”, 40% “no”, and 10% “a separate organizational unit”.

“How familiar are you with the concept of innovation management?” We asked them to indicate their level on a scale where “1 = not at all” and “4 = completely aware” means “I am fully aware”. 20% of respondents answered, “Not at all”, 30% “Yes, I am aware” and 50% “I am fully aware”. To our question *“Is there an innovation management activity built into the organisation’s operating procedures?”* 40% of respondents answered “no”, 20% “yes” and another 40% “partially”.

“If there is a lack of specialized expertise/technology in an experimental area within the organisation, how do they try to obtain it?” To our question, 80% of respondents said, “We are open to bringing it in from outside the organisation”, another 20% said “We would rather try to solve it from within the organisation”.

“Let’s say your company develops a special, new knowledge/product (even in the experimental stage), but later they don’t want/can deal with it. In this case, would you be happy to share it with another economic organisation so that it can continue

the work that has been started and later both companies can benefit from its results?" 40% of the respondents answered "No, what we started in-house stays there." Another 30% answered "Yes, we are open to this type of collaboration." 20% answered "Yes, there are situations when an external expert can take it further by thinking it over differently," and 10% answered "If we don't have the resources to deal with it further, we will share it with someone else."

"Does your organisation support the development of employee creativity in some way?" 50% of respondents answered "yes", 40% "partly, at certain employee levels", and 10% "only at management levels".

To the question *"Does your organisation support in some way the expansion of employees' knowledge, with the aim of stimulating innovation?"* 90% of respondents answered "yes", while only 10% answered "no".

Conclusion

The aim of our study was to learn about the relationship between human creativity and innovation, as well as their role in the life of economic organisations in Szekesfehervar and its region (Hungary). We see the small sample size as one of the limitations of our study, but the responses still provided an opportunity to gain insight into the views of business organisations on innovation and creativity. Another limitation of the study may be that representatives of large, medium-sized and small enterprises responded to our questions, but representatives of microenterprises did not respond.

To clarify the concepts of creativity and innovation, we invited survey participants to free association, even describing the meaning in one word. Summarizing the responses to *creativity*, the working definition is *a way of thinking that enables the ability to create something new*. Summarizing the responses to *innovation*, the working definition is that *it is a development that leads to modernization and improvement through innovation, the use of artificial intelligence and science as the key to competitiveness*. The close relationship between creativity and innovation is clearly demonstrated by the answers given to the clarification of concepts. Furthermore, in the answers describing the relationship to our last question (in the closing section of this group of questions), creativity appears as a precondition for innovation. This necessity is clearly present in the vocabulary of respondents: "necessary", "without creativity there is no innovation", "goes together", "comes from this", etc.

As expected, 60% of respondents partially allow the use of creativity during daily workflow, depending on the job. It should be emphasized that the responses received from all organisations are basically positive, they allow the use of creativity within some framework. We asked in which areas of the organisation this is possible. 70% of respondents indicated the areas of “technical/engineering” and “project/organisational development”, which clearly assume creative thinking in certain jobs. Human resource development areas (“education/training/specific HR areas/customer relations”), dealing with people may also require creativity, this was indicated by 30% of respondents. Regarding the use of creativity, the indication of the organizational level was present in 60% of the answers.

It can be stated that all respondents clearly consider it important for their business to be innovative. The difference can only be detected in the degree of importance, 70% consider it very important, 30% simply consider it important to operate as an innovative organisation. According to 40% of the responses, the organisational culture of the companies promotes innovation, while another 60% say it only partially does so. The respondents mentioned examples of which elements of their organisational culture support the emergence of innovation. The responses from the large corporate sector include elements that provide opportunities for employees: the possibility of continuous development; rewards/recognition and the inclusion of innovation in key corporate documents. The responses from the medium-sized corporate sector are dominated by supportive organisational elements related to the management's attitude (agile leadership role; management open to change, etc.).

It can be stated that a significant part of the surveyed senior company managers (70%) believe that those employed in managerial positions can play a role in enabling creativity to emerge in the work of employees. 30% made this dependent on the manager or the specific style of the manager. *Based on the responses, the working definition of an innovation-supporting manager is a role model manager who, through liberal regulation of jobs, communication, and openness, leaves space and time for employees to share their ideas and make mistakes, involves them in problem solving and joint developments, uses the opportunity for rewards, and acquires the resources to implement innovation.*

Based on the responses (90%), it can be highlighted that if an employee comes up with an idea that offers a novel solution to a workplace problem, the information usually reaches the relevant manager. According to a significant part of the respondents (78%), this employee idea reaches the decision-maker through two management levels. The first three named ways of delivering ideas are, in order: personal conversation (30%), email (27%), and idea box (20%). It is only interesting to mention that these three information channels appear in the case of all respondents in the large corporate sector. 60% of the responding organisations

have a designated colleague who coordinates these initiatives. In the case of the large companies, all organizations have one, $\frac{3}{4}$ of the medium-sized enterprises do not have one, and $\frac{1}{2}$ of the small enterprises have one.

Based on the responses, it can be stated that *a significant majority (80%) are familiar with the concept of innovation management*. Representatives of the large companies are familiar with the concept, $\frac{3}{4}$ of the representatives of medium-sized enterprises are also familiar with it, and $\frac{1}{2}$ of the representatives of small enterprises are also familiar with it. *60% of the respondents indicated that there is, or is partially built-in, innovation management activity in the organisation's operating processes*. Representatives of the large companies reported that they carry out some level of innovation management activity, $\frac{3}{4}$ of the representatives of medium-sized enterprises indicated that they do not carry out such activity, and half of the small enterprises indicated that they do.

