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E-SOCIAL WORK AS A NEW FORM OF PROVIDING SOCIAL SERVICES IN SLOVAKIA

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Abstract. E-social work is a modern approach to providing social services through information and communication technologies (ICT). Digitalization and technological progress create new opportunities for more effective communication with clients, monitoring their needs and coordination between professionals and institutions. Electronic platforms not only enable faster provision of assistance but also expand the reach of services, thus opening up space for innovation in social work. The rise of e-social work was driven by the COVID-19 pandemic, which necessitated the rapid adoption of digital solutions to maintain social services despite restrictions on personal contact. While international research increasingly explores the digital transformation of social work, empirical studies on this topic remain scarce in Slovakia. This study aimed to assess the status of e-social work implementation in Slovakia and explore social workers' perceptions of this new practice. A quantitative cross-sectional study was conducted targeting social workers in the social service sector with experience in e-social work. Data were collected via an online questionnaire distributed through the Survio.sk platform between September and December 2023. The questionnaire included 18 items, both closed and open-ended, focusing on the advantages, disadvantages, and thematic scope of e-social work. Responses were analyzed using descriptive statistics in SPSS ver. 24.0. The study provides insights into how e-social work is perceived and practiced in Slovakia, contributing to the broader discourse on digital transformation in social services.

Keywords: e-social work; digital transformation; social services; perception of social workers; quantitative research

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1. Introduction

Globalization and technological change - processes that have cyclically accelerated over the past fifteen years - have created a new global economy that is technology-driven, information-driven and knowledge-driven. Information and communication technologies (ICT), which include radio and television, as well as newer digital technologies such as computers, the Internet, mobile phones, are described as potentially powerful tools for enabling change and reform not only in education but also in the sphere of social service provision in the 21st century. Information and communication technologies (ICT) is an extended term for information technology (IT), which emphasizes the role of communication and the integration of telecommunications, computers and the necessary software, middleware, storage and audiovisual systems that allow users to access, store, transmit and manipulate information. ICT competence means having the technical and cognitive skills to appropriately access, use, develop, create and communicate information using technological tools.

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Historically, the earliest mentions of the use of modern technology in social work date back to the 1980s, when online support groups were documented. In the late 1990s, social workers began using information technology, including the internet and professional websites, and connecting through online chats (Reamer, 2015).

2. Review of literature

Cwikel and Friedmann (2019) talk about four generations of the establishment of information and communication technologies in social work. The first generation, during the 1980s, is associated with the use of computer databases for statistical purposes. In the late 1980s and throughout the 1990s, the second generation introduced expert systems, computer-assessment programs, therapeutic games, and treatment programs. The third generation, in connection with the development of the Internet, uses e-therapy and e-health to provide psychological interventions, health care, and psychoeducation. At the same time, social workers communicate with clients online or use web-based treatment programs. The fourth generation is characterized by advanced technologies such as therapeutic simulation programs, games, and 3D virtual environments.

The world of the 21st century is increasingly characterized by robotization and technologization of individual professions. ICT has caused a revolution in almost every area of society. Although social work in its activities and the social services offered is not directly threatened by replacing the position of a human social worker, within the framework of the best possible availability of social services it is affected by digitalization and some social services are becoming available within the framework of e-social work (Robles & Cano, 2019; Bruni et al., 2020; Aguilar-Idañez et al., 2020; Cavlak et al., 2026).

The COVID-19 pandemic period has globally accelerated this process. Social work methods in an online environment have also begun to be applied in the field of social work (Kapur et al., 2025). In Slovakia, we are also already recording efforts of cybersocial work, mainly in online counseling. ICT has gradually penetrated the field of social work over the years, eventually becoming an indispensable part of it (Afrouz & Lucas, 2023).

In addition to software and information systems, distance counselling is also used in Slovakia to make life easier for many people in difficult situations and crises. These are not applications directly related to and used by social workers, but they can help social clients with attacks of panic, anxiety, feelings of threat, depression (e.g., Nepanikar.sk).

As Markovič (2022) states, social workers have been using e-mails, electronic case reports, online resources for professionals, online education, assistive technologies intended for the blind, social networks, various software for working with information and data for a long time in the context of digital technologies. The author further states that, as of December 2021, some digital communication channels were already in use in Slovakia, as listed in Table 1.

Table 1 Digital communication channels in social work in the Slovak environment

Communication channel	Link
Online consulting (phone, chat, email, Skype, forum)	https://www.linkadeti.sk/domov/
Telephone counseling	https://linkanezabudka.sk/
Video counseling	https://www.vztahoveporadenstvo.sk/copy-of-podpora-v-rodicovstve
Cybertherapy	https://notalone.sk/
Self-service web interventions	https://www.union.sk/union-dusevne-zdravie
Social networks	https://www.facebook.com/ipcko
Mobile or computer applications	StressHelp

Source: Markovič (2022, p.31)

Abroad, the situation is much better, with a wide range of applications available that are directly intended for social workers, social work students or for diverse client groups (e.g., Caretivity, The Savy Social Worker, Social Work Mentor, DMS-5 etc.) (Vašková, Lovašová 2021; Neeraj & Nirmala, 2025).

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Telephone communication for people with social problems is currently being replaced by online chat, which is considered synchronous communication because it takes place in real time. Reamer (2015) states that some social workers use avatars, digitally created graphic images, in individual or group counseling services. The online space offers a number of questionnaires focused on various social problems. Based on the answers, participants receive electronic feedback generated by artificial intelligence software and, if necessary, the service of a clinical social worker (Reamer 2015).

E-social work is becoming a new specialization in a dual sense: as a specific area for professional intervention and as a cross-cutting area that affects the lives of people, groups and institutions, as well as the professional activities of social workers (through e-government, interventions using new technologies to solve traditional social problems that are redefined in the technological environment).

Within the framework of e-social work, it is about providing social services such as "distance counseling also referred to as e-therapy, cybertherapy, web counseling or cyber counseling... treatment of addictions, social support for various groups, one of which is the group of patients with chronic diseases" (Tóthová & Žiaková, 2018, p. 3).

In their paper, Almáši and Šavrnochová (2020) refer to social work conducted with clients in cyberspace via digital technologies as cybersocial work, defined as online contact between a social worker and a client. We agree with Markovič (2022), who states that e-social work is not a new, separate field of social work, but that information and communication technologies and the online environment enable the modification of social work's methods, forms, and techniques.

Berzin et al. (2015) point out that technological innovations in social work are not only about products and platforms, but also about integrating these changing products to meet social work goals. Various technologies can be used in ways not previously considered: mobile technologies, social media, robotics, and games, including gamification, offer ways to change how social workers understand and intervene in social problems in the 21st century. There are technologies yet to be discovered that could one day be integrated into social work to solve problems. On the other hand, the authors emphasize that the use of digital technologies provides a way to prepare social workers for today's clients. The integration of multiple technology platforms into the training space prepares social workers to practice with people whose relationships are ultimately completely influenced by technology (Berzin, 2015). However, the digital impersonal environment can cause insufficient perception of non-verbal communication, body language, and lack of sensory experience, which can result in overlooking hidden risks, for example when communicating with children or in cases of domestic violence. These reasons only confirm that e-social work is not suitable for all situations.

Tóthová and Žiaková (2018) also point out that the online way of communication, with its poorer and sterile form compared to personal communication, can cause loneliness, depression and weakening of social ties.

López Peláez and Marcuello-Servós (2018) identify opportunities to transform social work in the digital realm, particularly through new digital intervention strategies, as a number of new digital procedures have opened up a wider range of research, therapies, interventions, and social networks.

Giffords (2009, in Vašková & Lovašová, 2020) sees new technologies as a potential to encourage and build global communities of social workers who can share information with foreign colleagues, and can help their clients make contacts in communities with similar interests.

We agree with Markovič's (2022, p. 33) assertion that gradually, even in the non-pandemic period, a "hybrid work model, in which workers spend part of their working time in the office and part working from home.... digital technologies will also become an essential and irreversible element of social work practice, which will also need to be understood as a hybrid practice, integrating digital practices, such as video calls, chat and self-service web interactions, with face-to-face interactions. "The main benefits of online social services include their temporal, geographical and financial availability (Tóthová, Žiaková, 2018).

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Berzin et al. (2015) perceive the benefits of e-social work for society as being flexible and on-demand services or personalized services with an individual pace. At the same time, they point out the possibility of assessing a social problem in real time, immediate intervention and feedback. On the other hand, two main problems are visible in implementing information and communication technologies in social work, namely the digital divide at the level of regions and individual households and digital literacy, or illiteracy. Digital literacy is a typical feature of the younger, educated, qualified, socially strong and urban part of the population. On the contrary, the economically inactive, lower qualified, socially weaker and rural part of the population (retirees, unemployed) is characterized by a higher representation of the digitally illiterate.

Other significant risks of using digital technologies in social work include that it can lead to loss of identity, loss of classic skills, loss of freedom or the emergence of risky forms of behavior such as improper lifestyle, false identity, cyberbullying (Vašková & Lovašová, 2021).

Wilkerson and O'Sullivan (2023) present areas within the framework of developing digital social work in view of the COVID-19 pandemic measures. Figure 1 presents their digital practice map, grounded in social justice as a core value of social work. Social justice is applied in this map through digital equality and the more recently developed principle of data justice. The ethical standards of digital equality and data justice represent social justice of access to technology as a human right. In addition to accessibility, digital justice encompasses digital literacy and digital citizenship.

The authors of the Digital Social Work Map Wilkerson and O'Sullivan (2023) have identified six practice areas:

- Support - associated with the rise of social media, such as Facebook, YouTube, Twitter. These online support groups operating on social media sites are a rapidly developing and expanding area of digital practice. Sometimes called “virtual communities,” they are thematically diverse but share a common focus on managing stress and uncertainty. The growth of online support is based on information and the ease of development and use of communication technologies. Online support systems, operated through a variety of inexpensive and readily available synchronous and asynchronous technologies, provide a means to specialize in topics that would be largely unavailable in an in-person setting.
- Identity - the foundation of identity-based social action is self-concept, which involves integrating our personal and social identities. Developing a sense of self can be a lengthy process and a significant struggle, especially for members of oppressed and vulnerable groups. Identity-based social action focuses on using community action to achieve social justice for individual or cross-sectional aspects of self-concept that have been threatened, challenged, or otherwise negatively impacted by the dominant community.
- Community or community action is defined as collective action by community members, drawing on the power of numbers, participatory processes, and indigenous leadership, to reduce power differentials and achieve shared goals of social change. Online community actions and initiatives are influenced by social work values that focus on macro-level change.
- Psychotherapy is on the map for social work digital practice based on the urgent need to restore behavioral practice after the pandemic lockdowns of 2020.
- Education is on the map because of its importance in training for digital practice within the e-social work methodology and strengthening the necessary digital skills.
- Psychoeducation is being developed for digital practice to apply elements of digital individual and digital group work within a social problem-solving model (Wilkerson & O'Sullivan, 2023).

If information and communication technologies within e-social work are "used carefully and effectively, they can improve various methods of social work (for example, service provision, education and research)" (Vašková & Lovašová, 2021, p. 21), however, it is necessary to pay attention to ethical principles and a code of ethics (Banks et al., 2025).

3. Methodology of Research

The boom of e-social work occurred during the COVID period, when pandemic measures limited personal contact in individual spheres of society to a minimum. It was necessary to find methods and forms for

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communication and solving clients' social problems. One of the options was to use the online space to provide counseling, therapy and other social services. Abroad, more and more research is devoted to the digital transformation of individual services, including social work, brought about by the COVID-19 pandemic. In the context of Slovak social work, we find fewer empirical works on the described issue.

These facts were the motivation for conducting a nationwide study, the aim of which was: 1. to examine the status of the implementation of e-social work in the conditions of the Slovak Republic, 2. to determine the perception of e-social work as a new practice of social work among social workers working in social services.

Materials and methods

The research methods are based on a quantitative design. We present selected aspects of a descriptive cross-sectional study of subjective experiences and perceptions of e-social work by Slovak social workers in social services. We considered all social workers working in the network of social service providers in Slovakia as the basic set. The sample set consisted of social workers with experience in e-social work. Individual social service providers in Slovakia were approached during the selection process.

Data collection was carried out using a self-constructed questionnaire. We used a questionnaire created on the Survio.sk platform to reach as many social service providers with experience in e-social work as possible through the online space. We asked the Central Office of Labour, Social Affairs and Family in Bratislava, the Slovak Republic, for approval of the research and assistance in distributing the online questionnaire. We collected data in September - December 2023 via the Survio.sk platform.

The questionnaire contained 18 items, both closed- and open-ended. Some items were in the form of an ordinal scale, allowing responses on a 5-point or 4-point scale. The items aimed to identify the advantages and disadvantages of e-social work and the topics or social problems the respondents addressed through it. Since e-social work is a new form of social work, we also included open-ended questions in which respondents stated their own perceptions of e-social work compared with social work in direct contact. We thus obtained a clear picture of social workers' views on e-social work in the Slovak Republic. Given the partial nature of this study, we will not present the answers to all questionnaire items. For publication, we analyzed the obtained data using descriptive statistics in SPSS ver. 24.0.

Results

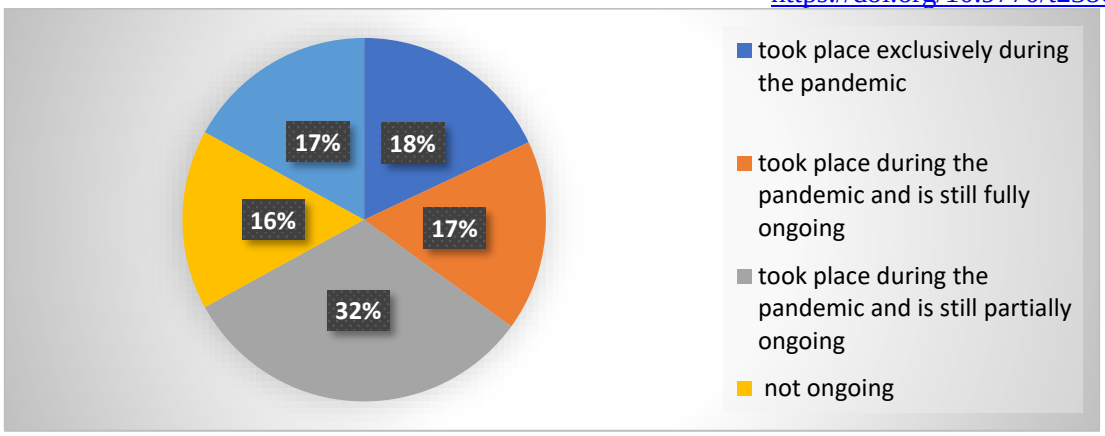
A total of 252 respondents participated in the research conducted via the Survio.sk platform and completed an online questionnaire. Data collection was conducted electronically, enabling a wider range of participants and ensuring the anonymity of responses. This method of administering the questionnaire also contributed to faster processing of the obtained data.

The gender structure of the researched set was significantly dominated by women, who accounted for 225 respondents, representing 89.3% of the total. Men were represented at 27, i.e., 10.7%. Given this significant imbalance in the representation of the sexes, the comparison of the results by gender is not sufficiently relevant or statistically balanced.

The average age of the respondents was 44.3 years, with a standard deviation of 9.736, indicating a relatively variable age distribution in the research sample. The largest group was women aged 41 to 50, specifically 74 respondents. The research sample was therefore concentrated in the middle-aged category.

We investigated the status of e-social work implementation in Slovakia, focusing on its continued use in social service facilities even after pandemic measures. Graph 1 describes the analysis of responses in relative frequencies.

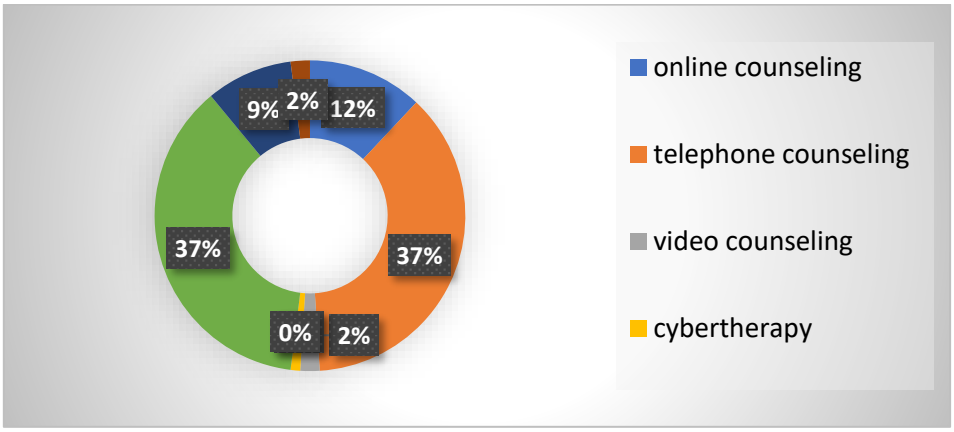
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Graph 1. Implementation of e-social work in social service facilities according to respondents
Source: own processing by the authors

The findings describe that e-social work is gradually becoming known and commonly used in everyday social work. 44 respondents (18%) stated that e-social work was used in the given social facility only during the COVID-19 pandemic, when personal contact was limited, and 43 respondents (17%) indicated that e-social work was carried out during the pandemic period and continues to be fully implemented at present. 81 respondents (32%) had experience with e-social work during the pandemic, and e-social work is also currently implemented to a limited extent at their social service facility. A total of 168 (67%) noted the implementation of e-social work in the provision of social services.

In Graph 2, we describe the results of the analysis of the item that determines which information and communication channels and forms of e-social work respondents use or have experience with.



Graph 2. Forms of e-social work used by respondents
Source: own processing by the authors

Respondents could mark more than one option in the offered options. The results show that telephone counselling and e-mail form of communication dominated. Online counselling was marked by 71 respondents (12%), and text messages were used by only 56 respondents. Other forms are used by respondents only to a small extent for immediate communication with a social client.

We achieved objective 2 by analyzing the answers in open items aimed at identifying the advantages and disadvantages of e-social work from the respondents' perspective. Based on the answers, we classified the respondents into three groups: in the 1st group were respondents who have experience with e-social work, especially during the pandemic, and perceive certain advantages for selected groups of the population. In the 2nd group we included the answers of respondents who criticize e-social work and do not perceive it as a suitable form of social work since there is no personal direct contact. The 3rd group of respondents has no personal

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experience with e-social work and cannot assess its advantages, disadvantages and provide suggestions for improving the conditions for e-social work.

Based on a qualitative analysis of individual responses, we created Table 2, which describes the advantages and disadvantages of e-social work. We ranked the responses by frequency. 14 respondents (6%) stated that they do not see any advantages of e-social work, and 21 respondents (8%) stated that they prefer personal contact, i.e. e-social work does not suit them.

Table 2. Advantages and disadvantages of e-social work according to respondents

ADVANTAGES OF E-SOCIAL WORK	DISADVANTAGES OF E-SOCIAL WORK
speed of provision	absence of personal contact
time flexibility	. insufficient equipment and internet connection
accessibility (no need to go to the office)	insufficient digital skills of clients
safety (protection from illness, protection from aggressive clients)	misunderstanding, lack of understanding on the part of the client
financial savings 5. indifference and reluctance of the client	financial savings 5. indifference and reluctance of the client
efficiency	misuse of personal data
home environment (client openness, sense of security)	cyberbullying
recording of the information provided	I don't see any benefits of e-social work
recommendation of electronic links to find more information	I prefer personal contact, e-social work does not suit me
provision of multiple clients	

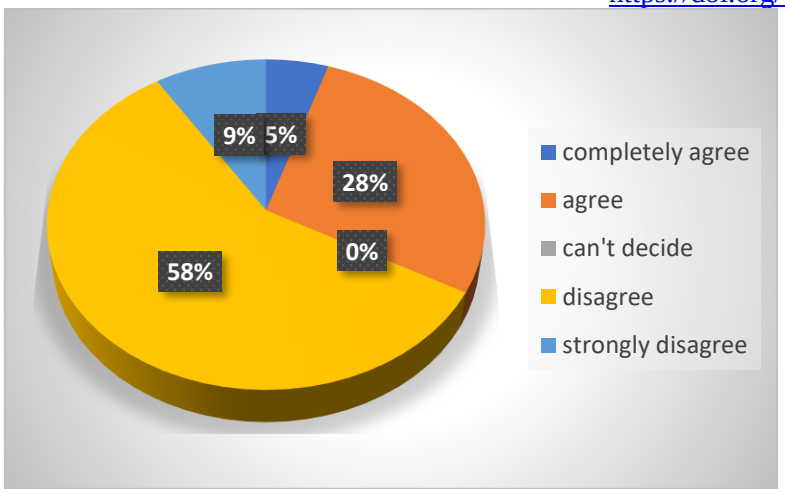
Source: own processing by the authors

Table 2 clearly summarizes the advantages and disadvantages of e-social work reported by respondents. The most frequently identified benefits include the speed of service provision, time flexibility and better availability of assistance without the need for a personal visit to the workplace. Respondents also appreciated the higher level of security, whether in terms of health protection or prevention of conflicts with clients. Financial savings, work efficiency, the possibility of communication in the client's home environment, which supports their openness, as well as the opportunity to use the information provided and recommend electronic resources, were also positively assessed. The possibility of working with multiple clients is also an advantage.

On the other hand, the table highlights several limitations of this form of work. A key shortcoming is the absence of personal contact, which is traditionally considered essential in social work. Respondents also pointed out technical barriers, such as work equipment and poor internet connections, as well as clients' digital skills. Risks include misunderstanding in communication, possible misuse of personal data or further occurrences of cyberbullying. Some respondents also stated that they do not see any benefit in e-social work or do not consider it a replacement for personal contact.

Since e-social work takes place mainly in the online space and the client has contact details for the social worker, we investigated whether respondents felt any threat from the client when providing e-social work services outside working hours and, if so, the degree of that threat on a 10-point scale. The results of the analyses are described in Graphs 3 and 4.

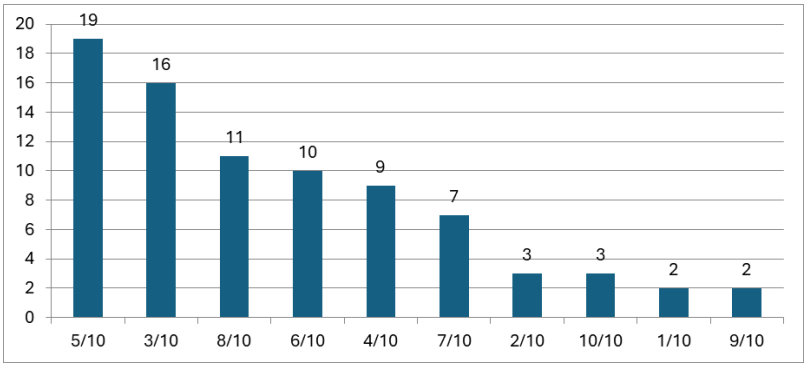
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Graph 3. Respondents' level of agreement with the feeling of threat when providing services through e-social work
Source: own processing by the authors

We can positively assess that 146 respondents (58%) and 24 respondents (9%) stated that they did not feel any threat from the e-client. A total of 82 respondents (33%) stated that they felt threatened by the e-client on social networks outside of working hours.

Graph 4 describes the distribution of responses of the 82 respondents who felt threatened. On a 10-point scale of perceived threat, pole 1 indicated the lowest level of threat and pole 10 the highest level of perceived threat.



Graph 4. Level of perceived threat by e-clients on a 10-point scale
Source: own processing by the authors

In our research, we found comparable results. On the one hand, the picture of the perception of e-social work by social workers and their attitude towards e-social work as a new form of social work was provided by open-ended questions in which respondents stated the advantages of e-social work, the disadvantages of e-social work compared to social work carried out directly, and provided an opinion on what should be changed in order to be able to carry out e-social work effectively and without restrictions.