We also wanted to get information about their attitude to Chesbrough's open innovation theory (Chesbrough et al, 2013). *Based on the answers of the senior managers, it can be stated that a significant part of them (80%) are open to knowledge flowing from the outside in*. The representatives of the large companies are completely open to this solution, $\frac{3}{4}$ of the medium-sized enterprises, and half of the small enterprises indicated that they did. Our next question concerned the inside-out type of open innovation. *Based on the answers, it can be stated that many of them (60%) are open to knowledge flowing from the inside out and cooperation*. $\frac{3}{4}$ of the representatives of the large companies are open to this solution, $\frac{3}{4}$ of the medium-sized enterprises are also open to this solution, and the small enterprises answered no to this question.

Based on the responses, it can be stated that large companies support the development of employee creativity in some form; medium-sized enterprises only "partly, at certain employee levels", half of small companies support it, and the other half only at the management level. 90% of the respondents support the expansion of employee knowledge regarding the stimulation of innovation.

In our opinion, despite the small sample size, we were able to come to some conclusions. In the study, based on the reviewed literature, we discussed the role of different thinking styles, the relationship between innovation and creativity, and summarized how creativity can be developed, and what role management and different management styles can play in this. By analysing the answers of the interviewed company senior managers, we were able to learn how many of them enable employees to use creativity during their daily workflows. It is clear to them that their economic organisation must be innovative, and we have shown with

examples which elements of their organisational culture support this. Based on their responses, we were able to formulate a working definition of creativity and innovation, but we could also characterize a leader who supports innovation. What chain of command must the ideas of employees navigate to reach decision-makers, and through what channels this is achieved. A significant majority of the respondents are aware of the concept of innovation management, and a smaller majority apply innovation management processes. A significant part of them is open to the outside-in knowledge acquisition of the open innovation theory, while only a smaller majority are open to the inside-out knowledge acquisition of open innovation and the cooperation that achieves this.

Our study contributes to understanding the opinions of economic actors on the relationship between creativity and innovation, the role of leaders and leadership styles, innovation management and touched on open innovation. It would be worthwhile to conduct further research in the region on a larger sample and compare the results with the literature and this study.

In our opinion, the basis of innovation is always a creative idea. Developing creative ideas is accessible to everyone, and this can lay the foundation for innovation. Let us not dismiss the possibility of a new idea by saying that “we are not creative”. The experience of creative creation is an opportunity for everyone, which can represent value for us and our community.

Recommendations

Local higher education institutions must enter the field of innovation cooperation through their third mission activities. Furthermore, the local HEIs need to catalyse these processes and expand knowledge transfer, support innovation management. Their important task is to build trust and strengthen social capital, with which they can even encourage open innovation cooperation during the development of a helix model-like operation. They can contribute to the sustainable development of the region and its urban development.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

Funding

* Project no. MEC_SZ 149231 has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the MEC_24 funding scheme.



PROJECT
FINANCED FROM
THE NRDI FUND

Conflict of Interest

* The authors declare that they have no conflicts of interest

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Management Economics and Business (www.iconmeb.net) held in Budapest/Hungary on August 28-31, 2025

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STRUCTURAL AND FUNCTIONAL CONCEPT OF THE LABOR MARKET ECOSYSTEM

Abstract: The purpose of the article is to identify the components of the labor market ecosystem, reveal the mechanisms of interaction and complementarity of these components, and identify opportunities for public authorities to influence the labor market in order to overcome its shortcomings and asymmetries. To achieve this goal, the authors used methods of correlation analysis, structural-logical and functional approaches, analysis and synthesis, induction and deduction, econometric and hypothetical methods. This made it possible to present the labor market ecosystem in terms of its internal and external environments, which should interact organically but in reality often act contradictorily, hindering and distorting the development of the ecosystem. By studying the process of forming the labor market ecosystem, the authors obtained reliable data on the correlation between employment and such components of the ecosystem as the volume of capital investments, the volume of final consumer spending, the volume of exports of goods and services, and the share of credit money in capital investments. The article pays particular attention to the creation of conditions for the development of human potential as a core component of the labor market ecosystem. The authors substantiate the role and directions of implementation of the regulatory component of the ecosystem, which is capable of limiting chaotic fluctuations and ensuring the purposefulness of the ecosystem as a whole.

Keywords: Ecosystem, Employment, Labor market, Human potential, Regulatory function.

Introduction

The functioning of the Ukrainian labor market during the period of its independence has been characterized by numerous contradictions, imbalances, and mismatches between the level and structure of professional and vocational training of the workforce and the requirements of employers, and vice versa, between the number and quality of jobs and the expectations of employees, as well as the enormous scale of shadow employment. The Russian-Ukrainian war has greatly exacerbated these contradictions and revealed the inadequacy of traditional approaches to labor market regulation in the new reality. Previous regulatory practices were adapted to a labor-surplus model of labor market functioning, whereas under current

conditions, a labor-shortage model has emerged, caused by the emigration of many thousands of able-bodied persons and the conscription of young men into the Armed Forces of Ukraine. The employment sector is undergoing radical changes related to the digital transformation of the economy, noticeable structural shifts, and regional changes. This requires the development of new approaches to understanding current labor market trends and introducing new mechanisms and tools for its regulation. From the authors' point of view, an ecosystem approach to interpreting the theoretical and practical problems of the Ukrainian labor market is relevant, as it allows us to reveal the interrelationships between the components of its internal and external environment and to determine the appropriate directions of regulatory influence on its ecosystem.

The Purpose of the Study

The purpose of the article is to formulate the main criteria (characteristics) of the components of the labor market ecosystem, to identify the most influential of them on this basis, to reveal the mechanisms of their interaction, and complementarity, and to identify those that are subject to regulatory influence by public authorities.