The respondents stated the speed of handling client requests as the greatest advantage, which also coincides with the opinion of Reamer (2013), who sees in online counseling the advantage of immediate response, which is very important in solving some social problems. We can conclude that even within the framework of the functioning of e-social work in Slovakia, there are visible advantages that can be Reamer (2006) also pointed out. Similarly, our respondents mentioned the advantages of e-social that e-social work services allow clients to access services at a time that suits them and from remote locations where mental health professionals may not be available (time flexibility and accessibility), among others.

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The negative perception of e-social work and the lack of understanding of the focus of e-social work were particularly noticeable in open-ended questions, where statements such as: "in my opinion, e-social work will never completely replace classic social work" were made, "Social work should be carried out exclusively in person, what is e-social work. Nonsense. You will NEVER provide professional and high-quality social work through electronic means.", "e-social work = all wrong", "this impossible American, progressive and supposedly democratic mindset of the young generation..." It follows from the above that these respondents do not realize that the goal of e-social work is not to replace social work with direct contact with the client, but rather it is a form that can be effective in social work with a certain group of clients who are comfortable with the online space. E-social work is therefore not for every client and, according to opinions, not for every social worker.

The limitations of the research include the uneven gender representation of respondents, which does not allow for relevant gender comparisons, as well as the use of an online questionnaire, which may have favoured respondents with higher digital competencies.

4. Discussion

The COVID-19 pandemic has changed the world and affected every aspect of our lives. Health systems have come under enormous pressure, economies have been shaken, and many people have had to deal with unemployment, social isolation, and psychological problems. The COVID-19 pandemic has had a significant impact on people's mental health, with many facing increased stress, anxiety, and depressive states. The long-term restrictions, isolation, and uncertainty associated with the pandemic have worsened the mental health of the general public. The importance of palliative and hospice care during the COVID-19 pandemic has been crucial, as these services have provided not only physical relief but also emotional and psychological support to patients and their families during difficult times.

During the COVID-19 pandemic, a significant psychological impact was clearly evident, which was manifested mainly by increased levels of stress and depressive feelings. Younger people were most affected by these studies, as also found by Babinčák and Babjáková (2022) and Hajdúk et al. (2022), which reached a high level of psychological burden. In addition to age, increased stress and depressive feelings were closely associated with a higher subjective perception of pandemic threat, which, according to Kohút et al. (2022), led to a more significant decrease in life satisfaction and overall psychological well-being among participants.

Andersen et al. (2023), Bengtsson and Bønnhoff (2024), and Zenarolla (2024) also address the importance of digitalization and digital data in social work, emphasizing that digital technologies are penetrating all areas of practice and require the development of social workers' skills, the adaptation of work practices, and further research into their effective use.

Aasback (2022) analyses the use of digital platforms in social work, highlighting the potential to streamline services through online tools. Aparicio and Sánchez (2023) describe experiences with the introduction of technological and innovative approaches in social work, emphasizing the importance of training and systematic implementation of digital tools for social service professionals.

Zhu and Andersen (2021) examine digital competence in the practice and education of social workers, emphasizing the need to develop digital skills and integrate technology into the professional training and daily work of social workers.

We can clearly state that the COVID-19 pandemic has dramatically changed the possibilities of human interaction and communication, and in particular, it has accelerated the integration of digital technologies into social work practice.

López Peláez et al. (2020), Markovič (2024), Maiboroda et al. (2025), Molala (2025). address the issue of digital transformation and innovation in social services, focusing on the development of digital skills of social workers and the adaptation of social work to the online and digital environment Their works emphasize the importance of e-social work as a new approach to the provision of social services in the context of modern technologies.

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Research by Nordesjö and Scaramuzzino (2023) has shown that in connection with the COVID-19 pandemic, social workers have been forced to reconsider how their professional values can be applied in new contexts and how remote work can ensure social workers' availability, sensitivity, acceptance, collaboration and a sense of belonging with the client. This trend has increased the need for training and education in social work on the use of digital tools, and social workers should be able to adapt digital services to specific needs. Their findings show that 90% of social workers agreed that they are using digital tools more often in their client relationships in response to the COVID-19 pandemic. We would also like to reiterate the statement of Markovič (2022), who points out that a hybrid model of social work will gradually be applied in social work, which will use both the online environment and personal contact, or as one of the respondents in the sample we studied stated that e-social work can be used effectively, anyway, a combination of personal meetings would be recommended.

One current study of Swedish social workers regarding e-social work reached similar conclusions: they see both advantages and disadvantages to using digital tools in social work. According to them, the most optimal is a combination of digital tools, but also the possibility of personal meetings if the client wishes" (Nordesjö & Scaramuzzino, 2023).

Our research shows that respondents perceived the digital form of social work ambivalently. Among the benefits, they included faster implementation of interventions, greater flexibility in timing, and better service availability without the need to visit the facility in person. The possibility of working in a safe environment, cost savings, higher efficiency, and the opportunity to support multiple clients simultaneously were also positively evaluated. Some also pointed out the need for more open communication between clients in the home environment and the possibility of storing or sharing information via electronic means.

On the other hand, the absence of direct interpersonal contact, technical shortcomings and low level of digital competences of clients were shown as limits. Respondents also pointed out the risks of misunderstandings, misuse of personal data, or online attacks. Some respondents expressed a preference for the traditional form of work and do not consider the digital method an adequate replacement for a personal meeting.

From the respondents' recommendations for making e-social work more efficient based on their own practice, we select:
- improve the level of digital skills of workers and clients;
- improve and modernize digital equipment in social service facilities but also for clients;
- strengthen clients' trust in social work in the online space.

We mention the ideas of the prominent pioneer of e-social work Reamer (2013), that the task of social work in the future is to thoughtfully and constructively, critically assess the acceptability of digital technologies in social work. The author points to the development of social work over more than a century and the transition from providing personal services exclusively to providing services using digital technologies. At the same time, he emphasizes that it would be a mistake in social work if social workers were to avoid all non-traditional treatment protocols and interventions that involve digital technologies, but instead should push the boundaries of traditional practice in a constructive effort to create, implement and evaluate new but effective ways of helping clients.

Conclusions

E-social work is a new and innovative approach to providing social services through ICT. This type of work allows social workers to communicate more effectively with clients, monitor their progress, and provide support through online platforms and tools. In addition, e-social work enables better cooperation among professionals and institutions in the field of social care by enabling information sharing in an online environment. It is our task to develop appropriate e-social work methodologies and train social workers to raise awareness of the possibilities and benefits of e-social work in solving clients' social problems. This will reduce digital exclusion, and e-social work can be used effectively as one form of social work for selected clients. It

is necessary to emphasize the protection of e-clients' personal data and require social workers to comply with the Code of Ethics.

The research found that e-social work in Slovakia was not just a temporary solution tied to the pandemic period; in many facilities, it remained in place even after the end of emergency measures. It thus appears that digital forms of intervention are gradually becoming a stable part of social service practice, although their scope and intensity of use vary between workplaces.

In practice, professionals primarily use simple, readily available communication tools, while more complex online platforms remain in the background. The digitalization of social work is thus taking place more evolutionary and pragmatically than as a systematically managed process supported by methodological standards.

The research also revealed the ongoing tension between technological possibilities and traditional social work values. Although respondents appreciate the greater availability, flexibility, and operability of services, they still consider personal contact an irreplaceable element of a professional relationship. The opening of the topic of safety and setting boundaries in the online space, especially regarding communication outside working hours, can also be significant, underscoring the need for clearer rules and support for professionals in the digital environment.

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POLITICAL FRAGMENTATION AND PUBLIC DEBT DEVELOPMENT IN EUROPEAN UNION COUNTRIES*

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Abstract. This paper examines the relationship between the ideological fragmentation of government coalitions and the development of public debt in European Union countries. The study examines whether political polarisation and the ideological range of governing coalitions influence both short-term public debt dynamics and the long-term level of public debt. The empirical analysis is based on panel data from 16 EU member states covering the period 2002–2022 and uses two-way fixed-effects panel regression models with country- and year-fixed effects. Two dimensions of political fragmentation are analysed: government political polarisation (cab_wpolar) and the ideological range of coalition parties (cab_prefrange). The results indicate that political variables are not systematically associated with year-on-year changes in public debt. In contrast, several model specifications suggest that political polarisation may contribute to higher long-term public debt levels, while broader ideological coalitions may under certain conditions be associated with lower public debt. The findings suggest that political fragmentation primarily influences public finances through gradual long-term fiscal mechanisms rather than through immediate annual debt fluctuations.

Keywords: political polarization; ideological range; public debt; European Union

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JEL Classifications: H63, E62, D72

1. Introduction

In recent decades, the rapid growth of public debt in advanced economies has intensified discussions on fiscal sustainability and the long-term stability of public finances (Olivella, 2020; Franchino, 2024). Alongside macroeconomic determinants, increasing attention has been devoted to the role of political factors in shaping fiscal outcomes, particularly political polarisation and ideological fragmentation within coalition governments.

Political fragmentation may complicate government decision-making, increase coordination costs, and weaken governments' ability to implement consistent fiscal strategies. The existing political economy literature does not provide a fully consistent view of the relationship between political polarisation and public debt. While some studies (Persson & Svensson, 1989; Alesina & Tabellini, 1990; Alesina & Drazen, 1991; Dziuda & Loeper, 2016) argue that increasing political polarisation contributes to higher public debt, other authors (Melki & Pickering, 2014; Piguillem & Riboni, 2015) suggest the opposite relationship.

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Despite growing interest in the political determinants of fiscal policy, existing research focuses predominantly on the long-term level of public debt, while paying considerably less attention to the distinction between short-term debt dynamics and long-term debt accumulation. Moreover, limited attention has been paid to differences between government political polarisation and the ideological range of coalition governments.

Against this background, the present study examines the relationship between political fragmentation and public debt development across 16 European Union countries during 2002–2022. The main objective of the paper is to analyse whether government political polarisation and the ideological range of coalition governments influence both short-term public debt dynamics and the long-term level of public debt.

The empirical analysis utilises panel data from the Representation and Democracy in Europe (REPDEM), Manifesto Project, and Eurostat databases. It applies two-way fixed-effects panel-data regression models with country- and year-fixed effects. The study contributes to the existing literature by distinguishing between short-term debt dynamics and long-term debt accumulation and by separately analysing two dimensions of political fragmentation: government political polarisation and the ideological range of coalition parties.

2. Theoretical background

Public debt development is influenced by a broad range of macroeconomic, fiscal, institutional, and political factors. Existing literature highlights the importance of fiscal rules, fiscal governance frameworks, and institutional settings in shaping fiscal outcomes and long-term debt sustainability (Kraemer & Lehtimaki, 2024; Locatelli, 2026). At the same time, public debt dynamics are strongly affected by external socio-economic shocks, such as financial crises, pandemics, or periods of economic instability, which may lead to increased government expenditure and fiscal imbalances (Brożek et al., 2022; Strachinaru, 2024). Previous studies also emphasise the role of discretionary fiscal policy decisions and the structure of public expenditure, particularly in areas related to public services, defence, and public safety (Vicente et al., 2024; Carnazza et al., 2025). Public debt, therefore, represents a complex and multidimensional phenomenon shaped by the interaction of economic conditions, fiscal governance, institutional frameworks, external shocks, and political factors.

The relationship between political polarisation and fiscal indicators, particularly public debt expressed as a percentage of GDP, represents a central research theme in contemporary political economy. Political polarisation, defined as increasing ideological divergence across the political spectrum, shapes the direction and effectiveness of fiscal policy.

The basic theoretical framework for understanding this relationship is provided by Alesina and Tabellini (1990), who argue that in a polarised environment, policymakers strategically utilise state debt. If ruling politicians face a high probability of being replaced in the following period by an opponent with different preferences, they tend to increase current spending and accumulate debt to limit the manoeuvring space of their successors. This concept of strategic debt is also confirmed by Persson and Svensson (1989) and Lee (2022), who demonstrate, using panel data from a sample of OECD countries between 1962 and 2015, that an increase in political polarisation statistically significantly raises the level of public debt.

Another dimension of polarisation is the so-called "gridlock" or decision-making stalemate. Greiner (2007), in a study on the European Union, emphasises that increased polarisation weakens the government's ability to make coherent fiscal decisions. At the moment when a rapid response to an economic shock is required, polarised government systems struggle to reach consensus. This phenomenon is particularly visible during periods of economic turbulence, when the necessity of austerity measures comes into direct conflict with populist demands, leading to fiscal imbalances and a deterioration in institutional quality (Economides et al., 2021; Rajaguru et al., 2021).

In addition to society-wide polarisation, the internal structure of government power, specifically the ideological range of coalition governments, plays a key role. This concept reflects the ideological distance between the parties that form the government majority.

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Franchino (2024) introduces the term "executive fractionalisation" to describe the fragmentation of power within the government. Their research demonstrates that ideologically fragmented governments suffer from chronic delays in fiscal reforms. Each coalition partner tends to protect its departmental spending and satisfy its specific voter groups, leading to constant pressure to increase public expenditure (Grechyna, 2016; Vuković, 2017).

This phenomenon was already elaborated upon by Roubini and Sachs (1989), who found that shorter terms of office and fragmented party systems are directly correlated with higher deficits. In such systems, a “tragedy of the commons” often occurs, where each coalition party draws from the collective budget regardless of overall debt sustainability. Fedeli and Forte (2003) add that this problem is more pronounced in countries with proportional electoral systems, where the formation of broad, ideologically diverse coalitions is almost a necessity. Conversely, ideologically more cohesive coalitions can implement more consistent fiscal strategies and exhibit more stable debt levels (Melki & Pickering, 2021).

Although several sources (Alesina & Perotti, 1995; Greiner, 2007; Lee, 2022) confirm a positive correlation between polarisation and debt, some exceptions enrich the discussion. A study by Melki and Pickering (2021) brings an unconventional finding from a sample of OECD countries. The authors state that in certain contexts, polarisation can lead to lower debt. This occurs if voters are sensitive to short-term benefits and political parties are motivated to distinguish themselves through extreme responsibility in an effort to win over undecided voters.

This discrepancy in the literature highlights the need to distinguish between the polarisation of government elites and the polarisation of the electorate. While polarisation within the government generally leads to inefficiency and debt, polarisation among voters can, under certain institutional conditions, create pressure for more responsible fiscal management. This complexity underscores the necessity of a nuanced approach to researching the political determinants of public finance in contemporary democracies.

Summarising the results of scientific outputs, it can be concluded that while right-wing ideology and political continuity (Bonet-Morón et al., 2024) are associated with higher fiscal stability, high polarisation and a wide ideological range of coalitions, combined with weak institutions, represent a significant risk to the long-term sustainability of public finances.

Based on a review of the theoretical and empirical literature, several mechanisms can be identified through which political factors influence government fiscal behaviour. Previous studies suggest that political polarisation and the ideological fragmentation of coalitions play a significant role, especially in the long-term development of public finances. At the same time, their impact on short-term fiscal fluctuations is less clear.

The examined studies (Alesina & Tabellini, 1990; Roubini & Sachs, 1989; Greiner, 2007; Melki & Pickering, 2021; Lee, 2022) focus on the relationship between selected political variables and the level of public debt, which speaks to the long-term effects of political factors on national indebtedness. In the present study, we supplement this with a view on the influence of political variables on the year-on-year change in public debt.

Based on the theoretical and empirical literature discussed above, the present study focuses not only on political polarisation at the government level, but also on the internal ideological structure of coalition governments, particularly the ideological range of coalition parties and the degree of executive fragmentation. Previous studies suggest that ideologically fragmented governments may struggle to implement consistent fiscal policies due to competing spending priorities among coalition partners. At the same time, the empirical evidence remains mixed, especially regarding the distinction between short-term debt dynamics and long-term public debt accumulation.

Building on these theoretical arguments and empirical findings, the study formulates the following research hypotheses:

- H1a (short-term effect): Higher political polarisation of the government is associated with stronger short-term public debt dynamics.

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- H1b (long-term effect): Higher political polarisation of the government is associated with a higher level of public debt as a percentage of GDP.
- H2a (short-term effect): The ideological range of the government coalition significantly affects short-term public debt dynamics.
- H2b (long-term effect): The ideological range of the government coalition significantly affects the level of public debt as a percentage of GDP.

3. Research objective and methodology

3.1 Main objective of the article and data sources

The main objective of the paper is to analyse the influence of political factors on the development of public debt in selected European Union countries, with an emphasis on distinguishing between short-term debt dynamics and the long-term level of public debt. In this context, two primary political variables are analysed: the political polarisation of the government coalition (cab_wpolar) and the ideological range of the governing parties (cab_prefrange).

Two alternative indicators of public debt dynamics are used as dependent variables in the analysis. The first is the year-on-year change in public debt (Debt_change), which captures short-term fiscal decisions and the government's reactions to economic conditions. The second is the level of public debt, expressed as a share of GDP, according to the Maastricht criteria (Public_debt), reflecting countries' long-term fiscal behaviour and the cumulative effect of political decisions.

The explanatory political variables used in this study are sourced from the REPDEM database, which provides comparable data on government composition, the ideological orientation of political parties, and characteristics of government coalitions in European countries (Hellström et al., 2025). The database is based on data from the Manifesto Project (Lehmann et al., 2025) and the Chapel Hill Expert Survey (Jolly et al., 2022), ensuring high comparability across countries and over time. The empirical analysis is based on panel data from European Union countries for the period 2002-2022. The time frame and the number of countries are determined by the availability of political variables, which are not systematically available beyond 2022. For this reason, 16 European Union countries were included in the analysis: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Latvia, the Netherlands, Poland, Portugal, Slovenia, Spain, and Sweden.

The variable cab_wpolar expresses the degree of ideological polarisation within the government coalition. It captures the extent to which individual coalition parties differ in their ideological positioning on the left-right axis. In accordance with the REPDEM database methodology, this variable is defined as the weighted standard deviation of the ideological positions of the parties forming the government, where the weights correspond to their share of government seats:

$$cab_wpolar_t = \sqrt{\sum_{i=1}^{N} w_{i,t}(p_{i,t} - \bar{p}_t)^2} \quad (1)$$

where:

$p_{i,t}$ – the ideological position of party *i* in year *t*;
$w_{i,t}$ – the seat share of party *i* in the governing coalition;
$\bar{p}_t = \sum w_{i,t}\, p_{i,t}$ – the weighted ideological mean of the cabinet.

Higher values of this variable indicate greater ideological fragmentation within the coalition and potentially higher costs of political coordination. This variable captures the ideological fragmentation within the government coalition rather than its specific ideological orientation.

The variable cab_prefrange expresses the ideological breadth of the governing coalition, specifically, the difference between the most left-wing and most right-wing parties in the government. Unlike the cab_wpolar variable, this metric does not account for the weight of individual parties; instead, it captures the range of the

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ideological spectrum represented within the government. Higher values indicate a broader ideological scope for the coalition, which may signal potential programmatic conflicts, though not necessarily their intensity.

Control variables in the present study include the primary balance of public finances (Primary_balance), economic growth (GDP_growth), and interest rate (Interest_rate), which are commonly used macroeconomic and fiscal controls in the empirical literature on public debt dynamics. All data are sourced from the Eurostat database for the period 2002-2022.

3.2 Econometric specification and estimation

The empirical analysis employs two-way fixed effects (TWFE) panel models, incorporating both country- and year-fixed effects. This approach allows for controlling unobservable, time-invariant country characteristics as well as common temporal shocks affecting all countries simultaneously.

The research is based on two primary model specifications that differ in their use of political variables, with each tracking a distinct aspect of the political heterogeneity of government coalitions. The econometric analysis was conducted in Python using panel data estimation procedures.

Model 1 (Government political polarisation) includes government political polarisation (cab_wpolar) as the main explanatory variable, capturing the weighted ideological dispersion of coalition parties. This model tests whether ideologically dispersed and less coherent governments exhibit different fiscal outcomes.

Model 2 (Ideological heterogeneity - alternative operationalisation) replaces weighted polarisation with the variable cab_prefrange, which measures the range of parties' ideological positions within the coalition. The objective of this specification is to verify the robustness of the results against a different conceptualisation of political polarisation.

Both model types are estimated for two alternative dependent variables: the year-on-year change in public debt (Debt_change) and the level of public debt as a percentage of GDP (Public_debt).

The estimated model has the following structure:

$$Y_{it} = \beta_0 + \beta_1 Political_{it} + \beta_2 GDP_growth_{it} + \beta_3 Primary_balance_{it} + \beta_4 Interest_rate_{it} + \alpha_i + \lambda_t + \varepsilon_{it} \quad (2)$$

where:

i - country;
t - year;
Y_{it} - dependent variable; year-on-year change in public debt (Debt_change), or level of public debt as a percentage of GDP (Public_debt).
$Political_{it}$ - political variable taking one of the following forms: cab_wpolar - weighted political polarisation of the government, cab_prefrange - ideological range of the governing coalition.
GDP_growth_{it} - annual GDP growth rate;
$Primary_balance_{it}$ - primary balance of public finances as a percentage of GDP;
$Interest_rate_{it}$ - long-term interest rate capturing the financial cost of public debt financing
α_i - country fixed effect;
λ_t - year fixed effect;
ε_{it} - random error term.

To mitigate simultaneity concerns and strengthen the temporal interpretation of relationships, the political variables and selected control variables are lagged by one year in the main specifications. This approach is consistent with the assumption that governments' political characteristics influence fiscal and macroeconomic outcomes with a lag. The use of lagged political variables also helps mitigate potential endogeneity concerns between political characteristics and fiscal outcomes. Consequently, three specifications were estimated for each dependent variable: a baseline model, a lagged specification, and a robustness specification including lagged public debt.

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Before estimating the models, standard panel-data diagnostic tests were conducted (Table 1). The Hausman test systematically rejects the random effects specification in favour of fixed effects models, thereby justifying the use of two-way fixed effects that include both country and year effects. Further diagnostic tests confirm the presence of:

- Heteroscedasticity (Breusch-Pagan LM test),
- Serial correlation within panels (Wooldridge test),
- Cross-sectional dependence between countries (Pesaran CD test).

Table 1. Diagnostic tests for panel regressions

Dependent variable	Model	F-test pooled vs FE	Hausman FE vs RE	Breusch–Pagan LM	Wooldridge serial corr.	Pesaran CD
Debt change	Model 1 (wpolar)	1.116 (0.341)	12.568***	60.798***	−8.543***	4.124***
	Model 2 (prefrange)	1.084 (0.370)	12.592***	61.876***	−8.480***	7.059***
Public debt (% GDP)	Model 1 (wpolar)	1.132 (0.312)	18.447***	84.231***	−9.214***	6.982***
	Model 2 (prefrange)	1.107 (0.334)	17.992***	83.765***	−9.186***	7.214***

Notes: p-values for F-tests are reported in parentheses. Diagnostic tests were performed for the baseline specifications. Robustness models, including lagged public debt, yielded qualitatively similar diagnostic patterns and are therefore not reported for brevity. Breusch-Pagan LM tests indicate heteroskedasticity; Wooldridge tests indicate serial correlation; Pesaran CD tests indicate cross-sectional dependence. *** p < 0.01, ** p < 0.05.