Analysis of Recent Research and Publications

The ecosystem approach has been developing in global science since the end of the last century and the beginning of this century. Foreign scientists Gutl and Chang (2008), Baruch and Altman (2016); Williamson and Meyer (2012), Schlauch (2014) and Moore (1993), Ukrainian scientists Kolot, Lopushniak, Poplavska, Azmuk, Marchenko, Fedulova have made a significant contribution to the development of the methodological foundations of the ecosystem approach to socio-economic processes. It has been determined that the ecosystem of this sphere consists of many components (elements) between which there are stable interrelationships, close interaction and mutual influence, ensuring flexibility and adaptability to change. Each component of the labor market ecosystem creates its own ecosystem, which can include a wide variety of links. In this context, it is worth highlighting the publication by Azmuk (2018) which recognizes that the labor market ecosystem, in functional terms, encompasses the following ecosystems: the economic development strategy of the country, regions, and cities; the entrepreneurial ecosystem, the

ecosystems of “education, science, innovation” and “resources for labor”; the digital and infrastructure ecosystems (Azmuć, 2018). Shlaugh (2014) was one of the first to reveal the content of the labor market as an ecosystem, although, in our opinion, he narrowed its understanding by including only the unemployed, the employed workforce, and employers in the ecosystem, i.e., only the internal elements of the labor market. Moore (1993) in his work “Predators and Prey: The New Ecology of Competition”, made the assumption, with which we agree, that any company is part of a business ecosystem that intersects with many sectors of the economy, evolves towards innovation through cooperation and competition, satisfies consumer needs, and prepares for a new round of innovation (Moore, 1993).

Based on a general approach, Gutl and Chang (2008) rightly point out that the concept of an ecosystem, which encompasses its external and internal aspects, can be applied to any system. More detailed characteristics of the ecosystem are highlighted by Pickett & Cadenas (2002). In their opinion, an ecosystem has five characteristics: 1) the presence of living and non-living components, as well as an appropriate level of their aggregation; 2) temporal and spatial dimensions; 3) physical boundaries of the system; 4) the type and scale of connections and interactions between identified components; 5) limitations on the behavior of the system. They also argue that the ecosystem approach can be widely used in relation to people and the processes and structures they create (Pickett & Cadenasso, 2002). We used these ideas when defining the criteria (characteristics) of the components of the labor market ecosystem.

Revealing the essential characteristics of socio-economic ecosystems, Williamson and DeMeyer (2012) point out that such ecosystems require the coordination of many ongoing, organic, diverse, and complex relationships with many different types of parties. Unlike the expansion of established rules for managing bilateral relations, according to the authors, the ecosystem is regulated indirectly, rather than through direct negotiations, command, and control (Williamson & De Meyer, 2012). This approach contributed to the formation of our understanding of the essence and functions of the regulatory component of the labor market ecosystem.

At the same time, we have found an extremely limited number of works dealing with the application of the ecosystem approach specifically to the labor market. Meanwhile, it is obvious that the system of relations that characterizes the functioning and development of the labor market under modern conditions is turning into an ecosystem. The factors of such a transformation are the processes of globalization and integration of economic processes, the presence of multi-subjectivity and multidirectionality of managerial influences,

the diversity of their objects, the emergence of new needs and opportunities to ensure a dynamic balance in the labor market.

One of the few publications that examines the labor market ecosystem is a study by Baruch and Altman (2016). Researchers view the labor market through the movement of labor, career mobility, as part of a business ecosystem that achieves its goals by constantly balancing needs and requirements in line with changes in supply and demand. They consider the key characteristics of this ecosystem to be the interconnections, interactions, and interdependencies of all its components. The authors present a vivid allegory of the modern labor market as an ecosystem: employers and employees are no longer two sides of the same coin. Rather, it is a one-sided coin that is a playing field where all interested parties are present (Baruch & Altman, 2016). The structure of the labor force ecosystem includes employees from both the internal labor market of the enterprise and the external labor market, both actual and potential, both those who work directly at the company and those who are engaged in remote work.

However, despite the significant achievements of domestic and foreign scientists, there is still no agreed vision of the structure of the labor market ecosystem, approaches to identifying its components, defining their functions, and mechanisms of interaction. At the same time, these provisions are crucial for exerting a reasonable and targeted social influence on the labor market in order to minimize barriers that hinder its development and preserve flaws, shortcomings, and imbalances. We should agree with the opinion of Kolot et al. (2023) who emphasize that when taking an ecosystem approach to solving any problem, it is necessary to see not only the problem itself, but also the reasons for its occurrence, and to analyze the functioning of interrelated entities and their interaction. In our opinion, the processes taking place within the labor market, their direction and depth, are largely determined by the influence of the components of the labor market ecosystem, which is the result of the interaction of the components of the external and internal environment.

Method

In writing this article, we used the monographic method, quantitative and qualitative analysis, and statistical analysis. Correlation analysis was based on statistical assessment of the components of the labor market environment for 2000-2013, a period with relatively stable conditions. Besides, we analysed the period 2014-2021, characterized by unpredictable circumstances and incomparable data. We developed structural-

functional and ecosystem approaches, which made it possible to determine the interaction between the main components of the labor market ecosystem and to set conditions for its regulation.

Results and Discussion

Minimizing gaps, imbalances, and asymmetries accumulated in the field of employment is largely associated with the introduction of the principles and provisions of the ecosystem approach into the theory, practice, and state policy of the labor market.

A study of the work of domestic and foreign researchers, as well as the authors' own research, provides grounds for identifying the following main characteristics of the components of the labor market ecosystem:

- a focus on achieving recognized common values, priority goals, and objectives aimed at rationalizing the behavior of labor market stakeholders and enabling them to more fully realize their potential, abilities, and talents;
- the ability to respond positively to the influence of public authorities, to interact with other components of the ecosystem on the principles of cooperation, complementarity, interpenetration, information transparency, consolidation of efforts, and the creation of synergy for the sake of socio-economic progress and human development;
- the ability to co-evolve, adapt to constant changes both within the ecosystem and beyond its boundaries, and embrace innovative ideas and developments, as well as social, humanitarian, and technological achievements;
- a fairly high impact on processes occurring directly within the labor market and in the field of employment, as confirmed by a close correlation – with a correlation coefficient above 0.5.