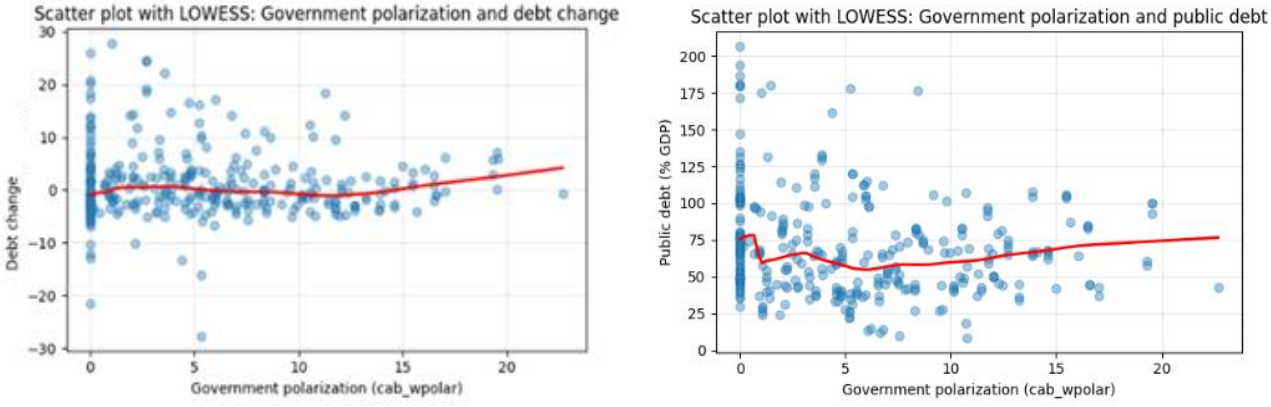
Source: authors

For this reason, all models are estimated using robust standard errors that account for violations of classical regression assumptions. High R^2 values in models featuring the level of public debt are interpreted as reflecting strong debt persistence and the inclusion of fixed effects, rather than as a sign of model overfitting.

4. Results

4.2 Analysis of input political variables in relation to public debt

Before the econometric analysis, it is essential to examine the fundamental empirical characteristics of the relationship between the political variables and public debt (in both forms). The graphical analysis utilises scatter plots supplemented by non-linear smoothing curves (LOWESS), which allow for capturing the general nature of the relationship between variables without assuming linear dependence. This approach is particularly suitable in the context of political-economic relationships, where effects often manifest non-linearly and with significant heterogeneity across countries and time.

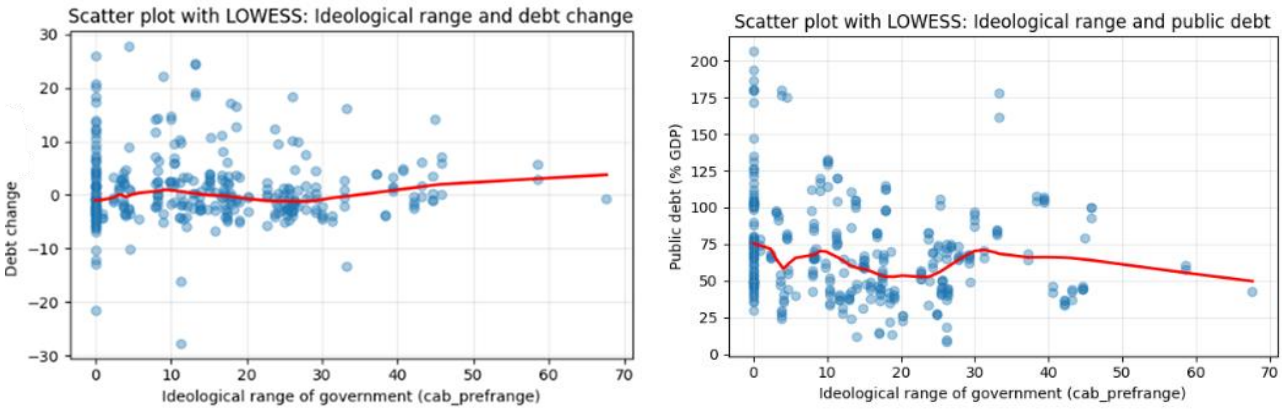


a) Debt change (%) **b) Public debt (% GDP)**

Figure 1. The relationship between government political polarisation (cab_wpolar) and fiscal indicators
Source: authors

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Figures 1 a) and b) illustrate the relationship between government political polarisation (cab_wpolar) and selected fiscal indicators. As shown in these figures, the relationship between political polarisation and year-on-year changes in public debt appears relatively weak and partially non-linear. In contrast, a more visible positive association can be observed between government political polarisation and public debt levels. The graphical evidence therefore suggests that political polarisation may be more closely associated with the long-term accumulation of public debt than with short-term debt dynamics.



a) Debt change (%) **b) Public debt (% GDP)**

Figure 2. The relationship between the ideological range of the governing coalition (cab_prefrange) and fiscal indicators
Source: authors

Figures 2a) and 2b) show the relationship between the ideological range of the governing coalition (cab_prefrange) and selected fiscal indicators. While the relationship between the ideological range of coalition governments and year-on-year debt dynamics appears relatively weak and unstable, a slightly non-linear association can be observed in the case of the level of public debt. Overall, the graphical evidence does not indicate a clear positive relationship between broader ideological coalitions and higher public debt levels, suggesting that the fiscal effects of coalition heterogeneity may depend on additional institutional or macroeconomic factors.

4.2 Econometric analysis of the impact of political variables on short-term public debt dynamics

In the first phase, this study focuses on interpreting regression model results with the dependent variable year-on-year change in public debt (Debt_change). The objective is to identify the extent to which selected political factors influence the short-term dynamics of public indebtedness. All models are estimated using two-way fixed effects (country and year), with robust standard errors. The results are presented in three specifications: the baseline model, a lagged specification, and a robustness specification including lagged public debt.

Table 2 presents the results of the panel regression models. Estimates are provided for two alternative specifications of political variables: government political polarisation (cab_wpolar) and the ideological range of coalition parties (cab_prefrange).

The results across all specifications indicate that the political variables are not systematically associated with short-term changes in public debt. Although the coefficients for the cab_wpolar variable are negative across all estimated models, they are not statistically significant in either the baseline or the lagged specifications. These findings suggest that higher ideological polarisation within government coalitions is not associated with immediate changes in year-on-year public debt dynamics.

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Table 2. Econometric analysis results for the dependent variable Debt_change

Variables	Model 1: Polarisation			Model 2: Ideological range		
	(1) Baseline	(2) Lagged	(3) Robustness	(1) Baseline	(2) Lagged	(3) Robustness
Public_debt (t−1)			−0.015** (0.007)			−0.014** (0.007)
Primary_balance	−0.786*** (0.133)			−0.790*** (0.130)		
Primary_balance (t−1)		−0.679*** (0.128)	−0.620*** (0.120)		−0.676*** (0.126)	−0.610*** (0.120)
cab_wpolar	−0.061 (0.075)					
cab_wpolar (t−1)		−0.053 (0.064)	−0.045 (0.060)			
cab_prefrange				−0.001 (0.016)		
cab_prefrange (t−1)					−0.005 (0.019)	−0.004 (0.018)
GDP_growth	−1.078*** (0.345)			−1.078*** (0.343)		
GDP_growth (t−1)		−1.207*** (0.325)	−1.100*** (0.300)		−1.202*** (0.327)	−1.080*** (0.300)
Interest_rate	−0.202 (0.362)	−0.486 (0.402)	−0.400 (0.350)	−0.345 (0.297)	−0.377 (0.312)	−0.350 (0.300)
Observations	336	320	320	336	320	320
Within R^2	0.173	0.163	0.200	0.173	0.162	0.190

Notes: Two-way fixed effects models (country and year). Robust standard errors in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.10.
Source: authors

A similar conclusion applies to the alternative measure of political heterogeneity, cab_prefrange. The ideological range of the governing coalition does not exhibit a statistically significant relationship with short-term debt dynamics, even in the lagged specifications. This suggests that the ideological diversity of coalition partners alone is not a decisive determinant of short-term fiscal developments.

From an economic perspective, the results indicate that short-term public debt dynamics are primarily driven by macroeconomic conditions and fiscal fundamentals rather than by the political composition of governments. At the same time, the robustness specifications, including lagged public debt, confirm the importance of debt persistence in explaining short-term debt developments. Consequently, the empirical findings do not provide support for hypotheses H1a and H2a.

4.3 Econometric analysis of the impact of political variables on the level of public debt

In this section, the analysis focuses on the relationship between the political characteristics of governments and the level of public debt expressed as a percentage of GDP. In contrast to the previous section, which examined short-term debt dynamics, the objective here is to identify factors associated with the long-term accumulation of public debt.

The empirical analysis is again conducted using panel regression models with country- and year-fixed effects. The results presented in Table 3 are reported for two alternative model specifications that differ in the operationalisation of political variables.

The regression results indicate that political factors are more strongly associated with the long-term level of public debt than with short-term fluctuations in public debt. In the case of government political polarisation (cab_wpolar), the baseline specification yields a positive, statistically significant coefficient, suggesting that ideologically fragmented governments are associated with higher public debt levels. This finding is consistent with theoretical arguments in political economy emphasising that politically polarised coalitions may face higher coordination costs and weaker incentives to maintain fiscal discipline.

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Table 3. Econometric analysis results for the dependent variable Public_Debt

Variables	Model 1: Polarisation			Model 2: Ideological range		
	(1) Baseline	(2) Lagged	(3) Robustness	(1) Baseline	(2) Lagged	(3) Robustness
Public_debt (t−1)			0.91*** (0.02)			0.91*** (0.02)
Primary_balance	−0.029 (0.023)			−0.010 (0.023)		
Primary_balance (t−1)		−0.804*** (0.023)	−0.42*** (0.04)		−0.806*** (0.024)	−0.43*** (0.04)
cab_wpolar	0.056*** (0.016)					
cab_wpolar (t−1)		0.018 (0.016)	0.015* (0.009)			
cab_prefrange				−0.016*** (0.006)		
cab_prefrange (t−1)					−0.000 (0.006)	−0.010** (0.005)
GDP_growth (t−1)	−0.313*** (0.028)	−0.148*** (0.028)	−0.07*** (0.02)	−0.357*** (0.028)	−0.150*** (0.028)	−0.08*** (0.02)
Interest_rate (t−1)	2.397*** (0.043)	2.468*** (0.043)	1.05*** (0.09)	2.374*** (0.043)	2.468*** (0.043)	1.03*** (0.09)
Observations	336	320	320	336	320	320
Within R^2	0.886	0.886	0.950	0.886	0.886	0.950

Notes: Two-way fixed effects models (country and year). Robust standard errors in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.10.
Source: authors

However, the relationship weakens in the lagged specification and remains only weakly statistically significant in the robustness model that includes lagged public debt. This suggests that the effect of political polarisation on long-term public debt accumulation is not fully stable across all estimated specifications. Therefore, the empirical findings provide only partial support for hypothesis H1b.

A different pattern emerges for the alternative measure of political heterogeneity, cab_prefrange. The baseline and robustness specifications indicate a negative, statistically significant relationship between the ideological range of coalition parties and public debt levels. In contrast, the lagged specification yields no statistically significant results. These findings suggest that broader ideological coalitions do not necessarily lead to higher public indebtedness. On the contrary, broader coalition structures may, under certain conditions, function as a mechanism of internal checks and balances, limiting excessive fiscal expansion by individual coalition members.

Consequently, the empirical results do not support hypothesis H2b, which posits a positive relationship between ideological range and public debt levels. Instead, the estimated models suggest a potentially stabilising role for broader coalition structures in the long-term development of public finances.

5. Discussion

Our results indicate that political variables are not systematically associated with short-term public debt dynamics, whereas their relationship with the long-term level of public debt appears more pronounced. This finding is broadly consistent with the existing political economy literature, which primarily examines the cumulative and long-term effects of political fragmentation on fiscal outcomes rather than immediate annual debt fluctuations. Previous studies by Alesina and Tabellini (1990), Roubini and Sachs (1989), Greiner (2007), and Lee (2022) mainly focus on the level of public debt or long-term fiscal imbalances. In contrast, evidence regarding short-term debt dynamics remains limited and less conclusive.

Regarding hypothesis H1b, the results provide partial support for the argument that greater political polarisation is associated with higher public debt levels. The positive, statistically significant coefficient of the cab_wpolar variable in the baseline specification is consistent with the strategic debt accumulation framework proposed by

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Alesina and Tabellini (1990), according to which politically polarised governments may strategically use debt in anticipation of future political turnover. Similarly, Lee (2022) finds that higher polarisation is associated with increased public debt in OECD countries due to weaker political consensus and delayed fiscal consolidation. Our findings, therefore, support the broader argument that ideologically fragmented governments may face higher coordination costs and weaker incentives to maintain fiscal discipline.

At the same time, the weakening of the estimated effect in the lagged and robustness specifications suggests that the relationship between political polarisation and public debt is not fully stable across all model specifications. This implies that the impact of political polarisation may depend on additional institutional or macroeconomic factors not fully captured by the present analysis. In this respect, our findings are also compatible with studies emphasising that the fiscal consequences of polarisation vary across institutional environments and governance structures.

The results for the ideological range variable (cab_prefrange) differ from the traditional expectations derived from the common pool problem literature. While Roubini and Sachs (1989), Grechyna (2016), and Vuković (2017) argue that broad and ideologically fragmented coalitions tend to increase fiscal imbalances because coalition members protect their own spending priorities, our findings point to a different mechanism. The negative coefficients for cab_prefrange in the baseline and robustness specifications suggest that broader ideological coalitions may, under certain conditions, contribute to lower levels of public debt.

One possible explanation is that ideologically diverse coalitions create stronger internal constraints on fiscal expansion. In such governments, coalition partners may mutually limit each other's spending demands, reducing the likelihood of unilateral fiscal expansion by individual parties. In this sense, ideological diversity may partially function as an internal system of checks and balances. This interpretation is closer to the arguments presented by Melki and Pickering (2021), who suggest that polarisation does not necessarily lead to fiscally irresponsible outcomes across all institutional contexts.

The findings also underline the importance of institutional quality in shaping the relationship between political fragmentation and fiscal outcomes. Previous studies (e.g., Calderón et al., 2012; Malik et al., 2022) emphasise that strong fiscal institutions, fiscal rules, and independent fiscal councils can mitigate the adverse fiscal consequences of political polarisation. Although institutional interactions are not explicitly modelled in this study, the mixed and partially unstable effects of political variables observed in our models indirectly support the argument that institutional settings likely moderate the fiscal consequences of political fragmentation.

From a policy perspective, the results suggest that strengthening fiscal institutions may be more important for long-term fiscal sustainability than limiting political diversity within coalition governments. Since coalition fragmentation is a common feature of many parliamentary democracies, especially within the European Union, the effectiveness of fiscal governance may depend less on the existence of political diversity itself and more on the institutional capacity to maintain fiscal discipline under politically heterogeneous governments.

Overall, the present study contributes to the existing literature by distinguishing between short-term debt dynamics and the long-term accumulation of public debt. While previous studies primarily focused on the level of indebtedness, our analysis additionally demonstrates that political fragmentation does not appear to exert a statistically significant influence on year-on-year debt fluctuations. The findings therefore suggest that political factors shape public finances mainly through gradual and cumulative long-term fiscal mechanisms rather than through immediate annual debt changes.

Conclusions

The objective of this study was to examine the relationship between the political characteristics of governments and the development of public debt in selected European Union countries, with particular emphasis on distinguishing between short-term debt dynamics and the long-term level of public debt. Using panel regression models with country- and year-fixed effects, the analysis focused on two dimensions of political fragmentation:

government political polarisation (cab_wpolar) and the ideological range of coalition governments (cab_prefrange).

The empirical findings indicate that political variables are more closely associated with the long-term level of public debt than with short-term annual fluctuations in debt. While no statistically significant effects were identified in the models explaining year-on-year changes in public debt, several specifications suggest that political fragmentation may influence the long-term accumulation of debt. In particular, government political polarisation was positively associated with public debt in the baseline specification, whereas broader ideological coalitions were in some cases associated with lower debt levels. These findings suggest that different dimensions of political fragmentation may affect fiscal outcomes through different mechanisms.

The study contributes to the political economy literature by distinguishing between short-term and long-term fiscal effects of political fragmentation. In contrast to much of the previous literature, which has focused primarily on debt levels, the present analysis also demonstrates that political variables do not appear to systematically influence immediate annual debt developments. This distinction may help improve the understanding of how political structures influence fiscal sustainability over time.

Several limitations of the study should nevertheless be acknowledged. First, the analysis relies on annual political data, which do not fully capture short-term political instability, intra-year coalition changes, or temporary government crises. Second, the selected indicators of political fragmentation simplify inherently complex political processes and cannot fully reflect the quality of coalition cooperation, bargaining dynamics, or institutional interactions within governments. Third, although lagged specifications help mitigate simultaneity concerns, the estimated relationships may still be influenced by unobserved institutional or country-specific factors that are difficult to quantify in cross-country panel data analysis.

Future research could therefore expand the analysis by incorporating alternative indicators of political fragmentation, measures of institutional quality, or variables reflecting fiscal governance and legislative effectiveness. Additional attention could also be devoted to differences across political systems, electoral frameworks, or economic cycles. A promising direction for future research is to examine whether strong fiscal institutions and fiscal rules moderate the relationship between political fragmentation and long-term public debt accumulation.

Overall, the findings suggest that the political composition and internal coherence of governments remain relevant factors in understanding the long-term sustainability of public finances in European Union countries.

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WHERE ARE WE GOING? FROM E-COMMERCE TO THE METAVERSE: CONSUMER BEHAVIOUR AND THE ROLE OF EMERGING TECHNOLOGIES

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Abstract. The emergence of the metaverse is poised to reshape e-commerce by integrating immersive technologies and new forms of consumer engagement. However, the extent of its impact on consumer behaviour and the directions in which it will develop remain unknown. To shed light, this study presents a systematic literature review of 62 peer-reviewed articles published between 2015 and 2022 in WoS and Scopus, examining how e-commerce is evolving toward the metaverse. The analysis identifies five main research categories: e-commerce strategy and marketing, online consumer behaviour, metaverse drivers, new business models, and the role of influencers. Online consumer behaviour is the primary focus of researchers and accounts for the largest proportion of publications, largely concentrated in China, the United States, and South Korea. The findings show that influencers, both human and virtual, play a decisive role in consumer trust and purchase intent. At the same time, emerging technologies such as AR, VR, AI, and blockchain facilitate interactive experiences and more effective personalisation in marketing. Furthermore, the metaverse fosters innovative and sustainable business models, particularly in the fashion industry. Despite these advances, consumer trust and risk perception remain significant challenges. The analysis highlights several research gaps, including the need to examine cross-country differences, gender dynamics, socioeconomic barriers to entry, and the integration of sustainability and circular-economy values into metaverse-based business models.

Keywords: metaverse; e-commerce; live streaming; fashion; technology

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JEL Classifications: M30, M31, L81, O33

1. Introduction

Continuous technological advances, both in electronic media and on the internet, favour the creation of new forms of e-commerce and new strategies to reach consumers (Saad & Yaacob, 2021; Chen et al., 2022; Chen et al., 2024). The current consolidation of e-commerce and the new scenarios that may arise represent a challenge and an opportunity for companies (Kennedy et al., 2022; Mustafa et al., 2022; Sonntag, et al., 2023) in this key global channel for companies and consumers (Gu et al., 2021; Mustafa et al., 2022). Companies hire influencers (actors, athletes, etc.) to increase their market share by boosting product sales (Chetioui et al., 2020; Hudders et al., 2021; Ma, 2021; Molina-Prados et al., 2021; Wang et al., 2021). This is intended to attract consumers' attention to their advertising messages and to establish connections between brands and celebrities (Ma, 2021; Wang et al., 2021; Zhou & Tong, 2022). The significant growth of social media has led to the rise of social media influencers (SMIs), who mention brands and generate positive and favourable feelings towards them

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(Khan et al., 2022; Molina-Prados, et al. 2021). The number of companies that employ their services has grown exponentially in recent years (Arora, et al., 2019; Le & Aydin, 2022).

The evolution of the metaverse, driven by advances in technologies that enhance interaction between the physical and virtual worlds, has received significant attention from both businesses and researchers (Buhalis, Lin & Leung, 2023; Sonntag et al., 2023). This metaverse represents a "post-reality" digital environment that is characterised by its continuous nature and ability to integrate physical and virtual reality (VR) into a shared multiuser experience (Davis et al., 2009; Fernandez, 2022; Mystakidis, 2022; Hollensen et al., 2023; Wang et al., 2022). The metaverse is a self-contained, immersive virtual space that combines physical, human, and digital worlds (Gursoy et al., 2022; Lee et al., 2022; Wang et al., 2022). Its development has been driven by new technologies such as artificial intelligence (AI), VR, the Internet of Things (IoT) and blockchain (Bhat et al., 2023), enabling users to interact within this environment for work, socialising, or entertainment (Grupac et al., 2022; Lee et al., 2022; Wang et al., 2022; Zabel et al., 2023). Recent studies highlight that the design of immersive experiences in the metaverse transforms user perception and creates disruptive opportunities for digital marketing and customer loyalty, especially through the integration of AI and augmented reality in human-machine interaction.

For these reasons, companies' interest in emerging digital technologies and the metaverse has grown (Grupac et al., 2022), as has their influence on e-commerce and consumer behaviour (Deng et al., 2021; Hung, Tse & Chan, 2022). Evidently, shifts in consumer demands and habits are prompting companies to rethink the online shopping experience, with a focus on brand personalisation that integrates both physical and virtual worlds (Dwivedi et al., 2022; Silva & Bonetti, 2021). In this way, the success of a brand will depend on a coherent and adaptable approach towards an innovative, physical, and interactive environment, increasingly tied to an immersive experience within the virtual world (Harrisson-Boudreau & Bellemare, 2021), where influencers serve as models of consumer engagement (Molina-Prados et al., 2021).

The evolution of the metaverse significantly affects e-commerce business models, particularly customer interactions and core company strategies (Balakrishnan et al., 2024; Chakraborty & Biswal, 2024). Consequently, new business frameworks are likely to emerge, and current models are expected to integrate the metaverse as an additional channel.

There is no clear forecast of when this transformation will emerge owing to the factors that condition it. However, a full shift towards digital products and a transition from traditional e-commerce to metaverse-based commerce are expected (Büchel & Spinler, 2024). Thus, this study explores the current state of knowledge on the transition from e-commerce to the metaverse in the fashion industry, emphasising consumer behaviour and the impact of opinion leaders on social media. Additionally, we aim to identify the current research taxonomy for these topics, providing a categorisation and structure for the available studies. Thus, this study aims to explore the following research questions:

General RQ: What do we know about the transition from commerce to the metaverse in the fashion industry, taking into account consumer behaviour and social influencers?
The following research sublines were formulated:

RQ1: What are the categories of articles that have been published to date?
RQ2: Can a taxonomy of current research on these topics be identified?
RQ3: What gaps exist in the literature on e-commerce, the metaverse, consumer behaviour and social influencers, and what future research directions should be pursued?

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2. Theoretical background

To answer our research questions, we have developed relevant concepts to establish relationships among them and to provide context for our search for related studies and research.

Metaverse

Recently, technologies linked to the metaverse have received significant global attention (Bousba & Arya, 2022; Buhalis, Lin & Leung, 2023; Zhang & Ye, 2023). The term "metaverse" combines "meta" (a Greek prefix meaning "beyond") and "verse" (short for "universe") (Lee et al., 2022). According to Mystakidis (2022), "the metaverse is a post-reality environment: a continuous, multiuser space that merges physical reality with digital virtuality". This immersive, virtual hyperspace combines physical, human, and virtual dimensions into a self-sufficient and time-independent realm (Wang et al., 2022). The incorporation of advanced technologies, such as VR, augmented reality (AR), AI or blockchain, has played a strategic role in the growth of the metaverse, allowing users to participate in work, social interactions, and recreational activities within a shared digital environment (Bousba & Arya, 2022; Kim & Kim, 2024; Lee et al., 2023; Zabel et al., 2023). These technologies foster a shared digital environment in which individuals can collaborate and create together (Lee et al., 2023; Mystakidis, 2022). According to scholars such as Mystakidis (2022) and Zhang and Ye (2023), the metaverse relies on a convergence of technologies that facilitate multisensory interaction beyond virtual environments, digital objects, and avatars, thereby distinguishing it from traditional VR or AR. Thus, the metaverse is viewed as a next-generation internet in which users can live as digital natives, experiencing an alternative existence in a three-dimensional virtual space with avatars or holograms (Wang et al., 2022; Kaur et al., 2024). According to the above authors, the same rules for verbal and nonverbal communication that exist in the real world, such as gestures, mimicry, or tone of voice, have been adopted in the metaverse through these technologies. Consequently, consumers' preferences, behaviours and brand commitments (consumer brand engagement) are changing.