To identify the main components of the labor market ecosystem and reveal the causal relationships between them, as well as their impact on employment processes, we consider it appropriate to use the methodological foundations of the modern understanding of common employment theories, as well as the results of our own research. Taking into account the existing state statistical base, we have selected a number of key components that meet the specified criteria and characterize: the volume of final consumption and new investments, the share of bank loans in capital investments, and the volume of exports of goods and

services. Naturally, the labor market ecosystem includes many other components whose impact on the labor market is difficult or impossible to measure in quantitative terms, such as labor market infrastructure and institutions, the match between jobs and the qualifications of the people who fill them, the level of support for entrepreneurship, and so on. Below, we will outline the reasons for including these indicators as important components of the labor market ecosystem and analyze their content and functions.

Capital investment as a component of the labor market ecosystem is essentially the cost of creating and restoring fixed capital, i.e., physical jobs that form the material basis of employment. Naturally, capital investments are also of great independent importance in connection with the need to reindustrialize Ukraine's economy on an innovative basis in the post-war period. However, in the context of this article, the emphasis is on capital investments as a means of creating physical jobs, a prerequisite for expanding employment.

The activation of investment from internal sources is linked to such a component of the labor market ecosystem as the banking system, which should play a leading role in business investment and, hence, in the creation of new jobs and the expansion of employment, as shown in Figure 1.

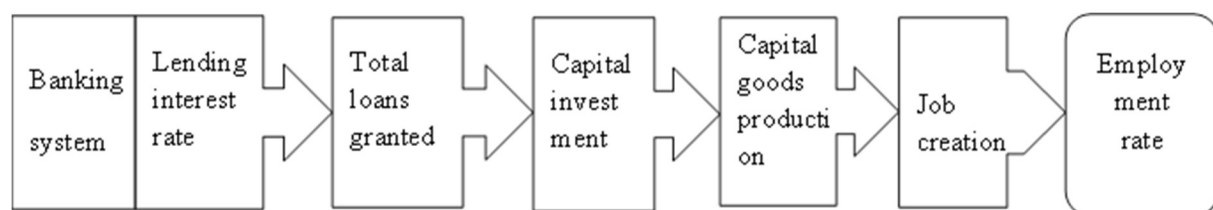


Figure 1. The chain of influence of the banking system on employment (author's version)

However, as can be seen from the data in Table 1, the share of bank loans in capital investments fluctuated on average around 8-10% and only exceeded 15% in certain years. For many years, the banking system of Ukraine worked mainly “for itself”: even in the stable conditions of the pre-war decades, its loans provided only a tenth of the total investment volume. Commercial banks preferred not to lend to businesses, but rather to engage in profitable and safe transactions with domestic government bonds, deposits in National Bank accounts, and foreign exchange transactions. In addition, Ukraine's banking system was vulnerable and unreliable. It was characterized by so-called “bank collapses” – bankruptcies that became acute in the mid-1990s, then in 2008–2009, and especially strongly in 2014–2017, when almost 90 commercial banks

were liquidated and tens of thousands of large depositors lost a significant part of their savings. Due to mistrust of the national banking system, authorities, law enforcement agencies, and courts, as well as for the purpose of “tax optimization,” businesses often transferred funds to other countries, particularly the EU and offshore jurisdictions. This behavior by domestic entrepreneurs served as a negative example for non-residents, who avoided investing in Ukraine's economy due to large and economically unjustified risks. Final consumer spending is also a component of the labor market ecosystem. Growth in consumption, which is driven by the population's monetary income, and thus growth in demand for labor, encourages entrepreneurs to meet this demand by expanding production and hiring additional workers (Fig. 2).

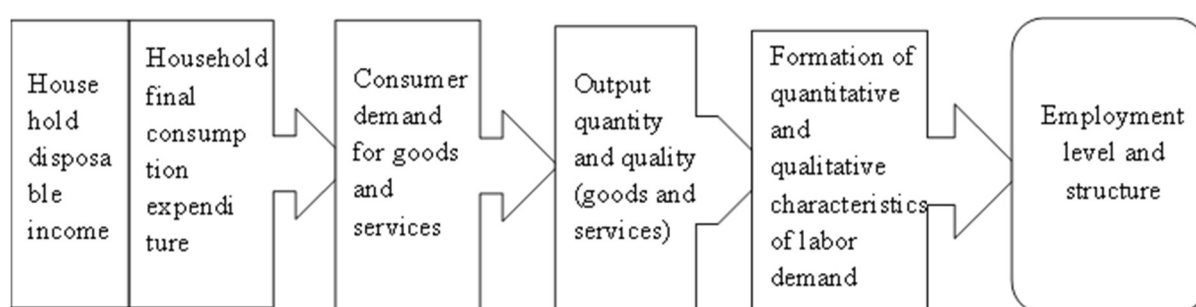


Figure 2. The chain of influence of household disposable income on the employment level

The next component of the labor market ecosystem is the export of goods and services. An increase in the volume of exports (all other things being equal) supplements domestic demand and influences the growth of consumption by foreign consumers, which stimulates producers to increase production and creates a need for additional labor (Fig. 3).

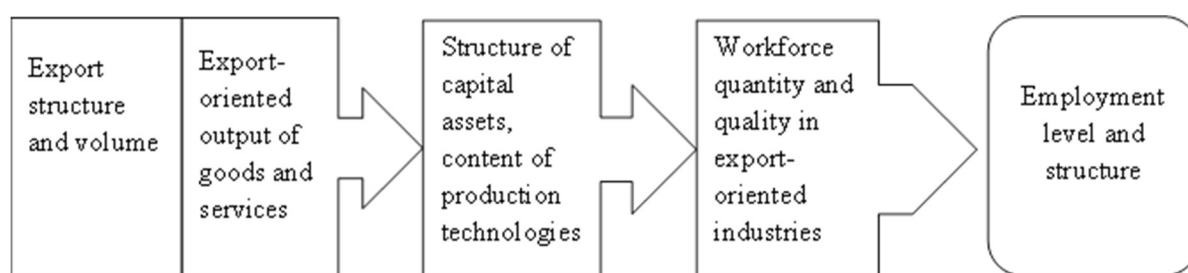


Figure 3. The chain of influence of exports of goods and services on employment level