Although interest in the metaverse has increased significantly, its development is still in an early stage (Lowry et al., 2024). According to the Metaverse eCommerce report (Statista, 2024), the metaverse e-commerce market in Spain is projected to reach USD 418.5 million in 2025, with a compound annual growth rate (CAGR) of 41.00%. By 2030, the market volume is forecasted to grow to USD 2.3 billion, with an estimated user base of 11 million. The user penetration rate is anticipated to rise from 9.1% in 2025 to 23.3% by 2030. The evolution of information and communication technologies has facilitated the development of internet- and social network-related technologies, leading to changes in conceptualisation and consumption habits (Chen et al., 2022; Saad & Yaacob, 2021; Su et al., 2023). This novel e-commerce scenario is continuously improving the consumer experience (Bae et al., 2022; Costa et al., 2022; Helm et al., 2020), driving sales growth through this channel.

The term social commerce was created in 2005 amid the growth of social networks (Curty & Zhang, 2011). The goal of social commerce was to extend e-commerce to social networks, exploiting their development and favouring the sustainability of these networks (Liang & Turban, 2011; Yan et al., 2016; Asma & Afreen, 2022; Herzallah et al., 2022), and it was characterised as a phenomenon consisting of the interaction of social media and e-commerce (Asma & Afreen, 2022; Zhang & Benyoucef, 2016).

Although social commerce has attracted interest from both academics and industry professionals, no consensus on its definition has been reached, though there is agreement on its elements (Braojos et al., 2019). Meilatinova (2021, p.2) defines social commerce as “an extension of e-commerce sites, integrated with social media and Web 2.0 technology to encourage online purchases and interactions with customers before, during, and after the purchase". Thus, social commerce has opened new channels that have improved communication between companies and customers, driving new dynamics in business practices (Molina-Prados, et al., 2021; Xu & Liu, 2019); providing a series of advantages, such as being able to buy at any time without having to travel; enabling "traditional" online purchases, in which the information that consumers receive basically comprises images, text or prerecorded videos (Liu & Zhang, 2024); and improving trust (Almajali et al., 2021; Asma & Afreen, 2022). According to Demaj and Manjani (2020), this information asymmetry between consumers and online sellers has contributed to consumer mistrust in online purchases. In this context, it is unsurprising that innovations associated with e-commerce, such as live streaming e-commerce (LSC) (Lyu et al., 2022), as well as novel

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technologies (AR, VR, immersive technologies, and gamification, among others) that emphasise the consumer experience, have emerged (Bae et al., 2022; Silva & Bonetti, 2021). Notably, LSC differs from traditional e-commerce in terms of the purchase process (Chen et al., 2022; Lin et al., 2022; Lyu et al., 2022). In LSC, merchants and suppliers can provide product or service information in real time (Chen et al., 2022; Wang et al., 2022), which is another element of entertainment that encourages consumer participation and another factor that influences decision-making.

Social media influencers

As the popularity and use of social media platforms have grown, consumers have been enabled to share their opinions and experiences with their peers (Asma & Afreen, 2022; Chetioui et al., 2021; Huang & Benyouce, 2013). The use of social networks has increased by 8.8%, reaching 58% of the world's population (Wearesocial, 2022). In this context, the figure of the influencer has emerged; this refers to a person with a high level of popularity (Cheng et al., 2022; Lyu et al., 2022), many online followers and a wide reach with a great ability to influence their followers' decisions (Geng et al., 2022; Hudders et al., 2021; Le & Aydin, 2022; Lyu & Kim, 2020; Meng et al., 2021; Tobon & García-Madariaga. 2021). Notably, social media influencers (SMIs) represent a new type of independent third-party endorser who shape audience attitudes through blogs, tweets, and other social media (Freberg et al., 2011, p. 90). SMIs can significantly influence a company, its product or service and its target audience (Lim et al., 2017; Molina-Prados, et al., 2021).

3. Methodology

In this study, we conducted a systematic literature review (SLR) to explore the interplay among e-commerce in the fashion industry, virtual environments such as the metaverse and emerging technologies, consumer behaviour, and digital marketing strategies. By using this methodology, we were able to determine the current state of the metaverse literature, structure the topics of interest, and summarise the findings. We followed the established guidelines to ensure that the study is transparent and replicable. In this way, key aspects of the metaverse and consumer behaviour are explored in depth, the literature is grouped homogeneously, and future research avenues are identified. SRL has already been applied in other studies of the fashion industry by Abdelmeguid et al. (2022), Thorisdottir and Johannsdottir (2019) and Yang et al. (2017)

Planning

In the first planning stage, we sought to develop an adequate research process that would, as a result, address the deficiencies in the literature regarding electronic commerce, the metaverse, consumer behaviour, and the role of influencers. Next, we established the objectives and research questions we sought to address in this review. These questions are key to the development of the entire process (Kitchenham & Charters, 2007; Xiao & Watson, 2019).

Databases and search string

The databases used were WoS (Web of Science), which is commonly used in reviews and is renowned in the field of research for its quality and rigorous controls. We also searched the Scopus database, which provides a wide collection of rigorous, peer-reviewed academic papers. After various tests to refine the search string, the following was formed: [("ECOMMERCE" OR "E-COMMERCE" OR "METAVERSE"), AND ("FASHION") AND ("INFLUENCER") AND ("CONSUMER" OR "CONSUMER BEHAVIOUR")]

Screening and assessment of articles

We systematically selected and evaluated articles from the databases, including those relevant to our objects of study. A series of generally accepted criteria, which were developed in several steps, had previously been defined. First, we conducted an initial review of the title and abstract, followed by reading the texts of those considered likely to be included in our analysis. For this process, we used appropriate tools to ensure the consistency of the methodology with our objectives and research questions. The articles for which no agreement was reached were resolved through collaborative authorship, reducing bias.

As a result of the selection phase, 201 articles were obtained from WOS and Scopus that met the initial criteria established, with the search terms appearing in the keywords, title, or abstract. The exclusion criteria established

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in Figure 1, including publication quality, language, and suitability for the research topic, were subsequently applied. Articles that appeared in both databases were also excluded. After applying these criteria, we obtained 62 articles. Figure 1 shows the flow of this analysis, based on the PRISMA methodology.

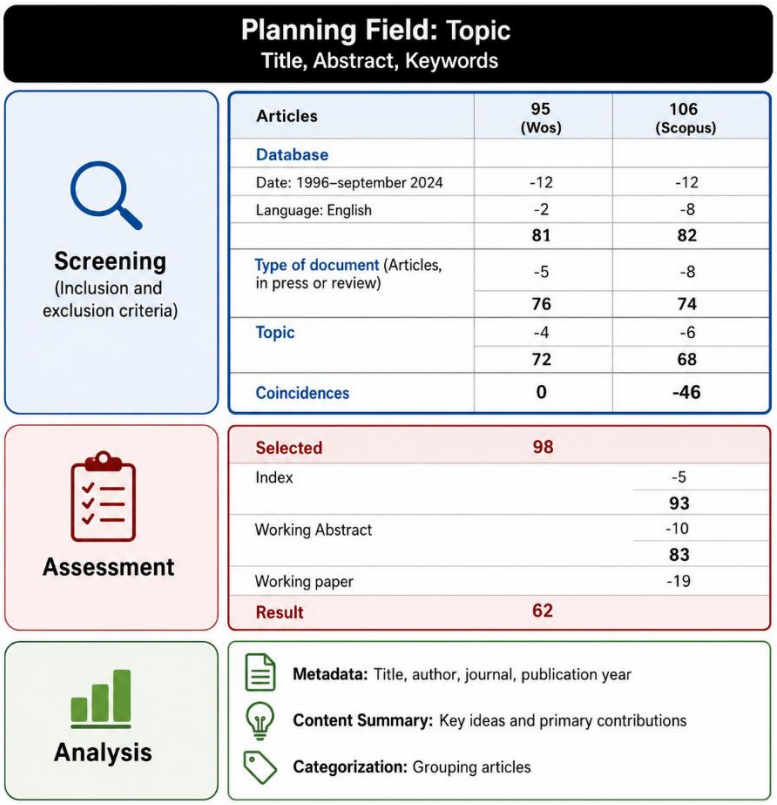


Figure 1. SLR Process
Source: Authors' own

Analysis

In this phase, the authors analysed and synthesised the articles obtained in the previous phase. To organise the process and make it transparent, we developed a database that compiles all relevant information and in which researchers work collaboratively, code the information, and follow established practices (Zahay, 2021), to reduce individual biases and improve the reliability and validity of the findings. The database was developed in a spreadsheet, including the essential aspects of the research. Finally, the information was synthesised, and the results and contributions identified were written.

4. Results

First, we conducted a descriptive analysis to provide an overview of the characteristics of the scientific production of the selected articles. Specifically, we presented the characteristics in relation to its evolution, thematic areas, main journal, methodology and theoretical background. Second, we conducted a content analysis. This analysis focused on identifying the main lines of research followed by the authors of the selected articles, as shown in Section 4.2.

The first article was published in 2015. Figure 2 shows the evolution of the documents in this line of research. Interest in this topic has also been growing in the scientific community since 2022. Our analysis of the publications revealed 10 main themes. Business, Management and Accounting, and Computer Science, with 35 and 31 publications, respectively, are followed by Social Sciences and Decision Science, with 12 and 7 publications, respectively. Figure 3 shows the distribution of the focal publications by thematic area.

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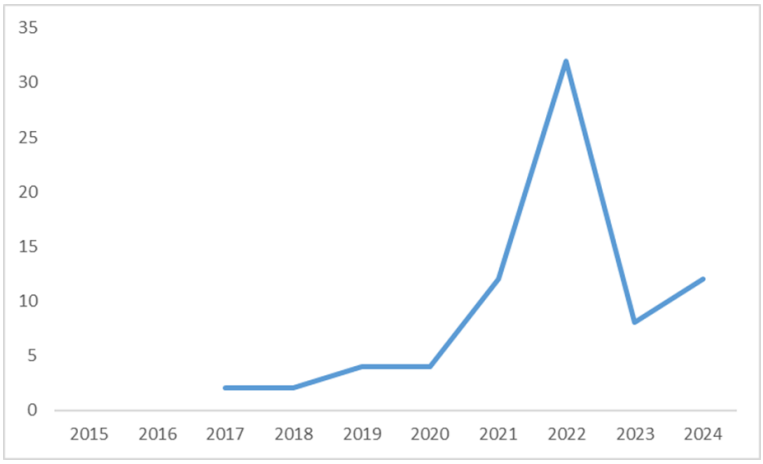


Figure 2. Evolution of publications
Source: Authors' own

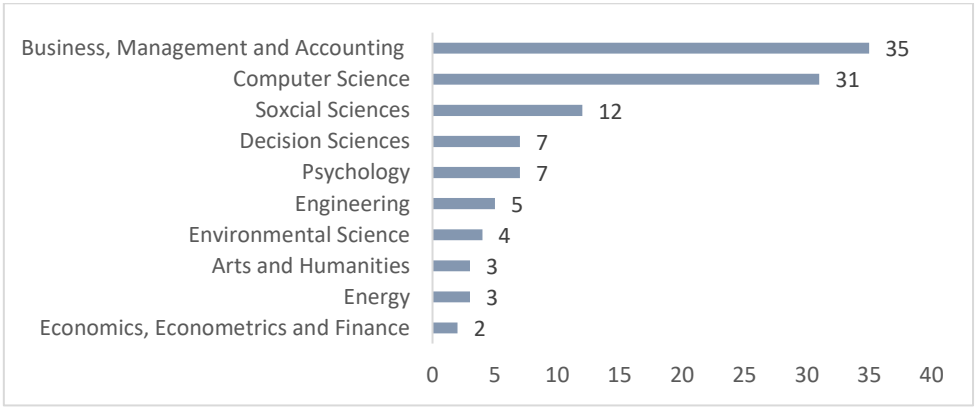


Figure 3. Distribution by thematic area
Source: Authors' own

We analysed the countries that have published works in this research area. Figure 4 shows that only ten countries have published more than two works. As the graph shows, China is the most prolific country, with twenty-four publications, followed by the United States and South Korea, with twelve publications each.

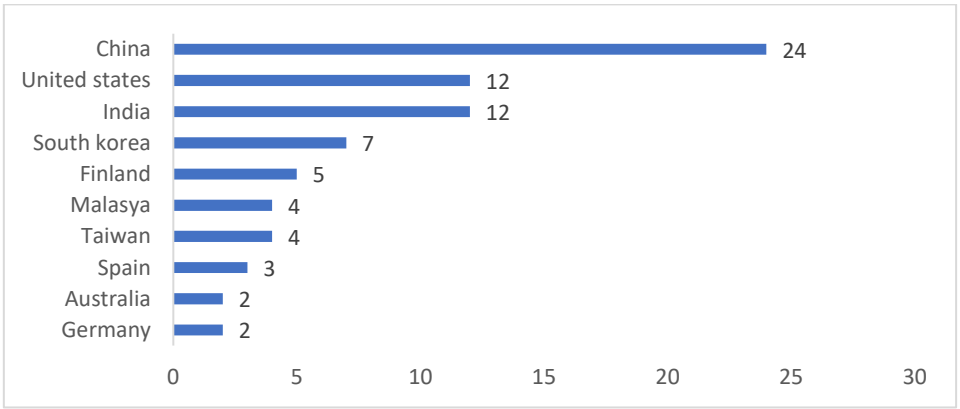


Figure 4. Countries by number of articles
Source: Authors' own

Additionally, we analysed the methodologies used in the research. We observed that 61% of the studies were quantitative, 18% were qualitative, and 8% used mixed methods (quantitative and qualitative). In quantitative studies, SEM is the most widely used technique. Quantitative research has been applied in most studies related to social commerce, live streaming, and consumer behaviour (see Figure 5).

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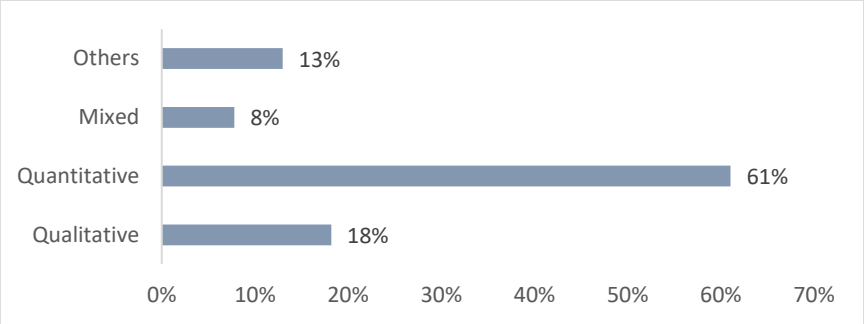


Figure 5. Research methods
Source: Authors' own

The theories used in the focal articles varied greatly, as shown in Table 1. Only 35% of the articles incorporated a theoretical framework for support. The most commonly used theories include stimulus–organism–response (SOR) theory and the technology acceptance model (TAM). Moreover, Mustafa et al. (2022) use the unified theory of acceptance and adoption and a TAM-based technology model (see Table 1).

Table 1. Theoretical framework

Theoretical framework	Author
Auction Theory	Xu et al. (2024)
Consumer value theory	Tan et al. (2022); Ng et al. (2022)
Diffusion of Innovation Theory	Chakraborty & Biswal (2024)
Dynamic Capabilities	Zabel et al. (2023)
Disruptive Technology Theory	Bhat et al. (2023)
Dual-process theory	Yuan et al. (2021)
Elaboration likelihood model (ELM)	Ng et al. (2022); Chung et al. (2018)
Embodied Cognition Theory	Huang & Chung (2024)
Emotional contagion theory	Meng et al. (2021)
Feelings-as-Information Theory	Chen et al. (2024)
Gamification Theory	Sharma et al. (2024)
Generational theory	Chung et al. (2018)
Information asymmetry theory	Xu, Cui & Lyu (2022)
Network Effects Theory	Zhang & Ye (2023)
Neuro-marketing psychology theories	Srivastava et al. (2022)
Parasocial relationship theory	Yuan et al. (2021); Xu, Cui & Lyu (2022)
Positivist philosophy	Silva & Bonetti (2021)
Psychological reactance theory	Asma & Afreen (2022)
Psychological sense of community	Lyu & Kim-Vick (2022); Lyu & Kim (2020)
Signaling theory	Srivastava et al. (2022); Tóth et al. (2022)
Social Exchange Theory	Tóth et al. (2022)
Social comparative theory	Tran (2022)
Social identity theory	Lyu and Kim (2020)
Social influence theory	Srivastava et al. (2022)
Source Credibility Theory	Garg & Bakshi (2024)

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Stimulus–organism–response theory (SOR)	Herzallah et al. (2022); Hewei & Youngsook (2022); Asma & Afreen (2022); Aafar et al. (2023); Lee et al. (2023); Payal et al. (2024); Lee et al. (2024); Lin et al. (2022)
Technology Acceptance Model (TAM)	Bae et al. (2022); Chung et al. (2018); Al Khaldy et al. (2022); Xi et al. (2024); Zhou & Tong (2022)
Transference theory	Asma & Afreen (2022)
UTAUT theory	Mustafa et al. (2022)

Source: Authors' own

The information we obtained from this SLR indicates that authors have been mostly concerned with online buyers on different platforms, such as Alibaba in Tóth et al. (2022), secondhand platforms, such as Bae et al. (2022) and Tan et al. (2022), and regular livestream viewers, such as Meng et al. (2021). With respect to the respondents' occupations, students, professionals, and practitioners have been considered, for example, by Cheng et al. (2022). Regarding age, some studies have focused on millennials and Generation Z, such as Bae et al. (2022). Finally, with respect to gender, some studies focusing on women stand out, such as that of Stofkova et al. (2022).

In qualitative studies, specifically those employing content analysis, Facebook comments have been evaluated, as in the work by Yang and Shin (2021); reviews on online shopping platforms have been investigated, as in the study by Tóth et al. (2022); fashion brands have been described, as done by Yu and Kim (2019); and Instagram posts have been scrutinised, as in the work by Saad and Yaacob (2021). Based on this analysis, we established five categories of research lines.

E-commerce marketing and strategy

Strong marketing strategies have supported the rise of e-commerce in recent years. In this context, live streaming has played an important role by influencing purchasing behaviour (Geng et al., 2022; Chen et al., 2022). It has also proven useful as a sales promotion tool, supported by influencers (Garg & Bakshi, 2024). These live streaming campaigns positively affect consumers' intention to purchase (Zhou & Tong, 2022), especially because of the trust and emotional value they perceive. Companies must thus strive to offer quality services in the metaverse to improve user satisfaction and loyalty (Kim & Yoo, 2024). Additionally, multichannel and omnichannel marketing strategies are needed for the metaverse, with fluid consumer experiences distributed across several different platforms to achieve greater effectiveness (Ramadan, 2023).

Content marketing is another influential element—a strategic communication approach aimed at attracting and retaining consumers to increase sales. Yang and Shin (2021) examined the effect of marketing actions communicated more informally, using hashtags and/or emoticons, on customer engagement, on the one hand, and the influence of the complexity of customer interactions, on the other hand. Moreover, social media influences consumers' brand awareness (Al-Dwairi et al. 2020). This brand value will provide companies with short- and long-term benefits, enabling them to retain consumers who will continue to buy their products. Consumers always remember a strong brand (Maskuro et al. 2022).

One of the main strengths of the metaverse is that immersive experience and perceived value have a significant positive effect on continued purchase intention (Hewei & Youngsook, 2022; Lee et al, 2023, 2024). To do this, the metaverse must rely on available technologies, such as machine learning and AI. Thus, Srivastava et al. (2022) use these technologies to predict consumer purchase intentions and to explore gamification as a digital marketing tool for companies and the benefits it can bring to consumer experience, engagement, and sales (Milanesi et al., 2022). Branded nonfungible tokens (BNFTs) can also enhance brand engagement in the metaverse by boosting consumer engagement and fostering loyalty through interactive, immersive experiences (Lee et al., 2023, 2024). This interactivity, through active control, two-way communication and synchronicity, significantly increases consumer trust, awareness and brand attachment (Jafar et al. 2023).

As a consequence, purchase intentions in the real world will increase. Thus, we position the metaverse as another key marketing element to transform interactions into purchases (Payal et al. 2024). These marketing actions can

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be integrated at the physical and digital levels through the enhanced second-scoring auction-based physical–virtual synchronisation mechanism to simultaneously allocate and match physical and virtual entities in the synchronisation service market of human-focused vehicular metaverses (Xu et al., 2024). Additionally, real-to-virtual platforms that rebuild their business models in the metaverse by leveraging network effects and bundling strategies are noteworthy (Zhang & Ye, 2023). These authors note that the bundling of real and virtual products, influenced by social and network effects, helps platforms differentiate themselves and capture market value.

Online consumer behaviour

Consumer purchase intention and behaviour must be explored further in relation to the sustainable growth of e-commerce (Mustafá et al., 2022). In fact, in this review, 33.7% of the articles fall within this line of research, highlighting researchers' interest in the subject and facilitating the construction of a map of positive and negative factors that influence purchase intention.

In this context, consumer trust is a key factor in the development of e-commerce, social commerce, and live streaming (Asma & Afreen, 2022; Kennedy et al., 2022; Jeon et al., 2021). The recommendation systems used by e-commerce platforms help build trust among consumers (Kennedy et al., 2022). Consumer trust in traditional commerce is transferred to online commerce, positively influencing consumers' repeat purchase intentions (Jeon et al., 2021). Buyer/seller trust and third-party recognition have contributed to the evolution of C2C e-commerce (Yoon & Occena, 2015).

The customer experience during the browsing and purchasing process is also a key factor in the development of online e-commerce. Companies can use technology to create more satisfying customer browsing experiences (Bae et al., 2022; Costa et al., 2022). There is a growing interaction between customers and platforms, which influences their purchasing behaviour. Undoubtedly, increased interactivity is a determining factor for the evolution of e-commerce and social commerce (Hewei & Youngsook, 2022; Lin et al., 2022; Lyu & Kim, 2020; Yuan et al., 2021). Some technologies, such as AI (Costa et al., 2022), AR and VR (Al Khaldy et al., 2023), stand out as elements that facilitate immersive experiences (Hewei & Youngsook, 2022; Huang et al., 2022), the use of avatars (Chakraborty & Biswal, 2024) or gamification (Milanesi et al., 2022; Sharma et al., 2024).

We have also identified a series of factors that positively influence consumer online purchasing behaviour, such as perceived usefulness, ease of use and security (Herzallah et al., 2022), eWOM (Tobon & García-Madariaga, 2021; Tóth et al., 2022), perceived enjoyment (Lin et al., 2022; Xi et al., 2024) and positive online reviews received (Chung et al., 2018). In terms of negative factors, risk perception has one of the greatest effects on purchase intentions through Instagram (Herzallah et al., 2022) and on group purchases (Ou et al., 2022), and is a main cause of shopping cart abandonment (Rejikumar & Asokan-Ajitha, 2020).