To confirm our hypothesis regarding the components of the labor market ecosystem, we will establish the level of correlation between the level of employment and certain indicators that we have classified as

components of the labor market ecosystem. The correlation analysis covers 22 years – the period from 2000 to 2021. The data for the analysis was taken from the “Statistical Yearbook of Ukraine” for 2001, 2011, 2015, 2020, and 2022 (Table 1). Subsequently, starting in 2022, due to the full-scale Russian-Ukrainian war, these indicators, like many others, are not covered by state statistical observations. To ensure the objectivity of the calculation and the accuracy of comparisons, adjustments were made: capital investment indicators to the industrial producer price index; final consumer expenditure – to the consumer price index. To calculate these indicators in 2000 prices, the deflator for a specific year was obtained by sequentially multiplying the price indices for all previous years up to 2000 (the 2000 index is equal to 1).

Table 1. Dynamics of labor market ecosystem components and their correlation with employment

Years	Employment Rate (ILO, %)	Capital Investments (bln UAH, 2000 prices)	Final Consumption Expenditures (bln UAH, 2000 prices)	Exports of Goods & Services (bln USD)	Share of Bank Loans (%)
2000	55,8	26,5	129,0	18,1	1,7
2001	55,8	33,7	108,9	19,8	4,3
2002	56,0	39,0	117,7	22,0	5,3
2003	56,2	46,6	132,5	27,3	8,2
2004	56,7	57,6	148,0	37,9	7,6
2005	57,7	61,5	179,4	40,4	14,8
2006	57,9	75,2	206,9	45,9	15,5
2007	58,7	94,0	241,1	58,3	16,6
2008	59,3	84,8	261,7	78,7	17,3
2009	57,7	56,4	229,9	49,3	14,2
2010	58,5	46,7	248,4	62,8	13,7
2011	59,2	52,4	297,4	82,2	16,3
2012	59,6	57,2	322,0	82,4	17,1
2013	60,2	52,4	350,6	76,5	15,3
Correlation coefficient for the period 2000-2013 pp.		0,57	0,98	0,97	0,90
2014	56,6	39,3	320	64,1	9,9.
2015	56,7	35,9	257,2	46,8	7,6
2016	56,3	39,2	266,8	45,1	7,5
2017	56,1	38,7	271,3	52,6	6,6
2018	57,1	42,6	395,6	57,3	7,8
2019	58,2	44,1	441,9	64,1	10,8
2020	56,2	38,5	469,4	59,4	6,7
2021	61,8	34,4	577,2	79,3	5,0

Correlation coefficient for the period 2000-2021 pp.	0,42	0,57	0,80	0,59
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The results of the analysis show that for the period 2000-2021, the correlation coefficient between the level of employment and the amount of capital investment was 0.42, between the indicator of final consumer spending – 0.57, and the share of bank loans in capital investment was 0.59. These relatively low levels of correlation between the defined indicators may cast doubt on the strength of the relationship. However, we believe that the main reason for the low level of correlation between these indicators is related to the violation of the mandatory requirement for comparing indicators – “all other things being equal.” It should be noted that during this period (after 2014), a series of events took place that significantly affected the change in the specified indicators: the occupation of the Autonomous Republic of Crimea, the city of Sevastopol, and parts of the Donetsk and Luhansk regions. As a result, significant economic potential (approximately 20% of the national total) was lost. As a result of these events, the number of powerful enterprises, including exporters of industrial products, decreased, and a large number of small and micro-enterprises ceased operations. There was an internal displacement of a large number of people (over 1.5 million) to other regions of the country, most of whom were unable to find employment in their new places of residence.

In 2020, the labor market was also significantly affected by the consequences of the COVID-19 pandemic, which led to the closure of many small and micro businesses and self-employed persons, a decline in production, and a reduction in employment at other enterprises. Together, these external (to the labor market) factors led to a decrease in consumer spending, a drop in exports, a reduction in commercial bank lending for capital investments and their size, and a decline in employment, i.e., the indicators on which the correlation coefficients are based. However, during the period 2000-2013, the events analyzed above did not occur and did not put pressure on the labor market, did not distort the correlation between the level of employment and the size of capital investments, consumer spending, exports, and the amount of capital investment lending by commercial banks. Therefore, the degree of correlation between these indicators was 0.57, 0.98, 0.97, and 0.90, respectively.

At the same time, we explain the low correlation coefficient between the level of employment and the size of capital investments by the impact of the global financial and economic crisis of 2008-2009 and the change

in the methodology for calculating the number of employed people in 2009. As well as the pattern identified in previous studies as investment waves (Marshavin, 2018). The first wave is associated with the inflow of investment funds into construction and domestic enterprises that produce machinery, mechanisms, and equipment, which stimulates a fairly rapid increase in the number of physical jobs in these industries and sectors of the economy. The second wave of capital investment affects employment over a longer period of time. This inertia is associated with the employment of workers in new and modernized jobs at enterprises that produce final consumption goods and services, as well as in logistics and trade.

In Ukraine, in particular, the inertia of the positive response of the employment sector to investment in fixed capital manifested itself in 2005, 2008, and 2013 as a result of increased investment spending in 2004, 2007, and 2012, respectively. In addition, investment waves can partially overlap, which makes it difficult to determine the investment period that resulted in a change in employment. Naturally, the correlation under analysis decreases if equipment, machinery, and final consumer goods are not produced in Ukraine but are purchased abroad. Of course, the combination of these factors weakened the strength of the correlation between the volume of capital investment and the level of employment, which manifested itself in a sufficiently high correlation coefficient for both the period 2000-2021 and 2000-2013.