Metaverse boosters

Through this review, we also identified a category we called metaverse enhancers. It includes 10.8% of the articles. Certain digital drivers are crucial for the evolution from pure e-commerce to commerce in the metaverse, especially related to the improvement of interactivity (Gursoy et al., 2022; Hewei & Youngsook, 2022), livestreaming (Chen et al., 2022; Lin et al., 2022), and gamification (Sharma et al., 2024). An example of this improvement is the development of avatars that foster a connection between celebrities and their followers (Bousba & Arya, 2022; Brito et al., 2022). Avatars are effective patterns that can generate engagement through a variety of strategies, from humanisation to robotisation (Brito et al., 2022). On the other hand, advances in AI, VR, AR and mixed reality facilitate the introduction of digital humans (Al Khaldy et al., 2023; Chen et al., 2024; Xi et al., 2024) with a more active role in the fashion industry, which requires a deeper understanding of how consumers interact with digital humans (Silva & Bonetti, 2021). Although the evolution of the metaverse faces challenges, such as user acceptance of and integration with technology (Al Khaldy et al., 2023), nascent technologies offer compelling benefits that drive its development. Examples include improved product visualisation for users, the ability to try on an item virtually with their avatar, product customisation, and social shopping supported by influencers.

VR and AR also play key roles in transforming the customer experience, making it more immersive, thereby improving customer satisfaction (Huang & Chung, 2024), the shopping experience (Chen et al., 2024), and the

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user experience (Xi et al., 2024). Another key technological development is avatars and direct commerce with avatars (D2A) in the metaverse, which enable brands to interact with customers more directly (Chakraborty & Biswal, 2024). We also highlight innovations derived from the application of big data and algorithms (Arora et al., 2019) for various utilities, such as personalised recommendations, dynamic detection capabilities (Zabel et al., 2023), the generation of image-based listings for mobile optimisation and geolocation-based feeds (Bae et al., 2022; Grupac et al., 2022), product classifiers based on machine learning (Arora et al., 2019) and customisable purchase filters (Bae et al., 2022), as drivers of the metaverse.

All this development has, in parallel, driven the growth of online resale platforms for secondhand products, a clear example of sustainable business models (Bae et al., 2022). Another group of driving technologies includes machine learning and AI, which use different algorithms, such as natural language, decision trees or convolutional neural networks, to estimate demand in the context of e-commerce and support marketing decisions related to product design and development (Arora et al., 2019; Srivastava et al., 2022). These technologies provide more accurate information about consumers' tastes and preferences (Srivastava et al., 2022).

Generation of new sustainable business models

A total of 12.2% of the papers address new business models in the fashion world based on electronics. The metaverse will generate new basic strategies and business models, but the question of when it will achieve widespread adoption remains. Thus, companies must already prepare for possible transformations in digital product sales and customer engagement (Büchel & Spinler, 2024). The increase in purchases of fashion products through e-commerce has driven the adoption of innovative practices that are leading us towards the development of new, more sustainable business models (Silva & Bonetti, 2021). Among these business models, we highlight secondhand platforms (Bae et al., 2022), collaborative economy platforms (Tan et al., 2022), online group purchases on community e-commerce platforms (Ou et al., 2022), subscription boxes (Andonova, Anaza, & Bennett, 2021), and the development of C2C social commerce (Saarijärvi et al., 2018; Yoon & Occena, 2015; Yrjölä et al., 2017).

Since these are new business models, researchers have addressed various aspects of them. In the case of online used-product sales platforms, Bae et al. (2022) explore technology-based strategies as a starting point for advancing research into technological innovations that contribute to their development. Other authors focus more on factors related to the consumer as a driver of these new business models (i.e., Andonova, Anaza, & Bennett, 2021; Ou et al., 2022; Tan et al., 2022). For their part, Bhat et al. (2023) indicate that new financial business models (Fintech) can exploit emerging technologies, including the metaverse, to improve their services.

The role of influencers

In the fashion industry, influencers play a crucial role in boosting sales and improving the effectiveness of promotions, thus driving the development and evolution of online commerce (Molina-Prados et al., 2021; Garg & Bakshi, 2024). Influencers are social agents with a wide reach and great capacity to influence the purchasing decisions of their followers, both in social commerce (Lyu & Kim, 2020; Meng et al., 2020; Tobon & García-Madariaga, 2021; Geng et al., 2022; Le & Aydin, 2022) and in traditional commerce (Ma, 2021; Wang et al., 2021; Zhou & Tong, 2022). Thus, unsurprisingly, there is great interest in analysing in depth the characteristics of influencers and their effects on purchase intentions. For example, personality and attractiveness are highlighted as characteristics that influence experience and perceived value and subsequently purchase intentions (Xu & Kim, 2022) or as moderators in the case of live streaming (Lyu et al., 2022). Furthermore, popularity (Cheng et al., 2022; Lyu et al., 2022), fairness (Stubb & Colliande, 2019), reputation, and perceived authenticity are also influential characteristics of influencers that affect purchase intentions (Le & Aydin, 2022). Influencers' credibility also positively influences consumers' experience and perceived value (Xu & Kim, 2022; Chaudhry, 2022; Garg & Bakshi, 2024), provided they do not engage in unethical practices (Chaudhry, 2022). Given the influence influencers have on purchasing intentions, it is interesting to develop mechanisms to measure their real impact on online commerce platforms, especially on social networks (Arora et al., 2019).

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The evolution of technology has enabled the emergence of digital avatars, which are becoming effective digital influencers due to the engagement they generate (Brito et al., 2022). These avatars help build relationships between companies and customers, boosting brand awareness, promoting their products, and fostering trust that translates into increased sales (Moreira et al., 2022).

In relation to the sectors in which new metaverse business models may emerge, Kou et al. (2023) suggest that tourism is the most promising sector for sustainable investments in the metaverse, with a focus on organisational effectiveness and on reducing environmental impact through clean energy. However, Singh et al. (2024) identify five key issues (physiological, psychological, legal, security and social) that can negatively impact customers in the tourism and hospitality sectors.

5. Implications of the obtained results

The transition of e-commerce towards a metaverse-based model is in an incipient state, with many unknowns yet to be clarified and progress in the research area. The results of the content analysis of articles published from 2015 to 2022 provide a general overview of research on the subject. We highlight the following as the main objects of study: on the one hand, the behaviour of the fashion consumer before e-commerce and the metaverse, and on the other hand, the role that influencers play in the purchasing process. Interest in the subject stems from diverse thematic areas, mainly business, management, accounting, and IT, as evidenced by the number of publications. Regarding the journals, we did not identify any with greater specialisation; rather, most published a small number of articles. The most productive countries are China, the United States and South Korea. Methodologically, quantitative studies stand out. These data indicate that this research area has attracted the scientific community's interest but remains underdeveloped.
Based on this analysis, we identified five categories of published articles on e-commerce and the metaverse. Table 2 shows the number of articles by category. We observe that the line of research that has attracted the most interest in the academic community is "Online Consumer Behaviour", accounting for 33.7% of the articles published.

Table 2. Percentage of articles by category

Categories	% Articles
E-commerce Strategy and Marketing	22.1%
Online Consumer Behaviour	33.7%
Metaverse drivers	10.4%
New business models	11.7%
Role of influencers	22.1%

Source: Authors' own

The first category is "E-commerce Strategy and Marketing", which describes how the metaverse leverages cutting-edge technologies to create new marketing strategies, for example, using live streaming (Chen et al., 2022; Geng et al., 2022) or influencers who expand their reach and build consumer trust (Garg and Bakshi, 2024). The articles analysed indicate that interactive and immersive experiences, facilitated by nonfungible tokens (NFTs) and reinforced by omnichannel marketing, can influence consumer purchase intentions (Kim & Yoo, 2024; Lee et al., 2023). Additionally, content personalisation and the use of gamification and AI tools, such as machine learning, improve the prediction of consumer tastes and behaviour (Srivastava et al., 2022; Milanesi et al., 2022). The development of strategies focused on creativity and user engagement favours e-commerce in the metaverse and builds customer loyalty.

The second category identified in our analysis is "Online consumer Behaviour". Consumer trust is a critical factor in the successful implementation of e-commerce in the metaverse (Kennedy et al., 2022; Asma & Afreen, 2022). Trust can be reinforced by the use of new technologies such as AR and VR (Costa et al., 2022; Hewei & Youngsook, 2022). On the other hand, risk perception is one of the most important factors leading to negative online shopping behaviours, such as cart abandonment (Rejikumar & Asokan-Ajitha, 2020; Herzallah et al., 2022). However, the metaverse, with its interactive capabilities and consumer engagement, can mitigate these risks and convey a sense of security in a personalised way (Lin et al., 2022).

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The third category is "Metaverse drivers". Technological advances, such as AI, VR, and AR facilitate the transition of current e-commerce to the metaverse. These elements improve interactivity and consumer engagement. Additionally, the use of avatars facilitates stronger connections between brands and their customers, creating unique interaction experiences that cannot be replicated in traditional e-commerce (Bousba & Arya, 2022; Brito et al., 2022).

The drivers of the metaverse facilitate better product visualisation and virtual testing, thereby improving consumer satisfaction and engagement (Chen et al., 2024; Huang & Chung, 2024). The challenges of user acceptance of technology and its technical integration must be addressed to realise the potential of the metaverse. (Al Khaldy et al., 2023). As these technologies evolve, deeper integration between the physical and virtual worlds of the metaverse will be promoted. The fourth category includes new business models. The metaverse will revolutionise traditional business models, particularly in the fashion industry. More sustainable business models will emerge that focus on secondhand platforms and collaborative economies (Bae et al., 2022; Tan et al., 2022). These platforms exploit the synergies of the metaverse by grouping real and virtual products, thereby contributing to brand differentiation and increasing customer loyalty (Zhang & Ye, 2023).

The rise of C2C social commerce and online group-buying models demonstrates the metaverse's ability to transform customer relationships and drive more sustainable business practices (Yoon & Occena, 2015; Saarijärvi et al., 2018). Companies must be prepared for this change, developing strategies that facilitate fluid transitions between the sale of physical and digital products and customer interactions (Büchel & Spinler, 2024).

Finally, we grouped the studies that analyse the "Role of influencers" in this environment into a fifth category. Influencers undoubtedly play a key role in encouraging consumer participation in sectors such as fashion or social commerce. Personality, attractiveness and transmitted confidence clearly affect consumers' purchase intentions (Xu & Kim, 2022; Le & Aydin, 2022). They are thus shown to be social agents with a wide reach and a strong capacity to influence consumer behaviour (Meng et al., 2020; Tobon & García-Madariaga, 2021). Furthermore, the emergence of digital avatars as influencers enables brands to interact with consumers in innovative ways, reinforcing brand loyalty (Brito et al., 2022) and building trust (Moreira et al., 2022).

6. Conclusion

Based on a systematic literature review of 62 articles published from 2015 to 2022, this study explored the shift from traditional e-commerce to metaverse commerce, focusing on new technologies and social influencers in the fashion sector. The analysis was organised around three research questions: firstly, *what are the categories of articles published to date?* Secondly, *can a taxonomy of current research on these topics be identified?* And, thirdly, *what gaps exist in the literature on e-commerce, the metaverse, consumer behaviour and social influencers, and what future research directions should be pursued?*

Regarding the first question, we have identified five generic research categories: e-commerce strategy and marketing, online consumer behaviour, metaverse drivers, new business models, and the role of influencers. Online consumer behaviour was the most researched among these categories, reflecting notable academic interest in trust, engagement, interactivity, and purchase intention, especially in virtual environments.

For the second question, this study establishes a taxonomy that organises existing knowledge of the interrelation between e-commerce and the metaverse. The outcome reveals that the metaverse is set to revolutionise e-commerce by combining futuristic technology with unique methods to deliver more effective, immersive consumer experiences. New technologies like AR, VR, and AI make personalised content possible and improve predictions of consumer trends, resulting in better marketing activities, greater involvement, and greater consumer buy-in. Similarly, the metaverse also encourages new sustainable business models, especially in sectors such as fashion, which is growing faster through secondhand platforms and collaborative economies. In response to the impact of influencers, the results find that influencers, human or digital avatar, are essential to improve consumer participation, influence purchase intention, develop brand loyalty, and build trust in these new virtual environments. Consumer trust plays a pivotal role in successful interaction in metaverse commerce,

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and personalisation and interactivity have been shown to contribute to a better user experience and a greater sense of security.

Regarding the third question (RQ3), the study identifies several significant research gaps. Consumer risk perception is an ongoing issue and is associated with negative online shopping behaviour, such as shopping cart abandonment. Future research thus needs to continue investigating mechanisms to reduce perceived risk through immersive and personalised experiences. Also, more research is needed on cross-country differences, gender-related behaviours, socioeconomic barriers to adopting the metaverse, and strategies to integrate sustainability and circular economy elements into metaverse-based business models.

Thus, this study adds to the academic literature by advancing an integrated approach to metaverse commerce, transitioning from its current form of e-commerce within the fashion industry. This analysis is novel, as it enables a systematic taxonomy in which consumer behaviour, influencer marketing, new-age technology, and viable business models can be closely associated. The findings additionally emphasise the strategic significance of immersive technologies and digital influencers in future online consumption experiences.

7. Limitations of the research and future lines

This study has several limitations. First, our SLR included only peer-reviewed scholarly articles published in English, from the first publications to 2022; we did not include conference proceedings or articles published in media, which, owing to the novelty of the focal phenomenon, could also offer some interesting contributions. Second, the review included articles published in WoS and Scopus, which, according to authors such as Harzing and Alakangas (2016) and Zhang and Eichmann-Kalwara (2019), are the main repositories of scientific publications and the most appropriate databases for our study. Thus, we excluded other publication types.

With respect to future lines of research, in line with Mumu et al. (2022), deepening understanding of trust across different contexts (platforms, influencers, and streamers) would be of interest. Furthermore, following the recommendations of Kennedy et al. (2022), certain factors that influence consumer behaviour on online platforms, such as order management, product variety, company image and reputation, and trust in their recommendation system, including online payments, should be explored (Stofkova et al., 2022).

From a gender perspective, as this is a relevant aspect increasingly integrated into marketing, it can facilitate segmentation and provide significant value. In addition to the gender variable, it would be interesting to explore the social and economic barriers to accessing the metaverse, consuming it, and interacting with and establishing relationships in this space. The differences across various countries could be analysed to evaluate the adoption variables in this new panorama. These aspects will be relevant for brands, companies and metaverse developers themselves when establishing the usability and functionality of the spaces in this area. Finally, it is critical to study and assess how the values of sustainability and the circular economy can be applied to the creation, development, and sale of NFTs (fashion products) in the metaverse, following Castillo-Alcántara (2022) regarding their innovative production in Spain.

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THE IMPLEMENTATION OF EUROPEAN DIRECTIVES: IMPACT ON MACROPRUDENTIAL SUPERVISION OF THE BANKING SECTOR AND FINANCIAL STABILITY

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Abstract. One of the major achievements of the Financial Stability Forum was the development, in partnership with the International Monetary Fund and the World Bank, of a key instrument for global financial supervision, namely the Financial Sector Assessment Program. This document, which substantially influences the policies that shape the development of the financial system, focuses on the European regulatory framework, including directives and capital requirements, as well as bank recovery and resolution. As a result, the implementation of European Union directives in the Republic of Moldova is the central pillar of the modernisation and securitisation of the financial sector, directly and profoundly impacting the country's economic stability. The adoption of these directives acts as a protection mechanism against crises and systemic fragility. In this context, the article aims to analyse macroprudential supervision, its impact on financial stability, and the extent to which the Republic of Moldova is prepared to participate in the conceptual framework for the systematisation and implementation of European directives.

Keywords: macroprudential instruments; debt service-to-income (DSTI); loan-to-value (LTV); countercyclical capital buffer; capital requirements; financial stability; macroprudential supervision; monetary policy (MP)

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JEL Classifications: E4, E5, E6, K10, K20

1. Introduction

Previous analyses and assessments of macroprudential policies from a financial stability perspective have largely been forgotten since the 2008 global financial crisis. Still, when anyone applies for a mortgage loan, two conditions are met: a maximum debt-to-income ratio and a minimum down payment. These are direct systematisations of the implementation of macroprudential instruments on borrowers in the form of DSTI (debt service-to-income) and LTV (loan-to-value).

To maintain financial stability, we anticipated that the potential for adverse side effects would be significantly higher under system-based regulation, with new indicators for analysis and monitoring and new public policy instruments being developed. Macroprudential policy plays a key role in ensuring financial stability, but it is not the only one in this endeavour (Polzer, Grossi & Reichard, 2022; Kenig, 2023). Macroprudential policy aims to safeguard the financial system's stability through proactive risk management. Strengthening institutional resilience and mitigating systemic vulnerabilities prevent financial disruptions and foster long-term, stable economic development (Chen, Deng & Peng, 2024). Microprudential policy acts in the same direction, by maintaining the health of the entities that make up the financial system (Gasparini et al., 2026).

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At the same time, financial stability is maintained if the monetary policy (MP), in accordance with the Long-term Monetary Policy Strategy of the National Bank of Moldova (NBM), to ensure and maintain price stability in the medium term, will maintain inflation (measured by the consumer price index) at the level of 5.0 percent annually with a possible deviation of ± 1.5 percentage points, this being considered the optimal level for the growth and economic development of the Republic of Moldova in the medium term.

If we talk about the resolution policy, it ensures that, in the event of a crisis, situations are adequately managed. Resolution tools protect the public interest in maintaining financial stability. They are applied when they are necessary to achieve the resolution objectives, namely, when the bank cannot be liquidated in accordance with the forced liquidation procedure, as this could destabilise the financial system. Infrastructure policy (the payment and settlement system is critical) helps maintain financial stability.

Countercyclical policies cannot be separated from systemic risk, since the countercyclical capital buffer helps manage it. This macroprudential instrument requires banks to accumulate additional capital during periods of excessive credit growth. The NBM has decided to increase this rate from 0.5% to 1.0% (in November 2025), to reach 1.5% in May 2026, to strengthen the resilience of the banking sector. Such a correlation can arise through various channels: engaging in investment activities, using common funding sources, interbank connections, and the convergence of risk management practices and trading strategies. To make the results measurable and ensure the transparency of decisions, policies have well-established final objectives.

We have highlighted several essential components of macroprudential policy: management of cyclical problems (accumulation of systemic risks); management of structural problems (resilience of the financial system); transversal dimension of risks. These components are monitored by the responsible authority in the Republic of Moldova, pursuant to Law no. 209/2018 on the National Financial Stability Committee (hereinafter – CNSF Law), the National Financial Stability Committee (hereinafter – CNSF) is the designated national macroprudential authority responsible for coordinating the implementation of macroprudential policy. CNSF members are representatives of the authorities that play an important role in maintaining financial stability: the NBM, the Ministry of Finance, the Ministry of Economic Development and Digitalisation, the National Commission for the Financial Market, and the Deposit Guarantee Fund in the Banking System. Also, the national framework for maintaining financial stability is completed by Law no. 232/2016 on bank recovery and resolution and Law no. 575/2003 on deposit guarantee in the banking system. The bank recovery and resolution framework provides a structured set of guidelines and mechanisms designed to manage failing financial institutions while preserving financial stability and minimising taxpayer exposure. NBM is a competent authority, as well as a resolution authority within the meaning of Law no. 232/2016 (see EUR-Lex, n.d. a,b,c,d).

2. Theoretical background

Each country in the European Union has established its own macroprudential authority. Macroprudential policy is designed and implemented by the macroprudential authority. For a central bank, it is important to know these effects as well as possible, because the institution is involved either directly or indirectly in the management/regulation of monetary policy, macroprudential policy, microprudential policy and resolution policy.

Thus, according to the Calvo model (or Calvo staggered contracts) (Nimark, 2005) being an economic mechanism used in neo-Keynesian macroeconomics to explain why prices do not adjust instantly to changes in the economy (a phenomenon known as nominal rigidity or sticky prices), three main types of institutional arrangements for financial supervision can be identified globally: the sectoral model, the integrated model and the partially integrated model.

In the case of the sectoral model (considered the traditional model), a national authority manages powers in the field of prudential banking supervision and usually also exercises supervisory duties over the business conduct of credit institutions (business conduct supervision). By conducting supervision, we must monitor how banks comply with their obligations to customers. Another authority deals with the insurance sector, and another with the capital market. We encounter this model in Spain, Luxembourg, Portugal, Slovenia, Bulgaria and Romania.

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It is important to note that this model was widespread 20 years ago, but as the lines of separation between financial sectors have become more transparent and clearer in some countries (e.g., the universal bank model allows the combination of specific lending and deposit activities with investment activity, such as offering fund units or underwriting on the occasion of corporate bond or government securities issues; also, in some countries mortgage loans can be offered not only by banks, but also by insurance companies or pension funds), supervisory authorities have also merged and partially or integrated. In the case of the integrated (or unified) model, a single national authority – which can be the central bank or a separate authority – concentrates all powers of prudential supervision, business conduct/consumer protection, with responsibility for monitoring all sectors of the financial system. This model was introduced in the mid-1980s, first in Singapore (1984) and then in Europe, particularly in the Scandinavian countries, but became famous with its implementation in the United Kingdom in 1997, through the establishment of the Financial Services Authority (FSA). Currently, in Europe, we find this model organised around the central bank in Ireland, the Czech Republic, Hungary, Slovakia, and the one integrated into a separate authority in Germany, Austria, Denmark, Sweden, Finland, Estonia, Latvia, and Poland. This model groups supervisory responsibilities among several authorities, depending on the political objectives for the development of the respective sectors. Two variants are known: "Twin Peaks" and the "Two-Authority Model". The model called "Twin Peaks", proposed by Taylor (2021) and applied the following year in Australia, starts from the premise that the function of regulating and supervising the financial market has two different primary objectives: that of ensuring the financial health of the system and that of protecting consumers from "unscrupulous operators". Since these objectives may conflict, they must be pursued separately to avoid confusion and problems. Taylor (2021) proposes assigning these objectives to two distinct authorities, one of which should deal strictly with the robustness of the financial system, including the banking, insurance and capital market sectors (e.g. to prevent the collapse of banks or insurance, thus protecting the entire economic system, to prevent abuses and to ensure that beneficiaries of financial services are treated fairly, etc.), and the second to ensure that institutions operating in these markets offer consumers fair services. In Europe, we find this model in the Netherlands, Belgium and the United Kingdom. An effective macroprudential policy needs durable and vigorous institutional foundations. And to achieve its objectives, macroprudential policy must overcome the inertia that can arise from inaction or late intervention.

Macroprudential policy is prone to such procrastination tendencies (inaction bias) because:
• the costs of the measures are immediate and visible, while the benefits only manifest themselves in the long term;
• the benefits are abstract and difficult to quantify (for example, it is difficult to demonstrate that the absence of a crisis is directly due to a particular policy);
• the costs are directly felt by specific interest groups in the financial industry, who can exert political pressure.

While fostering the willingness to act, institutional arrangements should ensure the capacity to act by providing macroprudential policymakers with appropriate powers. Finally, because of the close interdependence between micro- and macroprudential supervision, as well as the complex interactions among fiscal, monetary, and macroprudential policies, institutional arrangements need to ensure effective coordination among different authorities.

Any macroprudential framework put in place should be responsive to the emergence of new vulnerabilities, adapt as experience is gained, and ensure continued effectiveness. Good communication is essential at every stage of the macroprudential policy process (Table 1).

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Table 1. Roles and functions of a Central Bank

	Monetary stability	Financial stability
The role	Maintaining currency stability	Ensure seamless market operations and prevent economic imbalances.
The functions	1. Issuance of currency 2. Regulation of monetary conditions (the implementation of monetary policy to ensure price stability and preserve the currency's purchasing power).	1. Safeguarding payment infrastructures to prevent systemic disruptions and ensure settlement finality 2. Providing backstop liquidity to curb contagion and mitigate liquidity-driven systemic crises 3. Banking supervision

Source: authors, based on Moenjak (2017), p. 39.

In terms of the transparency and accountability of macroprudential policy, practices differ across countries (Nardo et al., 2017; Andrieş, Nistor & Sprincean, 2020; Kremen et al., 2021; Kladakis, Chen & Bellos, 2022).

"Post-meeting transparency practices vary widely across global macroprudential frameworks. Disclosure ranges from concise summaries of discussion points, as seen in France and Poland, to the detailed risk assessments published in the United Kingdom. These variations are often a function of the authority's institutional structure. Central bank-led models tend to adopt established monetary policy communication standards. In contrast, inter-agency bodies, like the Financial Stability Oversight Board in the U.S., integrate minute publication into standard public governance protocols (IMF Country Report No. 22/263).

Central bank frameworks must account for the secondary impacts of monetary actions on systemic financial stability. In this context, macroprudential policy has a key role in ensuring financial stability, but it is not the only one in this endeavour.

Resolution policy, being a set of administrative and financial measures, in the Republic of Moldova, the National Bank of Moldova (BNM) acts as the resolution authority, with the power to apply recovery measures and manage the Bank Resolution Fund. The Single Resolution Mechanism (SRM) will apply to banks in euro area Member States and to EU countries that choose to join the Banking Union, to ensure an orderly resolution of failing banks, with minimal costs to taxpayers and the real economy.

To ensure transparency and accountability, macroprudential policy should be employed to mitigate any undesirable side effects of monetary policy on financial stability. These effects typically manifest in borrower behaviour, excessive risk-taking by financial institutions, asset price volatility, and exchange rate fluctuations that affect trade competitiveness (Oyadeyi et al., 2026).

The borrower's balance sheet channel describes how shifts in interest rates affect creditworthiness. Lower rates stimulate demand by increasing net worth and encouraging higher leverage. In contrast, higher rates diminish collateral value and cash flows, restricting access to new financing as borrowing costs rise (Ciccarelli, Maddaloni & Peydró 2013; Mistrean, 2024).

The 'implicit channel' suggests that tightening monetary policy can deteriorate borrower credit quality, leading to higher default rates. Recognising this link is crucial for crisis prevention, as it highlights how rising interest rates expose underlying financial vulnerabilities (Allen, Carletti & Gale, 2000; Goodhart et al., 2009).

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Through the balance sheet channel, higher nominal rates tighten payment-to-income constraints. This process erodes borrower net worth and collateral value, leading to credit rationing and increased financial fragility (Gertler & Gilchrist, 1994; Bernanke, Gertler, & Gilchrist, 1994; Clichici, Dragoi & Covalschi, 2025). The Transmission Channels of Monetary Policy to Financial Stability and the Corresponding Macroprudential Mitigants are summarised in Table 2 below.

Table 2. Transmission Channels of Monetary Policy to Financial Stability and Corresponding Macroprudential Mitigants

Systemic Risk Factor	Transmission Channel	Impact of Policy Tightening (↑ r)	Macroprudential Tools to Limit Side Effects
Borrowing constraints	Balance sheet channel	↑	Limits on Loan-to-Income (LTI) and Debt Service-to-Income (DSTI) ratios
Borrowing constraints	Default channel	↓	Borrower-based measures to strengthen repayment capacity and reduce default risk
Risky behaviour of financial institutions	Risk-taking channel	↑	Capital buffers; leverage ratio requirements
Risky behaviour of financial institutions	Risk-shifting channel	↓	Net Stable Funding Ratio (NSFR); capital reserves
Externalities through aggregate prices	Asset price channel	↑	Loan-to-Value (LTV) ratio limits; minimum down payment requirements
Externalities through aggregate prices	Exchange rate channel	↓	Foreign exchange reserve requirements; limits on foreign currency lending; taxes on non-core foreign exchange liabilities

Source: authors, based on International Monetary Fund (2015)

Monetary policy significantly influences the risk appetite of financial intermediaries. According to Borio and Zhu (2012) and Jiménez et al. (2014), prolonged periods of low interest rates bolster bank capital ratios, incentivising institutions to expand their balance sheets and increase leverage, while potentially compromising borrower-screening standards. This phenomenon is driven by a reduction in perceived default probabilities, which leads to lower risk-weighted assets and encourages further risk accumulation. Conversely, when policy rates rise, particularly in environments characterised by maturity mismatch (short-term funding vs. long-term lending), intermediation margins may shrink. This pressure can compel thinly capitalised banks to "search for yield" by engaging in riskier lending to maintain profitability, especially when a flattening yield curve complicates traditional earnings models.

The relationship between monetary easing and asset price inflation remains a focal point of the macroprudential debate. Low interest rates can drive up real estate and financial asset valuations, fostering a feedback loop of rising leverage and collateral values—often termed the "financial accelerator" (Bernanke, Gertler & Gilchrist, 1996). However, empirical findings on this link are heterogeneous. While some argue that loose policy triggers bubbles, others suggest that the impact of interest rates on house prices is relatively modest compared to other fundamental drivers. In small open economies and emerging markets, monetary policy divergence from advanced economies introduces additional complexities. Interest rate differentials can trigger volatile capital flows, leading to currency appreciation (Hahm et al., 2012). This appreciation often masks underlying risks by encouraging unhedged foreign currency borrowing and excessive leverage. These vulnerabilities typically crystallise during the depreciation phase, creating significant systemic externalities (Bruno & Shin, 2012). *A central question for contemporary research is whether macroprudential tools can effectively neutralise the unintended side effects of monetary policy.*

Where monetary easing fuels credit expansion, targeted instruments such as Loan-to-Value (LTV), Loan-to-Income (LTI), and Debt-Service-to-Income (DSTI) ratios can serve as critical circuit breakers. For instance, DSTI limits are particularly effective in cushioning the impact of subsequent rate hikes on household solvency. However, the empirical evidence regarding the synergy between these two policy domains is mixed (see Table 3).

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Table 3. Effects of macroprudential instruments and interaction with monetary policy

Collection Position	Requirements of: Capital (CR)	Reserve LTV (LTV)	Reserve requirements (RR)	Terms of interaction: MP*CR	MP*LTV	MP*RR
Credit growth	■	■	■	□	□	□
Price increase	■	■	□	□	□	□
The price of the house	■	■	□	□	□	□

Source: the authors

The Independence Hypothesis. Aiyar, Calomiris, & Wieladek (2014, 2016) suggest that the efficacy of capital requirements on credit supply is independent of the monetary stance.

The Conditional Efficacy Hypothesis. In contrast, Tressel and Zhang (2016) find that LTV constraints are most effective when monetary policy is accommodative. Analysis of panel data (e.g., IMF surveys 2000–2011) indicates that while macroprudential measures—including capital gaps, LTV/DSTI limits, and reserve requirements—have a measurable impact on credit and house price growth, their marginal effectiveness often remains consistent regardless of the monetary policy stance. This lack of statistically significant interaction suggests that macroprudential tools function as robust, independent instruments for maintaining stability, even in highly accommodative monetary environments.

3. Research objective and methodology

Any policy generates synergies and conflicts with other policies. The last 15 years have brought the concept of "systemic risk" into the discussion to describe the shocks that have affected the global economy. At the international level, there are several definitions of systemic risk (Burucs, 2026).

Aligned with the regulatory framework of the National Bank of Moldova, systemic risk is conceptualised as the potential for widespread disruption within the financial infrastructure. Such instability poses a significant threat to both financial intermediation and the performance of the real economy, necessitating robust macroprudential oversight. At the same time, systemic risk represents a complex phenomenon, complicated to assess and monitor. Therefore they are indispensable for identifying, quantifying and monitoring the risks that can destabilise the entire financial system, through certain statistical techniques, namely:

- GARCH (Generalised Autoregressive Conditional Heteroskedasticity) models for estimating and persisting volatility and correlations between higher frequency (daily) time series are practical for indicators that monitor (systemic) stress in financial markets. They imply a series of restrictions on the parameters to avoid obtaining explosive solutions $\sum((\boldsymbol{\alpha_i} + \boldsymbol{\beta_j}) < \mathbf{1})$ or to ensure a positive variation (the parameters have positive values). The optimal number of lags (p,q) can be determined empirically by evaluating the net benefit of including additional parameters, taking into account the risk of over-parameterising the model. A *lag* represents the application of the delay operator of a certain period on a time series the first *lag* of the variable $\boldsymbol{x_t = L_{x_t} = x_t - 1}$. The Box-Jenkins methodology (Box & Jenkins, 2016) remains a cornerstone of time-series analysis,

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providing a systematic three-stage iterative process—identification, estimation, and diagnostic checking—for developing robust forecasting models. Within this framework, model selection is typically optimised using specialised information criteria designed to balance goodness-of-fit with parsimony. And to determine the optimal number of *lags*, the specification with the minimum values is chosen, using only its past and present as the database. These models enjoy wide use due to the quality of the generated forecasts, the flexibility of the models, the rigour regarding the mathematical foundation of the model and the fact that it is an appropriate method for forecasting variables that present an irregular evolution:

- Early Warning Signals (EWS), an econometric method used to estimate the probability of a crisis;

- Quantile regressions can capture interactions between variables across the entire distribution, such as financial crises. Quantiles are the basis of modern risk management methods in the financial and banking fields, the most eloquent example being the VaR (Value-at-Risk) risk measure. Quantile regressions are of two types: conditional and unconditional models. The conditional regression model is used to determine the GaR risk measure for macroprudential policy. The unconditional regression model (often related to simple linear regression or an unconditional explanatory variable approach) analyses the relationship between a dependent variable (Y) and one or more independent variables (X), assuming that the values of X are not fixed/conditional but observed. This models the mean Y as a function of X. The theory of risk assessment is based on statistical information about the moments of the distribution of financial asset prices – the mean and the variance.

Therefore, we are talking about volatility, which is the standard deviation of a financial asset's returns over a given period (usually 1 year). For example, an investor's risk appetite can be determined by the level of volatility they are prepared to accept. Investors with a high risk aversion may be interested in instruments such as bonds or government securities whose prices do not vary significantly over time, while investors with a higher risk appetite are willing to invest in assets with significantly higher volatility, such as shares. Modelling volatility in financial markets is an approach of increasing interest, including for financial stability, especially for monitoring the emergence of systemic stress.

In 2025, the National Bank continued to promote key reforms in banking regulation and legislative harmonisation, in line with European Union standards and Basel III requirements, thereby contributing to the modernisation of the banking system and advancing the European integration process. The financial situation of the banking sector during 2025 remained robust, reflecting the NBM's ongoing efforts to consolidate financial stability and bolster confidence in the banking system. During 2025, the banking system of the Republic of Moldova recorded solid positions in terms of capital and liquidity, with growth in assets, loans, own funds, and deposits from individuals and legal entities. The share of non-performing loans in total loans (prudential) remained at the level recorded at the end of the previous year, close to the lowest historical level. At the same time, banks fully complied with prudential requirements, maintaining key financial indicators at adequate levels and demonstrating a strong capacity to adapt and consolidate capital. However, banks must remain prepared to face potential challenges. In this context, it is essential to ensure prudent risk-taking and sound lending standards to prevent the accumulation of new non-performing loans. Basel III also introduced sector-specific capital requirements to control exposures to certain assets, such as mortgage/real estate loans. In addition to capital requirements, several countries have also introduced instruments targeting the demand for credit. These include loan-to-value (LTV) and debt-to-income (DTI) caps, which are designed to address the undesirable procyclicality of lending standards: fees during booms and accelerated growth during recessions. These quantitative restrictions, together with sector-specific capital requirements, aim to prevent banks from taking on large risk exposures. To the extent that these instruments temper asset expansion during the credit boom, the costs of adjustments during the recession will be significantly lower than in a no-intervention scenario. In addition, higher levels of capital serve as a buffer against losses, thereby reducing the risk of selling assets at distressed prices in times of recession. Basel III also uses liquidity requirements (such as the liquidity coverage ratio and the net stable funding ratio) to ensure that banks have adequate liquidity buffers when bank funding markets are disrupted. A related way to limit the use of secondary funding is to rely on fees calibrated to the cost difference between core and non-core funding, as well as between long- and short-term funding. A dual-objective framework characterises the current economic landscape: monetary policy aims at macroeconomic stability (inflation and output), while macroprudential measures target systemic risk. As shown in Figure 1, the

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European banking sector harmonises these efforts via the Single Rulebook, ensuring that prudential standards and directives provide a consistent regulatory environment across the Eurozone.

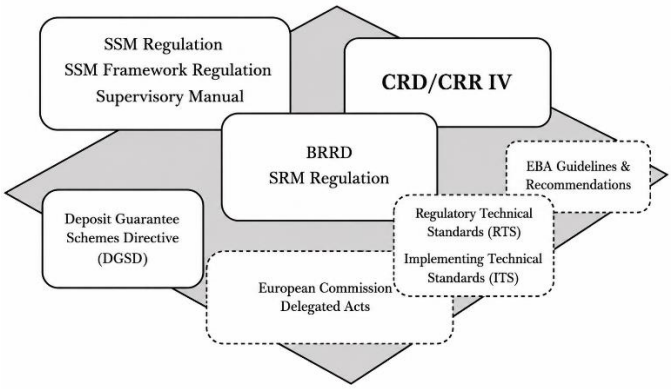


Figure 1. The single rulebook for the European banking sector
Source: the European Council (n.d).

The specialised literature from the Republic of Moldova addresses systemic risk, including the implementation of European directives on macroprudential supervision and its impact on financial stability, using statistical techniques (Secrieru, 2022; Stakhova, Zhyvko & Petryshyn, 2023; Paslari, 2023; Ababii, 2024).

The Moldovan academic and institutional landscape has seen a significant shift toward adopting sophisticated quantitative methodologies to address financial stability and macroprudential oversight. Central to this evolution is the integration of advanced time-series analysis and non-linear modelling to navigate the specificities of an emerging market.

1. Forecasting and Macroeconomic Volatility Building on the foundational Box-Jenkins methodology (Box & Jenkins, 2016), researchers have applied these iterative processes to forecast capital market indicators and inflation trends within the national economy (Bogatencov et al., 2021). This is complemented by the work of Mija (2022), who pioneered the application of GARCH (Generalised Autoregressive Conditional Heteroskedasticity) models to estimate exchange rate volatility and develop Early Warning Systems (EWS) for banking crises in the Republic of Moldova.
2. Risk Management and Systemic Resilience in the banking sector, the focus has shifted toward tail-risk assessment and shock resilience. Cobzari has utilised regression models to identify correlations between macroeconomic stability and external shocks, establishing a basis for early warning indicators (Cobzari et al., 2001; Cobzari & Mărgineanu, 2013; Cobzari & Ștefîrță, 2018).
3. Quantile Regression and Non-Linear Dynamics: a notable trend in recent Moldovan scholarship is the use of Quantile Regression to move beyond average effects and analyse extreme economic conditions. Public Sector Efficiency. Scientists have applied these methods to examine competitiveness and growth disparities (Sârbu & Cimpoieș, 2018; Moraru, 2025). Institutional application: the National Bank of Moldova (BNM) has integrated Growth-at-Risk (GaR) frameworks—a methodology championed by the IMF—to estimate the distribution of future GDP growth based on prevailing financial conditions.
4. Toward a Harmonised Macroprudential Framework. The convergence of these individual research efforts provides a robust foundation for systematising the assessment of EU macroprudential directives. By synthesising high-frequency data monitoring (such as the Financial Stress Index) with the econometric models, current research aims to quantify the impact of European regulatory alignment on the long-term stability of the Moldovan financial system.

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4. Results and Discussion

The Single Supervisory Mechanism (SSM) is widely regarded as the cornerstone of the Banking Union for several key reasons. First, it was the pioneering pillar to become fully functional (November 2014).

Second, the scope of its continuous supervisory activities covers the most significant institutions within the Eurozone. Consequently, its robust framework is essential for maintaining market discipline and operational integrity across the European banking landscape. At the same time, the origins of the SSM are older; the idea of creating a supranational banking supervision system has been discussed, including in the European Parliament, several times since the early 2000s. For example, this proposal appears clearly in the European Parliament's resolution of 13 April 2000 on the European Commission's communication on the time horizon for the implementation of the 1999 financial markets action plan (European Commission, 1999).

At that time, however, Member States were not yet ready for such a fundamental change, which would have implied the surrender of sovereignty in a key area of their economies. Established by Council Regulation (EU) No. 1024/2013, the SSM Regulation empowers the European Central Bank to perform specific tasks in the prudential supervision of credit institutions. As an EU Regulation, the act has direct effect and is binding on all Member States. Starting with 4 November 2014, one year after the entry into force of the specific regulation, the SSM became fully operational, and the ECB began to effectively exercise its new tasks in the field of prudential supervision of credit institutions in the Eurozone. According to point 12 of the preamble of the SSM Regulation, this first step towards the establishment of the Banking Union was intended to ensure the coherent and effective implementation of the common policy in the field of banking supervision, the uniform and rigorous application of the single regulatory framework. It is also mentioned that this mechanism creates the prerequisites for large banking groups to be subject to prudential supervision to the highest quality standards, without prejudice from political or other interventions. The main objective of the SSM is to restore society's confidence in the financial markets, confidence that was seriously affected by the developments of the financial crisis which in the first phase generated huge losses in the banking sector, and in the next phase undermined the functioning of the government securities market, through the negative feedback loop between these financial instruments and the banking sector, endangering the very existence of the single currency. At the heart of the new financial supervision system is the ECB, which works with the "national competent authorities" (NCAs) of the participating Member States (the institutions exercising prudential supervision powers at the national level) that are part of the mechanism. The ECB's choice to exercise these supervisory powers, although criticised, was not surprising. First, in many EU Member States, the task of prudential supervision falls to the central bank. An alternative would have been to choose the EBA rather than the ECB, but this option was ruled out for political and legal reasons. Thus, according to the Meroni doctrine, prudential supervision of credit institutions in the Eurozone can only be exercised by a specialised body of the Eurozone, a condition that the EBA does not meet, and the creation of a new institution, strictly dedicated to this activity, would have required amending the Treaty on the Functioning of the European Union, a complicated and lengthy process.

The SSM Regulation addresses the 'conflict of objectives' dilemma by mandating a clear separation between the European Central Bank's monetary and supervisory functions. Article 25 specifically outlines the procedural and organisational safeguards designed to ensure that supervisory decisions are made independently of monetary policy considerations. The practical solution to this consists of clearly stating the principle of separation and applying organisational and corporate governance measures, which together form the so-called “Chinese wall”: the supervisory and monetary policy functions are located in different buildings (the supervisory function in the institution’s former headquarters), with different reporting and decision-making lines and distinct governance structures, which will be presented in detail below. The creation of the SSM required aligning the EBA’s tasks with the new institutional philosophy and clearly separating the prudential supervision and banking regulation activities. The establishment of the SSM necessitated a revision of the European Banking Authority's legal framework. Consequently, Regulation (EU) No. 1022/2013 was adopted to harmonise the EBA's functions with the new prudential supervisory powers granted to the ECB by Council Regulation (EU) No. 1024/2013. Thus, the EBA's mandate was strictly limited to developing the single rulebook, including regulatory or implementing technical standards adopted at a later stage by the European Commission, or issuing guidelines and recommendations addressed to prudential supervisory authorities or

directly to financial intermediaries. These legal acts, which EBA originated, are also binding on the ECB. Given the size of the two institutions, there was a need to create the conditions for closer coordination between them, so that EBA representatives could participate in the meetings of the ECB Supervisory Board and vice versa, ECB representatives in those of the EBA Committee of Supervisors, even if without the right to vote. Some authors close to the European decision-making process (Boccuzzi, 2016) suggest that the ECB has made a consistent contribution to the development of the single rulebook by the EBA over time and that it has often advocated insistently for the issuance of certain regulatory acts as quickly as possible and has decisively influenced their final form. Regulation (EU) No. 1022/2013 confers some regulatory powers on the ECB. Still, these are limited to measures necessary to organise and clarify the way the tasks arising from the SSM Regulation are carried out. The SSM applies automatically to the Member States of the European Union that have adopted the euro and is optional for those with a derogation. They can participate in the SSM and implicitly in the Banking Union through the close cooperation procedure, provided for in the SSM Regulation in art. 7 – "Close cooperation with the competent authorities of participating Member States whose currency is not the euro". Subsequently, to detail the conditions and functioning of this close cooperation procedure, the Governing Council of the ECB issued Decision ECB/2014/5 (2014/434/EU) of 31 January 2014.

Conclusions

The banking supervision priorities for the period 2026–2027 reflect the National Bank of Moldova's (NBM) medium-term banking supervision strategy for the next two years. NBM sets priorities based on a comprehensive assessment of the main risks and vulnerabilities for licensed banks. They are reviewed annually to reflect developments in the risk profile, as well as the results of various supervisory exercises, in particular the conclusions of the Supervisory Review and Evaluation Process (SREP), as well as the progress made in implementing the priorities set in previous periods. These priorities ensure an efficient allocation of available resources within the banking supervision process and, if necessary, can be adjusted, depending on the evolution of the risk spectrum. During 2026–2027, the NBM will focus its supervisory efforts on identifying, assessing, and appropriately managing relevant risks in key areas of banking supervision, through on-site inspections, to maintain a sound and sustainable banking sector.

The banking supervision priorities for 2026–2027 reflect the need for banks to remain resilient to geopolitical risks, macroeconomic uncertainties, and risks related to core activities. They aim to address vulnerabilities identified through SREP exercises and on-site inspections, while ensuring operational resilience and strong information and communication technology (ICT) capabilities.

The implementation of EU directives in the Republic of Moldova's financial sector is characterised by selective adoption, adaptation to local context, and ongoing efforts to harmonise with EU norms. While these reforms aim to enhance governance, regulatory compliance, and integration with European markets, significant challenges persist, including institutional capacity, local ownership structures, and the need to balance standardisation with flexibility. Moldova's experience reflects broader regional trends, where alignment with EU financial directives is gradual and shaped by both external influence and domestic realities.

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CIRCULAR ECONOMY: A GROWING MARKET FOR SUSTAINABLE INNOVATIONS

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Abstract. As a paradigm shift in sustainable development, a circular economy enabled by innovative business models ensures a competitive advantage by prioritising and improving resource efficiency, reducing waste and costs, creating value, and meeting sustainable demands. This paper explores the circular economy as a growing market for sustainable innovations, analysing key drivers, economic opportunities, and challenges for businesses and economies. The information base for the research is the Eurostat and World Bank panel data for the European Union (EU) countries covering the period from 2014 to 2020. The research aims to examine the impact of circular economy indicators (Private investment and gross added value in circular economy sectors; patents related to recycling and secondary raw materials; persons employed in circular economy sectors) on gross domestic product (GDP) per capita in the selected countries. The research results, obtained through descriptive statistics, correlation, and regression analysis, indicate a positive association between circular economy indicators and GDP per capita. By examining the circular economy indicators in the EU, the authors emphasise how economies and businesses can leverage circular strategies to enhance competitiveness and resilience. The research findings suggest that businesses embracing circular economy models benefit from increased profitability, reduced environmental impact, and enhanced consumer engagement, positioning sustainability as a core driver of long-term economic growth.

Keywords: Circular economy; EU countries; sustainable innovations; economic growth

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1. Introduction

In a world being faced with growing concerns regarding resource scarcity, climate change, and intensive resource consumption that induced many economic, social and environmental challenges over the recent decades, achieving and maintaining sustainable economic development has emerged as a priority goal for policy makers, governments and businesses (McDowall et al., 2017; Dantas et al., 2021). According to the Circle Economy report (2022), over the last decade, about 70% of the world's resources have been consumed faster than they could be safely replenished (Circle Economy, 2022). The overall consumption of resources has more than tripled since 1970, nearly doubled since 2000, and now totals 100 billion tons. This has resulted in 420 million hectares of land lost to deforestation, nearly 50% of the soil severely degraded, 85% of fish stocks in question, and 70% of wildlife populations declining over the last 50 years (Circle Economy, 2023). If this trend continues, together with an estimated increase in the human population, it could result in enormous resource depletion in the coming years, thus placing the concept of "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" at severe risk. In accordance

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with such fast global changes, there has occurred a need for an economic model transformation, which would shift from a linear economy that is based on an unreasonable, by production maximisation justified, unsustainable resource exploitation towards a circular economy that is motivated with a waste reduction and an efficient resource usage (Moraga et al., 2019; Markovic et al., 2020; Neves & Marques, 2022).