When analyzing investment processes, it is also important to identify its sources and priority areas. Under certain conditions, foreign investors could become the main real source of investment resources in post-war Ukraine. However, in order to attract them, it is necessary to overcome many long-standing obstacles, in particular to ensure reliable protection of the rights of owners (shareholders) and to achieve real results in the fight against corruption in government, law enforcement, and judicial systems. Under these conditions, the governments and corporations of the European Union, the United States, and other countries, as well as international financial institutions, can participate in the implementation of large-scale investment projects in Ukraine. At the same time, attracting external creditors does not exclude, but rather highlights the need to increase the efforts of Ukrainian authorities at all levels, business structures, and civil society aimed at mobilizing internal investment resources, which also serves as a signal to external investors.

The state monetary policy during the post-war recovery period should focus on preventing fraud and risky operations by commercial banks, orienting the banking system towards lending to the real sector of the economy and innovation, building trust in the Ukrainian banking system among entrepreneurs, the population, and non-residents, and ensuring the availability of credit resources. Investment should be

focused on high value-added industries, as well as science and research. The international community has recognized the minimum acceptable level of funding for research and development as 2% of GDP, while in Ukraine it was only 0.4-0.5% throughout most of the 2000s (*State Statistics Service of Ukraine **SSSU**, 2020*). In the post-war period, it is necessary not only to increase the volume of funding for scientific research and development, creative development, including by the state, but also change the algorithm of this funding. In particular, it is advisable to move from state maintenance of scientific institutions and departments (except those engaged in fundamental research) to a grant-based model of their functioning.

Despite the fact that nominal wages, as the basis for the population's purchasing power, grew in the 2000s, high inflation rates prevented this from leading to a symmetrical increase in physical consumption. The average real wage during this period was several times lower than in neighboring EU member states, and its share in GDP in 2021 was 43.8%, while in European countries that were formerly socialist, it was: Bulgaria – 51.3%, Lithuania – 52.5%, Latvia – 57.3%; Poland – 47.3; Slovakia – 53.3; Czech Republic – 56.3%; Estonia – 56.4% (UNECE, n.d.). Optimization of such a component of the labor market ecosystem as final consumer spending should be linked to an increase in household incomes, primarily those of employees and pensioners (these categories do not usually transfer funds abroad) and a reasonable reduction in utility bills, the cost of electricity and other energy carriers for the population, medical services, and medicines.

As can be seen from Table 1, the correlation coefficient between export volume and employment level is very high – 0.97. However, it should be noted that despite the steady growth in export volume in the 2000s, ferrous metals, primary and intermediate products dominated its structure, and from the second decade of the 2000s – agricultural products: in 2007 – 13%, in 2012 – almost 25%, in 2021 – 53% (SSSU, 2022). At the same time, very few science-intensive and high-tech products were exported in the electronics and electrical engineering, mechanical engineering, and metalworking industries, as well as in the light and food industries. This export structure had a negative impact on the demand for skilled labor and the structure of employment. As a result of the Russian-Ukrainian war, due to the destruction of a significant part of export-oriented economic entities and the occupation of territories where many such enterprises are located, a decrease in the volume of industrial products in exports should be expected in the near future, and therefore a reduction in the demand for industrial workers. To improve the processes and increase the role of this component in the labor market ecosystem, it is necessary to stimulate exports, which should be based primarily on the production of high-tech, competitive products with high added value.

We have identified entrepreneurship as an important component of the labor market ecosystem, as its development creates jobs, increases the purchasing power of the employed population, and fills budgets and state social funds. Small businesses play an important role in expanding the role of the entrepreneurial component in the labor market ecosystem. In addition to the significant impact of small businesses on employment indicators, they also play an important role in personal fulfillment, achieving economic independence, continuing (starting) family traditions of entrepreneurship, and the opportunity to receive (transfer) a significant inheritance. Employment in small businesses during the period under review accounted for about 30% of the total employed population, taking into account the number of individual entrepreneurs.

At the same time, the importance of small businesses in the labor market ecosystem should not be exaggerated. We disagree with researchers who attribute to it the role of the “locomotive of the economy” (Vashchenko et al., 2008), a panacea for all economic woes – declining production, unemployment, inflation, etc. Small businesses have a number of inherent flaws: low labor productivity (which, according to our calculations, is 1.5-2 times lower than in medium and large businesses); the complexity of implementing costly innovative technologies; and the virtual impossibility of conducting effective marketing research and advertising activities.

In our opinion, increasing the role of entrepreneurship in the labor market ecosystem during Ukraine's recovery phase requires, first and foremost, improvements to the institutional environment, in particular the legislative definition of the scope of state bodies, the frequency and procedure for conducting inspections, and restrictions on law enforcement interference in business. Taking into account the expansion of the powers and financial capabilities of local communities and relevant authorities in accordance with the 2015 reform (*Verkhovna Rada of Ukraine*, 2010), in order to develop the labor market ecosystem, as we noted in previous publications, it is necessary to improve infrastructure support for small businesses at the local level, in particular, to stimulate the creation of business incubators, training centers, and leasing resources in cities, towns, and villages (Marshavin & Kytsak, 2023).

A key component of the labor market ecosystem is human potential, the quantitative and qualitative composition of the workforce (Petrova et al., 2022). The importance of professional competence, production and social experience, and creativity of employees is growing in the context of the reindustrialization of the domestic economy based on Industry 4.0 technologies and its digitalization. In the

era of digital transformation and the spread of non-standard forms of employment, including platform-based employment, entrepreneurs require employees to have high professional competence, flexible professional skills, significant professional and territorial mobility, and creativity (Fig. 4).