Circular economy, that has occurred in 1970s as a response to the above revealed challenges, which through resource devastation, waste accumulation, pollution and related matters threaten to limit social welfare and business profitability, provides a range of opportunities for ensuring a sustainable development complying with both, environmental quality and economic prosperity goals and social equity across current and future generations (Weigend Rodriguez et al., 2020; Oberc et al., 2022). A concept of circularity, built as a new approach to economic development, which relies on the 7R principles (reduce, redesign, repair, reuse, recycle, recover, and renovate) and promotes a long-term product life cycle, brings many benefits on micro, meso and macro levels (Morseletto, 2020). The motivation behind such an extended lifespan of a product approach is found in preventing the unjustified exploitation of resources and thus increased efficiency of resource use, and minimising the waste where the product being in the ultimate stage of its life cycle, i.e. becomes a waste for a consumer, is brought back to a new product life cycle beginning stage through a recycling as a core operation under the circular economy (Morseletto, 2020). A new production and consumption paradigm, driven by technological advancements during the latest industrial revolution, offers a wide range of opportunities for innovation, job creation, and economic growth, thereby advancing all socio-economic aspects of society (Popovic, 2021). With a completely redesigned approach to economic development (relying on the 7Rs), the circular economy aims to regenerate finite resources, turning waste into a new resource. Thus, with an extended product life cycle, a more efficient and sustainable production model is designed, thereby diminishing the conflict between economic prosperity and sustainability goals (EMF, 2022).

Since a traditional linear model of production and consumption which dominated the world economy over the last two centuries, where the goods are produced, sold, exploited and discarded, could not any longer hold under the changed reality, the transition to a new economic model has become rather a necessity than an option in the world of increased economic volatility, resource depletion, and growing concerns over the preserving environment and future generations prosperity. Having recognised a new paradigm as the best available approach for achieving sustainability goals, both businesses and policymakers across the Globe have made the inclusion of the circular economy principles into their strategies and practices a priority in completing the agenda of social welfare and profit maximisation (Nikolaou & Tsagarakis, 2021; Suchek et al. 2022; Zeng et al., 2022). As such, through the decrease in the use of primary resources and exploiting full the materials being already in the system based on recycling and other circularity principles implementation, circular economy is expected to be a meaningful tool for triggering sustainable economic growth in the upcoming years being less dependent on raw materials and energy (Esposito et al., 2018; Geng et al., 2019; Andronicean, et al., 2021). Despite promising results, not all countries and businesses have been equally successful in implementing circularity. This could be explained by the fact that some countries had a greater impact in increasing public awareness of the concept and its potential and/or were more effective at creating and implementing relevant laws and policies (Mazur & Wierzbicka, 2021). In line with that, the disparities in the circularity principle led to achievements across the countries, which are expected and certain.

The EU has demonstrated its commitment to promoting and implementing the new paradigm. Such a commitment could be understood given the European Commission (2020) report estimates which predict the creation of 1.2 million new jobs, mostly in the waste, recycling, repair and service sector, being followed by an annual increase of 600 billion euros in the manufacturing sector and respectively about 0.5% increase in EU economic growth by 2030, mostly arising from the transition to circular economy led business models and development of new innovative technologies. Nevertheless, such developments are expected not to be evenly distributed across the EU; Central and Eastern EU countries are expected to benefit more than Western Europe due to earlier investments in fossil fuel sectors (European Commission, 2020).

In line with these predictions, the European Union (EU) has taken several steps and introduced legislative and policy initiatives to embed the circularity paradigm into its economy better (Korhonen et al., 2018; EC, 2022). Those initiatives started in 2015 with the Paris Agreement on the Sustainable Goals that was followed by the

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Circular Economy Action Plan which was based on the previous waste directives, being renewed and turned into the EU Green Deal in 2019 which focuses on regions, industries and workers affected by the new policies (European Commission, 2020; Fellner & Lederer, 2020; Kuo & Chang, 2021; Zeng et al. 2022). The results of such initiatives are expected to be measured by considering gross value added, private investment, and jobs created in the related sectors (European Commission, 2020). To ensure favourable outcomes in the full implementation of the circularity principles, the European Commission has established a monitoring body to assess progress along this path, evaluate the benefits and contributions of the new paradigm to achieving sustainability goals, and address potential risks to their realisation (Eurostat, 2025).

Given its identified relevance, the circular economy has also become an area of increasing interest among economics scholars in recent years (Korhonen et al., 2018; Alnajem et al., 2021). Accordingly, the Circular economy has been intensively addressed through both theoretical and empirical research aimed at assessing the potential, implications, effectiveness, advantages, and limitations of circular model implementation (Kirchherr et al., 2017; Geissdoerfer et al., 2017; Esposito et al., 2018; Korhonen et al., 2018; Martinho & Mourao, 2020; Markovic et al., 2020). In this sense, several attempts have been made to evaluate the effects of the new paradigm using relevant indicators, focusing only on specific aspects of this transformation, such as eco-innovation, waste management, or energy efficiency (Smol et al., 2017). Others conducted a more extensive analysis of the effects of the recent underlying shift in the world economy (Hysa et al., 2020; Karman & Pawlowski, 2022).

Even though more recent research has provided a better understanding of the new paradigm and the implementation of business models, the economic, social, and environmental effects at all levels, there is still a lack of conclusive evidence on its impact on economic growth in Europe. Moreover, the current findings rely heavily on ad hoc evaluation models and are often theoretical in nature, thus providing a range of opportunities for further research. Even though its implementation was expected to be associated with meaningful positive effects in terms of innovation and technological advances, job creation, and economic prosperity, there is still vague evidence to confirm this assumption (Chen et al., 2020; EMF, 2022).

In line with the above, this study aims to narrow the existing gap by deepening the understanding of the relationships between circularity principles and economic growth in the European Union (EU). More precisely, employing the Eurostat and World Bank panel data for a set of EU countries in the period from 2014 to 2020, correlation and regression analysis, this research aims to examine the impact of the set of circular economy indicators (Private investment and gross added value related to circular economy sectors, Patents related to recycling and secondary raw materials, Persons employed in circular economy sectors) on a gross domestic product (GDP) per capita in the selected EU countries. In this view, the study explores the circular economy as a growing market for sustainable innovations, analysing key drivers, economic opportunities, and challenges for businesses and economies. Accordingly, adopting a macro-level perspective, this research contributes to current knowledge on the circular economy's implications for national economic performance, aiming to provide useful insights into the effectiveness of circular economic models and the convergence of new-paradigm applications and their performance implications across EU countries. This way, the study provides further evidence on whether the new paradigm is intended to boost economic prosperity, as expected, which could be relevant to the business sector and policymakers who may be on the road towards "becoming circular". This is of particular importance for EU countries, which, being strongly concerned with resource availability, have implemented CE strategies earlier than other nations but are at different stages of implementation.

The rest of the paper is structured as follows. After introducing the theoretical background, a literature review of the economic implications of the CE concept is presented. After that, the methodology, applied data, and hypotheses are presented, followed by the research results and their discussion in the context of the existing literature. Lastly, concluding remarks are provided.

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2. Literature Review

Despite the notion of circularity becoming a popular subject of scholarly discourse worldwide, the scientific research literature in this field remains vague, inconsistent, and unorganised. There have been studies that provide evidence of the positive impact of the principles of circularity on economic prosperity and sustainable development. Accordingly, some researchers point out the fundamental and increasing role of renewable energy for achieving economic sustainability and growth (Lee, 2019; Guney, 2021; Aboul-Atta & Rashed, 2021), which could be explained by the fact that their production costs have been decreasing over the recent period, making them much more attractive for efficiency goal achievement (Mukoro et al., 2021; Kostakis & Tsagarakis, 2022b). Similarly, a positive long-term association between renewable energy use and economic growth was identified for seven emerging countries (Cetin, 2016). In the same context, Lee (2019) has provided evidence of a positive relationship between the aforementioned variables within the EU framework. Following this approach, a few studies have found evidence on the positive impact of RE on the job creation worldwide (Johansson & Henriksson, 2020; Khobai et al., 2020).

Meaningful research evidence was provided regarding the relationship between the sharing and second-hand principles and economic benefits. Given that this policy implementation implies an increase in the product lifespan through multiple usage of the material resources, it therefore significantly contributes to properly managing the issue of overconsumption and resource savings, thus providing a huge potential for meeting sustainability goals (Mhatre et al., 2021; Munoz & Cohen, 2017; Jabour et al., 2020; Schwanholz & Leipold, 2020; Frenken, 2017). Moreover, the sharing principle is also seen as a factor that meaningfully contributes to economic prosperity through the job creation opportunities it brings (Cheng, 2016). Significant savings opportunities from sharing have been identified in energy use, building and infrastructure costs, and CO2 emissions in the automobile industry, bringing both economic and environmental benefits (Schwanholz & Leipold, 2020).

Similarly, research examining the relationship between the repair and remanufacturing principles of the circularity framework and economic progress has provided significant evidence of a positive link. Seen as a means to extend the product's life and maintain its value for as long as possible, this principle is identified as an important tool for increasing resource efficiency, achieving resource savings, and lowering economic costs (Mhatre et al., 2021). The positive impact of this practice on economic benefits generation was confirmed by a number of studies, according to which this policy implementation leads to job creation, full product value exploitation, an increase in profit margins and social wealth (Matsumoto et al., 2016; Jansson, 2016; Llorente-González & Vence, 2020).

Similar to previous circularity principles, recycling was identified as an important contributor to achieving economic sustainability and progress targets. Prioritising the use of secondary raw materials reduces the need for primary raw materials and their exploitation, bringing many benefits, particularly for countries that depend on imports (Kostakis and Tsagarakis, 2022a). Nevertheless, empirical evidence of its positive impact on economic growth remains limited. While such a positive relationship was confirmed in some studies (Busu, 2019; Hysa et al., 2020; Kostakis & Tsagarakis, 2022a), Guoyan et al. (2022) found mixed evidence for this link, suggesting that the effects of the circularity principle differ over time. Nonetheless, substantial employment opportunities arising from recycling are evidenced by several studies (Ellen MacArthur Foundation, 2022).

Although the new circularity paradigm may seem driven by environmental motives, most related legislative documents and EU research reports are rooted in deeper reasons, many of which are economic in nature. Accordingly, such incentives were designed to promote circularity across industries, achieve relevant targets, and implement a circular economy as a new sustainable strategy defined for the EU (Siekelova et al. 2020; Mazzoni, 2020). Nevertheless, despite such strong incentives for the transition of the EU economy, some studies point to distinct outcomes regarding the success achieved on this path. A survey of European companies suggests that almost 95% have identified a new paradigm as an imperative for achieving competitiveness, diversification, cost efficiency, and increased market share (Haller, 2020). Still, several factors are obstacles to the full adoption of the new economic model in the EU.

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Some empirical studies aimed to assess the causality between circularity and economic development within the EU and the implications of implementing the circularity model have confirmed significant changes in EU economies and their outcomes due to the new paradigm's application.

In line with that, many studies have provided evidence of an association between economic growth and recycling efficiency. Androniceanu et al. (2021), who examined the circularity model and its relationship with economic development across EU economies in 2019, confirmed a strong correlation between GDP per capita and municipal waste recycling rates, thereby demonstrating that economic growth is closely associated with the adoption of a new economic model. Similarly, using the Granger causality test for panel data, Dumitrescu and Hurlin (2012) identified two-way associations between the same variables. Similarly, Razzaq et al. (2021) identified, using ARDL, that recycling solid municipal waste is an important driver of economic growth in both the short and long run. Tantau et al. (2018), who applied the Durbin-Wu-Hausman test to panel data for 28 EU members over the period 2010-2014, found that material resource utilisation and resource productivity were strongly correlated with municipal waste recycling rates. Aiming to assess the linkages between economic growth and specific circular economy indicators, Busu and Trica (2019) applied the pooled least squares (PLS) method, which identified labour productivity, followed by resource productivity and municipal waste recycling, as having the strongest impact on economic growth. Using the same methodological approach, Busu (2019) and Trica et al. (2019) identified a strong association between environment-relevant circularity indicators and economic growth. Following this view, Gardiner and Hajek (2020) applied a panel error-correction model to a dataset of EU countries' data, providing evidence of two-way causality between waste generation and economic growth. In line with this, Androniceanu (2021) have noted a strong association between employment after circularity implementation and socio-economic development indicators. In addition, the authors revealed one-way causality between circularity and employment. With an attempt to assess the socio-economic implications of the new concept on the linkages between material resource exploitation and economic growth in 28 European countries, Bianchi and Cordella (2023) provided evidence according to which the annual consumption of primary resources in relation to economic growth is about four times greater compared to the resources saved through the circularity concept implementation. Thus, the study has confirmed that the circular economy initiatives contribute to primary resource saving. Taking a similar approach, Knable et al. (2022) have annualised the impact of circular economy implementation on the three dimensions of sustainable development in 25 selected European countries. Their results suggest that, as expected, the new paradigm application has proven beneficial to the economic, social, and environmental aspects of sustainable development in the countries examined.

Many studies have assessed the linkages between the circularity concept, or its specific aspects, and economic prosperity. A meaningful portion of these studies provided evidence of a strong positive relationship between the variables examined, thus confirming their interdependence and supporting the implementation of the new paradigm as an inevitable step towards building a sustainable future for society (Busu & Trica, 2019; Radivojevic et al., 2024).

Nevertheless, some studies offer alternative evidence on the impact of circularity on a society's socio-economic prospects. Accordingly, Repp et al. (2021), who studied the value chains of EU clothing imports from large global exporters (China, Bangladesh, India, Turkey, and Cambodia) and worldwide employment trends, found that this new concept could have a significant negative impact on employment in non-EU upper-middle-income countries. In line with that, the authors conclude that the implementation of a new circularity paradigm may have uneven effects across the nations, with negative impacts being borne mainly by non-EU countries.

With the above in mind, the transition from the linear economy, which has been the dominant model since the start of the Industrial Revolution, does not seem to be an easy task. Such a substantial transformation implies radical shifts in consumption and production trends but also an in-depth understanding of circularity concepts, processes, and their power towards the creation of positive economic, social and environmental implications for sectors and value chains to create and implement the proper incentives and policies for full exploitation of its potential (Rizos et al., 2017).

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Despite a meaningful degree of convergence on the path toward "becoming circular" being noticed in the EU, but also worldwide over the recent decades, the lags and diversity in effects of the concept implementation are clear, which could be attributed to the fact that building a new approach to sustainability is still based on conceptual modelling and a few case studies. In addition, while defined circularity policies and goals may not be vague, their implementation requires greater awareness, participation, and coordination across all levels and stakeholders involved. To leverage circularity toward building a better future, companies need to redesign their business models and strategies, become more innovative in creating value, and better address environmental and social aspects (Sehnem, 2019).

3. Research Methodology

Based on well-elaborated theoretical insights into the circular economy and its significance for economic growth, this research focuses on circular economy indicators from the EU monitoring framework (Eurostat, 2025). The EU monitoring framework examines the circular economy in five areas: *1) production and consumption, 2) waste management, 3) secondary raw materials, 4) competitiveness and innovation, and 5) global sustainability and resilience*. The list of variables used in the analysis falls under the fourth thematic area of the EU monitoring framework: competitiveness and innovation (Table 1). The independent variables used in the research are Private investment and gross added value related to circular economy sectors (PIGVA), Persons employed in circular economy sectors (PE), Patents related to recycling and secondary raw materials (PAT), while the dependent variable is GDP per capita in PPP constant 2021 international $ (GDPpc)

Table 1. List of variables

Variable	Variable type
GDP per capita in PPP constant 2021 international $ (GDPpc)	Dependent
Private investment and gross added value related to circular economy sectors (PIGVA)	Predictor
Persons employed in circular economy sectors (PE)	Predictor
Patents related to recycling and secondary raw materials (PAT)	Predictor

Source: Authors

The importance of circular economy indicators for competitiveness and innovation has already been recognised in numerous studies (D'Adamo et al., 2024; Grybaitė & Burinskienė, 2024; Lehmann et al., 2022; Fang et al., 2024). The indicator "Private investment and gross added value related to circular economy sectors" consists of gross investment in tangible assets and value added at factor costs across three sectors: recycling, repair & reuse, and rental & leasing (Eurostat, 2025). This indicator is crucial to the transition toward a circular economy, as it signals innovations and investments that reduce environmental strain. Thus, the authors expect a positive relationship between Private Investment and economic growth. The indicator "Persons employed in circular economy sectors" estimates the number of persons employed in the same three sectors as stated for the Private Investment. This indicator covers all persons employed by observation companies, as well as persons who work outside the companies but are affiliated with and financed by them (e.g., sales representatives) (Eurostat, 2025). Given the benefits of job creation for the overall economy, it is expected to boost economic growth. The third circular economy indicator in the competitiveness and innovation group is "Patents related to recycling and secondary raw materials", measuring the number of patents related to recycling and secondary raw materials (Eurostat, 2025). To avoid double counting, this indicator covers patent families, including all documents related to inventions submitted to different authorities. Encouraging research and development, new products and services, and thus leading to further economic development, the authors expect Patents to have a positive impact on economic growth.

To analyse the impact of circular economy indicators on economic growth and test the formulated hypotheses, the information base for the EU27 countries is applied in the research covering the period from 2014 to 2020. The information base sources are the Eurostat database for Circular Economy Indicators (Competitiveness and Innovation indicators) and the World Bank database for World Bank Indicators (GDP per capita).

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The research investigates the following hypotheses:
H1: A positive correlation exists between Private investment and Gross added value related to circular economy sectors (PIGVA), Persons employed in circular economy sectors (PE), Patents related to recycling and secondary raw materials (PAT), and GDP per capita;
H2: Private investment and gross added value related to circular economy sectors (PIGVA), Persons employed in circular economy sectors (PE), Patents related to recycling and secondary raw materials (PAT) positively influence the GDP per capita.

To address the main research goal of evaluating the impact of circular economy indicators on GDP per capita for EU27 countries, correlation and regression analyses are applied. Given a sample of 27 EU countries (27 cross-sectional units) over 7 years (7 time periods), the panel data analysis will be employed. The normality of the database is assessed using the Shapiro-Wilk and Shapiro-Francia tests. The relationship between variables is tested using the Spearman correlation coefficient, which ranges from -1 to +1, where values close to ±1 indicate a strong correlation. The correlation is very weak if the coefficient ranges from 0 to 0.19, weak from 0.20 to 0.39, moderate from 0.40 to 0.59, strong from 0.60 to 0.70, and very strong above 0.80 (Cohen, 2003).

Given the panel data in the research, the regression model was selected using the F-test, Breusch-Pagan LM test, and Hausman test. The F-test's null hypothesis approval proposes the Pooled Regression Model (Pooled), while its non-acceptance supports the Fixed Effects Model (FEM). The Breusch-Pagan LM test's null hypothesis is that the Pooled model is appropriate, while its non-acceptance supports the Random Effects Model (REM). Finally, the approval of the null hypothesis in the Hausman test suggests the REM test (Gujarati, 2004).

3. Findings and Discussion

The descriptive statistics are presented in Table 2. The average PIGVA in the EU27 countries is 3,525.249 million euros. The minimum value of 33 million euros was recorded in Cyprus in 2004, while the maximum value of 34,489 million euros was recorded in Germany in 2018. The average PE in the analysed countries is 150,152. The minimum PE value of 6,457 full-time persons employed was recorded in Luxembourg in 2015, while the maximum PE value of 764,026 was recorded in Germany in 2019. The average PAT value across the analysed countries is 11.84116. The minimum PAT value of 0 was recorded in several years in Bulgaria, Cyprus, Estonia, Croatia, Lithuania, Latvia, Malta, Poland, the Slovak Republic, Slovenia, and for one year in Greece (2018), Hungary (2020), Portugal (2014). The maximum PAT value, 103.78, was recorded in Germany in 2019. The average GDP per capita in the EU27 countries is 49,398.32 PPP (constant 2021 international $), while the minimum value of 22,938.83 PPP (constant 2021 international $) was recorded in Bulgaria in 2014, and the maximum value of 132,836.1 PPP (constant 2021 international $) was recorded in Luxembourg in 2016.

Table 2. Descriptive statistics

Variable	Min	Max	Mean	SD
PIGVA	33	34489	3525.249	6094.25
PE	6457	764026	150152.6	185830.1
PAT	0	103.78	11.84116	185830.1
GDPpc	22938.83	132836.1	49398.32	21308.43

Source: Authors

Prior to the correlation analysis and to select an appropriate methodology, the Shapiro-Wilk and Shapiro-Francia normality tests are conducted on the sample data. The results of normality tests confirmed the non-normality of the data ($p<0.05$) (Table 3). Thus, the correlation analysis has been performed using the nonparametric Spearman's correlation coefficient.

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Table 3. Normality tests

Variable	Shapiro-Wilk		Shapiro-Francia	
	W	p-Value	W'	p-Value
PIGVA	0.59660	0.00000	0.59394	0.00001
PE	0.70242	0.00000	0.70376	0.00001
PAT	0.67858	0.00000	0.70223	0.00001
GDPpc	0.77784	0.00000	0.77726	0.00001

Source: Authors

The correlation analysis has been employed to test hypothesis H1. Namely, the correlation analysis will examine the relationship between the analysed indicators and the strength of their correlation. According to the correlation results from Table 4, there is a positive correlation between GDPpc and two circular economy indicators (PIGVA and PAT). The results indicate that the positive correlation between circular economy indicators (PIGVA and PAT) and GDPpc is moderate and statistically significant ($p<0.01$). In addition, a positive correlation exists among circular economy indicators, and it is strong between PE and PIGVA (0.7222), between PE and PAT (0.6027), and very strong between PAT and PIGVA (0.8561). However, the correlation between GDPpc and PE is negative. The results of the research confirm a positive correlation between PIGVA, PAT, and GDPpc, but not between PE and GDPpc (hypothesis H1).

Table 4. Correlation results

Variable	PIGVA	PE	PAT	GDPpc
PIGVA	1			
PE	0.7222*	1		
PAT	0.8561*	0.6027*	1	
GDPpc	0.4672*	-0.1471*	0.4832*	1

Source: Authors

Note: *Correlation is significant at the 0.01 level (two-tailed).

Following the correlation analysis, three tests (F-test, Breusch-Pagan LM, and Hausman) were conducted to determine the appropriate panel data model. Based on the research data in Table 5, the fixed-effect model (FEM) is selected for the regression analysis. Specifically, the F-test results favour the FEM model, whereas the Breusch-Pagan LM results favour the REM model. The decision on the appropriate panel data model is based on the Hausman test results, which indicate the FEM model is preferred at the 1% significance level ($p = 0.0000$).

Table 5. Test results for the evaluation of the proper panel data model

Model	F-test H_0: Pooled, H_1: FEM	Breusch-Pagan LM H_0: Pooled, H_1: REM	Hausman H_0: REM, H_1: FEM
Model	99.82 (0.0000)	402.08 (0.0000)	45.81 (0.0000)

Source: Authors

Note: p values are given in ( ).