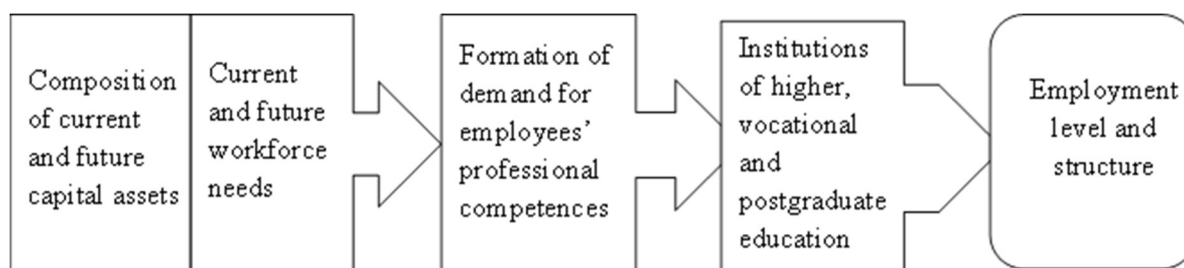


Figure 4. Chain of influence of professional competencies and other qualities of the workforce on the level and structure of employment – the professional competence component of the labor market ecosystem

We proceed from the assumption that the labor market ecosystem should primarily include those components (elements) that have stable links with it and interact with many other components. Moreover, each component can be considered both a component of the labor market ecosystem and a separate ecosystem. These ecosystems can intersect and interact, figuratively speaking, creating a three-dimensional structure. Together, they form a specific environment. As a result of the synergistic interaction of different levels,

The diverse and varied components form a complex synthesis – a three-dimensional dynamic structure that influences the labor market and determines the content and direction of the processes taking place, as well as the quantitative and qualitative parameters of employment. Improving the structure and content of the components of the labor market ecosystem, strengthening their organizational interconnection, interpenetration, and coordination contributes to achieving higher productivity of human, natural, economic, and intellectual factors of production.

The competitiveness of enterprises and the national economy as a whole is determined by the interest of employees in the results of production activities, in particular, in the high profitability of enterprises. However, these requirements contradict the low motivation of hired workers to work, which has prevailed in Ukraine in recent decades. This has led to widespread shadow employment and large-scale external labor

emigration. Most likely, in the post-war period, due to the high cost of housing and utilities compared to the size of legal incomes in Ukraine, difficulties in finding suitable work, and domestic discomfort, it can be expected that not all migrants will actually return to Ukraine from abroad.

According to a study by the Center for Economic Strategy, many of those who previously expressed their intention to return are reconsidering their decision and are inclined to continue staying abroad. Thus, when asked, “Do you plan to return to Ukraine?”, 41% of respondents answered affirmatively in May 2023, 26% in January 2024, and only 20% in December 2024 (*Centre for Economic Strategy*, 2025). This means that, most likely, no more than 1.0-1.2 million working-age people will return, and this number will continue to decrease as the migration period continues, since migrants find work abroad, solve problems with their children's education, and form new social ties. These factors will also hinder the attraction of foreign migrants to the country. At the same time, emigration sentiments within the country will intensify, leading to a reduction in the quantity and deterioration in the quality of human resources, as well as a shortage of certain professional groups of workers.

In the context of dynamic changes in technology and techniques, the dynamic development of employees' professional competencies through the formation of a need for lifelong learning is of particular importance. This necessitates the expansion and improvement of national, sectoral, and corporate systems of postgraduate education and professional training. We are confident that in the post-war period, the development of human potential as a component of the labor market ecosystem should be linked not only to wage growth, but also to moral and ethical factors – respect for employees as equal participants in the production process, their ability to participate in the management of enterprises, the distribution of profits, and the receipt of their share. In this context, it is advisable to legislate a provision on the mandatory membership of employees in the management and supervisory boards of all types of business entities.

In our opinion, there is also every reason to talk about the key role of the regulatory component of the labor market ecosystem. In our opinion, it is wrong to consider the labor market ecosystem to be completely similar to biological systems that are prone to self-development. The labor market ecosystem needs public regulation in order to minimize the negative consequences of spontaneous self-regulation. A purely market-based mechanism is unlikely to ensure compliance with the principle of “human dimension” (“human-centeredness”) introduced into the concept of social ecosystems by Kolot (2024). It is also insufficient to limit oneself to James Moore's advice on protecting individuals involved in the struggle between ecosystems.

In his opinion, “society must find ways to help members of dying ecosystems move to more viable ones, avoiding the temptation to support failed ecosystems” (Moore, 1993). We are convinced that without the regulatory role of public authorities, the labor market ecosystem is unable to ensure: first, the constant reproduction of a workforce of the appropriate quality (general education and qualification characteristics, level of working capacity, physical and mental health, moral and volitional qualities); secondly, rational use of labor (productivity and content of work, job satisfaction, workplace democracy, opportunities for professional growth); thirdly, adequate social protection for the unemployed and additional assistance in finding employment for certain categories of citizens, in particular women, young people, people with disabilities, etc.

We should agree with the opinions of V.V. Blyzniuk and L.P. Huk, who rightly link the problems of the Ukrainian labor market with “failures” in its state regulation (Blyzniuk & Huk, 2021), and Azmuk (2018), who reasonably notes that the Ukrainian labor market ecosystem lacks effective communication and well-established interaction between its elements (Azmuk, 2018). In this context, the scientific provisions formulated by representatives of the first generation of supporters of the ecosystem approach in economics, Williamson and De Meyer (2012), are of fundamental importance. In their opinion, ecosystems require “coordination of diverse and complex relationships with many different types of systems” and should be coordinated and regulated indirectly, rather than “through direct command and control” (Williamson & De Meyer, 2012). We believe that regulatory influence on the components of the labor market ecosystem should be exercised by public authorities through the formation of sound regulatory mechanisms and instruments and ensuring their proper coordination. However, the system of regulatory instruments of public authorities, which includes normative and legislative acts, state and public institutions, infrastructure and intermediary organizations, which was formed in Ukraine in the 1990s and early 2000s, needs radical reform. Although in the post-war period, the main regulatory function of public authorities will be to counterbalance the negative effects of spontaneous market forces and to restrain them.

During Ukraine's recovery phase, an important function of public authorities is to ensure the consolidation and coordination of the efforts of all components of the labor market ecosystem, directing them towards the common goal of productive employment and decent work based on a combination of regulation and self-regulation mechanisms. The synergy of the labor market ecosystem will contribute not only to the digital transformation of Ukraine's economy during the Fourth Industrial Revolution, but also

to expanding the opportunities for workers to realize their abilities and talents in the social and labor sphere, as the foundation of a people-oriented society.

In the regulatory component of the labor market ecosystem, it is necessary to improve the role of its information support. It should be emphasized that this is not so much about the development of technical aspects of IT and cloud technologies, but above all about the operational provision of labor market participants with complete and reliable primary (input) information. Throughout the entire period of market reforms in Ukraine, state statistics, including information from employment centers, have contained no more than a third of the actual vacancies and job seekers. It should be added that surveys of household economic activity using the methodology of the International Labor Organization (the main source of factual data on the labor market) are conducted only at the regional level and do not cover the primary link – settlements and administrative districts. As a result, employees do not have objective data to optimize their behavior in the labor market, and employers and local authorities do not have objective data to make informed management decisions. The information component of the labor market ecosystem should help overcome the fragmentation of processes and trends in the field of employment and the low information transparency of labor market institutions.

In the era of globalization, the Ukrainian labor market is significantly influenced by international institutions (in particular, the International Monetary Fund, the World Bank, the International Labor Organization, and the International Organization for Migration), the governing bodies of the European Union, and its specialized institutions. The implementation of the function of regulating the national labor market, its means and instruments in the context of globalization, becomes dependent on a large number of variable factors that are beyond the influence of the Ukrainian state and Ukrainian institutions. This It primarily concerns global institutional and economic components: customs tariffs, quotas, phytosanitary regulations, and other barriers to exports, rules for concluding international trade agreements, foreign investment, and lending. Together, these form the global external shell of Ukraine's labor market ecosystem, which, using a variety of tools, influences the corresponding components of Ukraine's labor market ecosystem. This requires national institutions to thoroughly analyze global and European phenomena and trends in the socio-economic sphere, take them into account when designing public regulation tools and instruments, and constantly improve them.

Study Finds

The study found that the formation of Ukraine's labor market ecosystem is determined by the interaction of a number of key components, among which capital investment, final consumer spending, exports of goods and services, entrepreneurship development, human capital, and the regulatory function of public authorities are of particular importance. Correlation analysis showed a close relationship between the level of employment and these indicators during the relatively stable period of 2000–2013, confirming their decisive role in shaping employment. At the same time, the events of the last decade – economic crises, the pandemic, and war – have significantly distorted these links, highlighting the need to strengthen the regulatory component and create conditions for the development of human potential as the core of the labor market ecosystem. The results obtained indicate the advisability of combining mechanisms of state regulation and self-regulation of the labor market to achieve a synergistic effect, increase its stability, and ensure decent work in the context of modern transformations.

Conclusions

Overcoming the imbalances and asymmetries of Ukraine's labor market, which have resulted from years of mistakes in state socio-economic policy and have been significantly exacerbated by the shocks and destructive processes caused by the COVID-19 pandemic and Russian military aggression, is primarily associated with the implementation of the conceptual principles and provisions of the ecosystem approach in economic policy and business practices.

The labor market ecosystem encompasses many components that establish stable interconnections and complementarities, ensure flexibility and adaptability to changes, and generate a synergistic effect. Moreover, the components of the ecosystem form their own ecosystems (chains), which may intersect and interact, figuratively speaking, creating a three-dimensional (3D) structure. As a result of the synergistic interaction of multilevel, multidirectional, and diverse ecosystems, a complex synthesis is formed – a dynamic three-

dimensional structure that influences the labor market, defining the content and direction of processes, as well as the quantitative and qualitative parameters of employment.

The identification and definition of the functions of labor market ecosystem components and the disclosure of their interaction mechanisms make it possible to apply targeted regulatory influence by public authorities and social institutions aimed at overcoming defects and disproportions in the employment sphere and facilitating Ukraine's accelerated innovative recovery. The correlation analysis carried out, along with the use of research methods such as theoretical generalization, induction and deduction, abstract-logical reasoning, econometric and hypothetical approaches, supported the justification of key identification features and the definition of labor market ecosystem components. These include the volume, structure, and direction of capital investment, final consumer spending, exports of goods and services, commercial bank lending for capital investment, and the system of public labor market regulation.

The successful reindustrialization of Ukraine's economy and the application of Industry 4.0 technologies will largely depend on the key component of the labor market ecosystem – human capital, particularly workers' professional competence, production and social experience, creativity, and interest in the outcomes of production activities. The content of employee motivation is becoming increasingly relevant, especially in the context of the development of industrial democracy – employees' opportunities in both material and non-material spheres. The development of the labor market ecosystem, especially the implementation of the principle and fundamentals of "human dimension", requires improvement of its regulatory component, the essence of which lies in the public determination of development priorities, ensuring and coordinating the functioning of ecosystem components, creating counterbalances to spontaneous market forces, and restraining them while preserving mechanisms of internal self-regulation.

Recommendations

It is advisable to strengthen the role of the state in creating a favorable institutional environment for investment and entrepreneurship development, orienting the banking system toward supporting the real sector. It is necessary to stimulate exports of high value-added products, increase household incomes to boost domestic demand, and invest in human capital development through education, professional retraining, and innovation. An important condition is to improve information transparency and

communication between elements of the labor market ecosystem, which will contribute to its sustainability and balanced development.

Scientific Ethics Declaration

* The authors declares that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

Conflict of Interest

* The authors declare that they have no conflicts of interest.

Funding

* Project no. MEC_SZ 149231 has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the MEC_24 funding scheme.



Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Management Economics and Business (www.iconmeb.net) held in Budapest/Hungary on August 28-31, 2025.

* The authors would like to thank the conference organizers for providing them with the opportunity to present their research to the wider scientific community.

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