The proposed Fixed effect model (FEM) is employed to examine the impact of PIGVA, PAT and PE on GDPpc across 27 EU countries for the period 2014-2020. The obtained results show that Private investment and gross added value related to circular economy sectors (PIGVA) and Persons employed in circular economy sectors (PE) have a positive and significant impact on economic growth (GDPpc), while Patents related to recycling and secondary raw materials (PAT) has positive but not significant impact on GDPpc ($p = 0.875$) which can be explained by a low number of available data for this indicator. The estimated model explains a 98.41% change in GDPpc, and based on the F statistics is statistically significant at a 1% level of significance (see Table 6). If Persons employed in circular economy sectors (PE) increase by 1%, GDPpc will increase by 0.19%, ceteris paribus. If Private investment and gross added value related to circular economy sectors (PIGVA) increase by 1%, GDPpc will increase by 0.12%, ceteris paribus.

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Table 6. Regression results

	Constant	In PIGVA	In PAT	In PE	R^2	F statistics
In GDPpc	7.67514 [15.77] (0.000)	0.1287344 [8.59] (0.000)	0.0000935 [0.16] (0.875)	0.1925958 [4.26] (0.000)	0.9841	42.33 (0.0000)

Source: Authors

Note: t values are given in [ ], p values are given in ( ).

The significance of competitiveness and innovation circular economy indicators on GDP growth was also examined in other studies (Hysa et al., 2020; Murray et al., 2020; Busu, 2019), but without statistical significance, while the importance of innovations as the significant driver of sustainable and economic development has been confirmed by Aid et al. (2016), and Lieder and Rashid (2016). Variables associated with the innovation capacities of the EU27 countries confirmed their positive and significant impact on GDP per capita, proving they are important dimensions of economic growth.

Conclusions

Given that, over the last decades, the traditional linear model of production and consumption, which dominated the world economy since the Industrial Revolution, could no longer hold in the changed reality, the transition to a new economic model has become imperative. Having recognised circularity as a promising approach to achieving sustainability goals, both businesses and policymakers worldwide have made the adoption of the circularity model a priority in their strategies and practices to advance the agenda of social welfare and profit maximisation. Despite the expected results, not all countries and businesses have been equally successful in benefiting from the concept of circularity.

In line with the above and given that scientific research in this field appears vague, cursory, and unorganised, this research aims to assess the assumed interdependence between circularity and economic prosperity in the EU. More precisely, by employing the Eurostat and World Bank panel data for a set of EU countries in the period from 2014 to 2020, correlation and regression analysis, this research examines the impact of the set of circular economy indicators (Private investment and gross added value related to circular economy sectors, Patents related to recycling and secondary raw materials, Persons employed in circular economy sectors) on a gross domestic product (GDP) per capita in the selected EU countries. In this view, the study explores the circular economy as a growing market for sustainable innovations, analysing key drivers, economic opportunities, and challenges for businesses and economies.

Accordingly, this research contributes to current knowledge on CE's implications for national-level economic performance, aiming to provide useful insights into the effectiveness of circular economic models and the relevant convergence among EU countries. This way, the study provides further evidence on whether the new paradigm boosts economic prosperity, as expected, which could be relevant to the business sector and policymakers who may be on the road towards "becoming circular". This is of particular importance for EU countries, which, being strongly concerned with resource availability, have implemented CE strategies earlier than other nations but are at different stages of implementation.

The study confirms that competitiveness and circular-economy innovation indicators positively affect economic growth in the analysed EU27 countries. Private investment and gross added value related to circular economy sectors (PIGVA) and Persons employed in circular economy sectors (PE) have an equally strong influence on economic growth. In contrast, Patents related to recycling and secondary raw materials (PAT) have a positive but not significant impact on economic growth. These results, confirming hypothesis 2 (H2), indicate that innovations play a crucial role in driving economic growth. However, while the importance of Patents related to recycling and secondary raw materials is positive, it should be further examined to substantiate its significance by complementing it with additional data. Nonetheless, the findings of this study indicate that European countries differ meaningfully in the quality of their systems and in how they approach competitiveness and innovation related to circularity model implementation. The results also imply that Central and Western

countries, which are considered traditionally competitive and innovative economies, have taken greater advantage of circularity principles than other countries.

Therefore, despite a meaningful degree of convergence on the path toward "becoming circular" being noticed in the EU, the lags and diversity in the effects of the concept implementation are clear, which could be attributed to the fact that building a new approach to sustainability is still based on conceptual modelling and a few case studies. In addition, while defined circularity policies and goals may not be vague, their implementation requires greater awareness, participation and coordination of all the levels and stakeholders involved, but also an in-depth understanding of circularity concepts, processes and its power towards the creation of positive economic, social and environmental implications for sectors and value chains. To take advantage of circularity to build a better future, companies need to redesign their business models and strategies, become more innovative in creating value, and better address environmental and social aspects. The major limitation of this study could be the narrow list of circularity indicators employed, largely due to a lack of available data, as the EU circular economy monitoring data sources cover a short, uneven period. Nevertheless, it would be useful to direct future research toward a broader set of circularity indicators when assessing the contribution of new economic models to the EU's economic prospects, even over shorter time periods. Comparing the interdependence among these variables across European regions, i.e., groups of countries, could be another approach worth future attention in this research field.

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AI-DRIVEN CORPORATE ORGANIZATIONAL RESTRUCTURING IN THE EUROPEAN UNION*

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Abstract. This study examines whether the growing adoption of artificial intelligence (AI) technologies is associated with measurable organizational restructuring processes within enterprises across the European Union (EU). While existing research mainly focuses on the determinants and performance effects of AI adoption, the organizational consequences of AI integration remain insufficiently explored. To address this gap, the study develops a capability-based conceptual framework linking internal enterprise-level capabilities, AI adoption mechanisms, and organizational restructuring outcomes. The empirical analysis is based on comparative Eurostat datasets covering EU countries and includes indicators related to digital capabilities, organizational innovation, AI adoption, and middle-management employment structures. Methodologically, the study applies a two-stage quantitative approach combining K-means cluster analysis and linear regression analysis. The results reveal substantial heterogeneity among EU countries in terms of digital integration, organizational innovation, and AI adoption intensity. The findings further suggest that AI-driven organizational restructuring does not manifest itself through simple managerial displacement. Instead, enterprise analytical capabilities – particularly the diffusion of Business Intelligence (BI) software – are positively associated with changes in middle-management structures in more digitally advanced organizational environments. The study contributes to the literature by shifting attention from AI adoption itself toward its organizational implications and by providing an indirect quantitative assessment of AI-driven corporate organizational restructuring within the EU.

Keywords: digital and innovation capabilities of enterprises; artificial intelligence (AI) adoption; corporate organizational restructuring; cluster analysis; regression analysis; European Union

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1. Introduction

The adoption of artificial intelligence (AI) technologies among European enterprises has increased significantly in recent years, reflecting their growing role in business operations and decision-making. In 2025, 19.95% of enterprises in the European Union (EU) reported using AI technologies, while adoption among large enterprises

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reached 55.03% (Eurostat, 2025). The use of AI spans multiple functional areas, with 34.70% of AI-adopting firms applying these systems in marketing and sales, and 31.05% in the organisation of business administration processes or management. In contrast, AI applications in logistics remain comparatively limited, accounting for only 6.08% of enterprises using AI technologies (Figure 1). These figures indicate not only the increasing diffusion of AI across firms but also its uneven integration across organizational functions, suggesting differentiated impacts on corporate structures and governance mechanisms. At the same time, the EU Artificial Intelligence Act and the AI Continent Action Plan make enterprise AI adoption a governance and competitiveness issue rather than only a matter of technological efficiency (European Parliament and Council, 2024; European Commission, 2025).

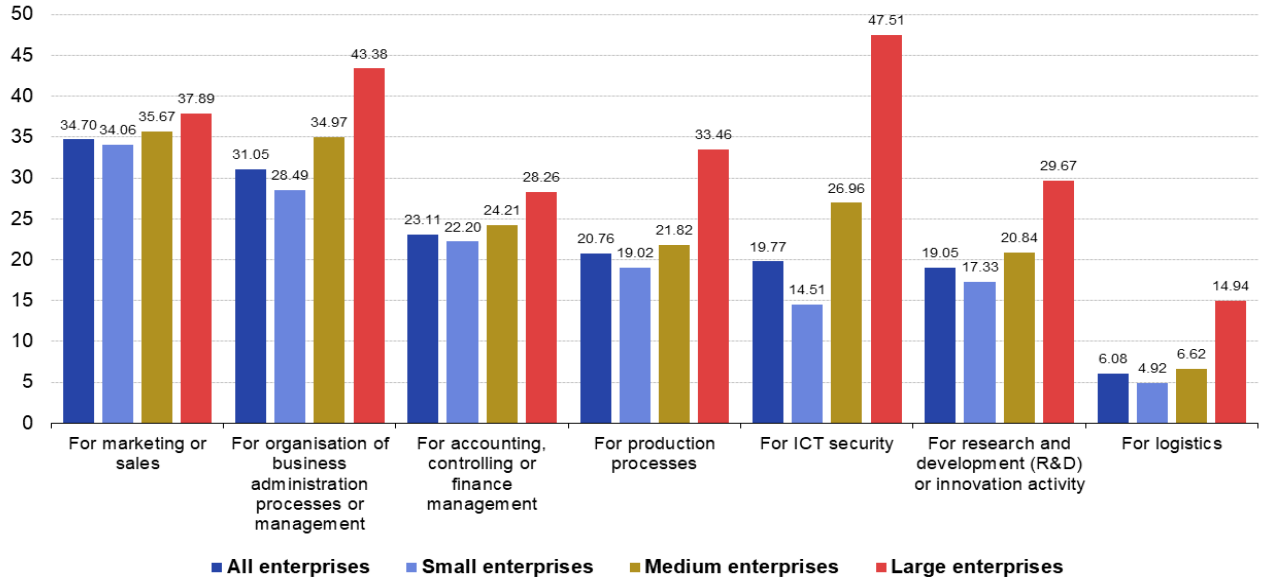


Figure 1. EU Enterprises Using AI Technologies by Type of Purpose and Size Class, %, 2025

Note: In 2025, 157,000 of the 1.53 million enterprises in the EU were surveyed. Of these enterprises, approximately 83% were small, 14% medium-sized and 3% large enterprises.
Source: Eurostat (2025).

Public disclosures from large firms also indicate that AI adoption is not limited to efficiency gains but is actively reshaping organizational boundaries, workflows, and hierarchies. In retail, Walmart's AI-powered warehouse automation illustrates how operational decisions and inventory flows are increasingly embedded in digital infrastructures, while automation changes the composition of warehouse work and reduces reliance on traditional supervisory routines (Walmart, 2025).

In platform and service-oriented firms, digital transformation processes and their impact on organizational structures and operations are especially evident (Cheng et al., 2025). Klarna's deployment of AI chatbots in customer operations was linked to workforce reduction and reconfiguration of service roles, demonstrating how automation can substitute routine functions and compress organizational layers (Klarna, 2024). In enterprise software, SAP's AI-related restructuring illustrates both capability building and workforce reallocation, indicating a broader shift toward technical-core dominance and hybrid coordination roles (SAP, 2024). Across these cases, a consistent pattern emerges: AI enables local units to experiment and operate more autonomously, but governance over standards, data and model interpretation becomes increasingly centralized. This dual-track architecture - combining operational decentralization with centralized control - redefines authority, reshapes middle-management functions and embeds governance mechanisms within algorithmic systems and organizational artifacts.

Against this background, the present study aims to examine whether the growing adoption of artificial intelligence technologies is associated with measurable organizational restructuring processes within enterprises across the EU, with particular attention to changes in middle-management structures. To address this objective,

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the study combines capability-based and organizational perspectives on AI-driven transformation and applies a two-stage empirical methodology. First, cluster analysis is used to identify relatively homogeneous groups of EU countries based on indicators reflecting enterprise-level digital and innovation capabilities, as well as AI adoption mechanisms. Second, linear regression analysis is employed to assess the statistical relationship between these explanatory variables and organizational restructuring outcomes, operationalized through the share of employment in middle-management occupations (ISCO-08 groups 12–13 (International Labour Organization (ILO), 2026)). Within this framework, the study seeks to provide an indirect quantitative assessment of AI-driven corporate organizational transformation in the EU and to evaluate whether higher levels of AI integration, combined with stronger organizational capabilities, are associated with changes in managerial architecture and labor allocation patterns across EU countries.

2. Literature Review

The growing diffusion of artificial intelligence (AI) technologies has generated an expanding body of literature examining their role in firm-level digital transformation. A substantial stream of research focuses on the determinants of AI adoption, emphasizing the importance of internal capabilities, such as digital and innovation capacities, as well as external environmental conditions shaping technological uptake. Within this perspective, AI is primarily understood as a strategic and technological resource that enhances firm competitiveness through improved efficiency, data processing and decision-making quality (Enholm et al., 2022; Weber et al., 2023; Arroyabe et al., 2024; Rizana et al., 2025).

The study by Arroyabe et al. (2024) provides a strong empirical and theoretical foundation for understanding AI adoption processes, particularly within European SMEs. Drawing on dynamic capabilities and resource dependency theories, the authors demonstrate that internal organizational capabilities - especially digital and innovation capabilities - play a decisive role in enabling AI adoption, while external business environment support has a weaker and more context-dependent effect. Their large-scale empirical analysis highlights not only the direct positive effects of these capabilities but also their synergistic interaction, emphasizing the importance of capability integration. Notably, the findings indicate that digital capabilities exert a stronger influence than innovation capabilities, underscoring the centrality of technical readiness in AI implementation (Wamba, 2022; Arroyabe et al., 2024; Daly et al., 2025; Komarova et al., 2025).

Complementing this capability-based perspective, research on digital innovation explores how firms leverage AI to enhance performance and strategic outcomes. Fan (2025), for example, demonstrates that AI technologies significantly influence business strategies across multiple dimensions, including content creation, operational efficiency and customer engagement. The study highlights the dominant role of data analytics in shaping strategic decision-making, reinforcing the idea that AI enables more adaptive and data-driven organizational processes. Similarly, Cheng et al. (2025) provide a configurational analysis of digital innovation in platform enterprises, showing that innovation outcomes depend on the alignment of digital capabilities with ambidextrous learning strategies. Their findings reveal that no single factor is sufficient to drive digital innovation; instead, multiple pathways emerge through the interaction of technological and organizational elements. This perspective emphasizes the heterogeneity of platform firms and the importance of capability configurations in shaping innovation performance (Talaei-Khoei et al., 2024; Fan, 2025; Cheng et al., 2025).

Beyond strategic and innovation outcomes, digital transformation research has also examined broader economic, relational and capability-related effects. He et al. (2026), for instance, provide a detailed analysis of how enterprise digital transformation reshapes risk-sharing dynamics between firms and financial institutions. By reducing information asymmetry and alleviating financing constraints, digitalization enables more synchronized risk-taking between banks and firms, fundamentally altering traditional financial relationships. Related work also shows that digitalisation, knowledge management and technology transfer influence organizational capabilities and circularity, which is relevant for understanding how technological change extends beyond single firms into wider organizational ecosystems (Radavičius & Tvaronavičienė, 2022; He et al., 2026).

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At the organizational level, complementary insights can be drawn from research on organizational capabilities, data-driven culture and AI-enabled performance. Studies of AI assimilation and AI capability show that organizational agility, customer agility and data-driven culture mediate the relationship between AI capability and firm performance. This perspective underscores the importance of structural and behavioral conditions in shaping collective performance and suggests that organizational effectiveness depends on the integration of multiple interrelated factors rather than on the presence of AI tools alone (Wamba, 2022; Wamba et al., 2024; Murire, 2024).

More direct attention to the organizational implications of AI is found in studies examining socio-technical dynamics and governance challenges. Lanne et al. (2025) conceptualize AI adoption as a process characterized by inherent tensions, requiring organizations to balance competing demands such as efficiency and ethics, or control and flexibility. Their analysis highlights that AI integration disrupts established processes, introduces new coordination challenges and reshapes human-technology interactions. Earlier organizational research similarly shows that AI changes decision-making architectures, creates an automation-augmentation paradox and introduces new forms of algorithmic control, which is directly relevant to the transformation of managerial roles (Jarrahi, 2018; Kellogg et al., 2020; Bankins et al., 2022; Menshikov et al., 2024).

The literature on AI governance further expands this view by examining how organizations design and implement mechanisms to manage AI systems. Birkstedt et al. (2023) conceptualize AI governance as a socio-technical system encompassing rules, processes and stakeholder interactions, and identify key themes such as regulation, technological infrastructure and organizational context. Papagiannidis et al. (2023) and Papagiannidis et al. (2025) emphasize the gap between high-level ethical principles and their practical implementation, arguing that effective AI governance requires the integration of ethical considerations into organizational processes and decision-making frameworks. Together, these studies highlight that AI governance is a dynamic and multi-level challenge that extends beyond compliance toward continuous organizational adaptation (Birkstedt et al., 2023; Papagiannidis et al., 2023, 2025).

Legal and regulatory perspectives provide additional insights into the institutional environment shaping AI adoption. Wachter et al. (2017) critically examine the concept of a “right to explanation” under the General Data Protection Regulation (GDPR), demonstrating that existing regulatory provisions offer only limited transparency and accountability mechanisms. This limitation has important implications for organizational governance, as it constrains the ability to fully understand and challenge algorithmic decision-making processes. Building on this, Vacek (2026) introduces the concept of role responsibility, suggesting that AI systems can be understood as occupying functional roles within organizations. This perspective offers a novel way to conceptualize the redistribution of responsibility and authority in AI-enabled environments.

Further contributions come from studies examining regulatory frameworks and their impact on organizational practices. Cors and Thiébaut (2025) analyze the EU AI Act as a risk-based regulatory system that both constrains and enables innovation. Their findings suggest that compliance requirements may impose operational challenges while simultaneously enhancing trust and legitimacy, thereby influencing firm behavior and strategic choices. In a similar vein, Minotakis (2025) adopts a critical, worker-centred perspective to examine how AI reshapes labor processes and organizational power dynamics. The study highlights that algorithmic management systems can intensify surveillance and reinforce power asymmetries, while existing regulatory frameworks provide only partial protection for workers. The adoption of Regulation (EU) 2024/1689 and the EU AI Continent Action Plan strengthens this institutional perspective by linking AI deployment with risk management, transparency, industrial capacity and organizational readiness (European Parliament and Council, 2024; European Commission, 2025; Murire, 2024).

Despite the breadth of existing research, several important gaps remain. First, while capability-based and innovation-oriented studies provide detailed insights into the determinants and strategic outcomes of AI adoption, they largely overlook its internal organizational consequences. Second, research on digital transformation and inter-organizational dynamics tends to focus on financial, relational, or performance-related outcomes, rather than structural changes within firms. Third, although studies on AI governance and regulation highlight the complexity of managing AI systems, they often remain at a conceptual or institutional level,

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providing limited empirical evidence on how governance mechanisms translate into concrete organizational restructuring. Finally, while emerging research acknowledges the socio-technical and power-related dimensions of AI, there is still insufficient understanding of how AI adoption reshapes hierarchical configurations, decision-making centralization, and the role of middle management.

Against this background, the present study aims to address this gap by moving beyond the analysis of AI adoption toward its organizational consequences. Specifically, it seeks to examine how AI usage influences corporate organizational restructuring, with particular attention to changes in decision-making centralization, hierarchical configurations, and the role of middle management. By integrating insights from capability-based theories, governance frameworks, and empirical observations of enterprise-level transformations, the study contributes to a more comprehensive understanding of how digital transformation translates into structural change within organizations.

3. Conceptual Framework and Research Methodology

The development of a conceptual framework and research methodology for analyzing AI-driven organizational transformation requires a clear integration of theoretical perspectives on technology adoption, firm capabilities and organizational change. In recent literature, artificial intelligence is increasingly conceptualized not merely as a technological tool, but as a socio-technical system that interacts with organizational structures, human capital and managerial processes. This perspective emphasizes that the effects of AI are mediated by internal capabilities and organizational conditions, rather than being determined solely by the availability of technology. In particular, AI-driven transformation unfolds through mechanisms such as general AI adoption and administrative AI integration, which reshape not only productivity outcomes but also coordination structures and the distribution of roles within enterprises (Jarrahi, 2018; Raisch & Krakowski, 2021; Enholm et al., 2022; Weber et al., 2023;).

Within this broader context, the study by Arroyabe et al. (2024) provides a valuable conceptual and methodological foundation for examining AI-driven organizational restructuring, although its empirical scope is limited to AI adoption rather than organizational outcomes. Conceptually, the article demonstrates that AI adoption in enterprises is primarily driven by internal capabilities – particularly digital and innovation capabilities – while external environmental support plays a comparatively weaker and contingent role (Arroyabe et al., 2024). This insight is directly relevant for our research, as it suggests that organizational restructuring is likely to be endogenous to firm-level capabilities rather than externally imposed, thereby supporting a capability-based explanation of changes in hierarchy, decision-making centralization, and the role of middle management. In line with this reasoning, our conceptual framework links internal capabilities, AI adoption mechanisms, and organizational outcomes, as illustrated in Figure 2.

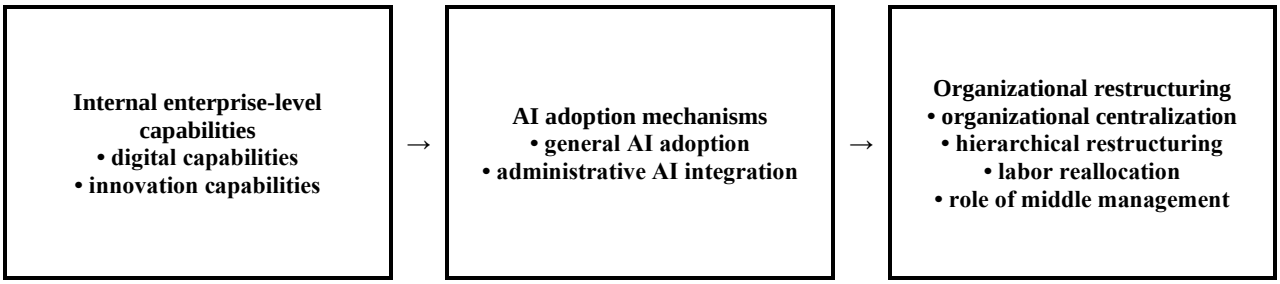


Figure 2. Conceptual Model of AI-Driven Corporate Organizational Restructuring
Source: elaborated by the authors based on Arroyabe et al. (2024), Jarrahi (2018), Raisch & Krakowski (2021), Filippucci et al. (2024) and Komarova et al. (2025).

Although external environmental support may influence AI adoption, the present study focuses primarily on enterprise-level organizational dynamics and therefore operationalizes only internal organizational dimensions. In this framework, internal enterprise-level capabilities are conceptualized as enabling conditions that facilitate AI adoption, while AI adoption itself is treated as an intermediate mechanism through which organizational restructuring processes emerge. Consequently, the conceptual model distinguishes analytically between

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capability-related factors, AI adoption mechanisms, and organizational outcomes in order to preserve causal consistency between the different stages of transformation.

To translate the conceptual framework into an empirical research design, the study operationalizes each conceptual dimension through a system of indirect and direct indicators derived from Eurostat datasets. Accordingly, Table 1 serves as a methodological bridge between the conceptual model presented in Figure 2 and the empirical analysis by linking abstract theoretical dimensions with measurable statistical indicators and corresponding data sources.

Table 1. Indicators Methodologically Related to the Conceptual Model of AI-Driven Corporate Organizational Restructuring

Conceptual dimension	Conceptual variable	Operational indicator	Empirical proxy / measurement	Source of data	Expected relationship
Internal enterprise-level capabilities	Digital capabilities	Enterprise digital integration capacity	Share of enterprises using Enterprise Resource Planning (ERP) software	Eurostat, 2026a	Higher ERP diffusion increases enterprises' capacity to integrate AI into organizational coordination and decision-making
		Data-analytics capability	Share of enterprises using Business Intelligence (BI) software	Eurostat, 2026b	Higher BI usage supports AI-enabled analytical and centralized management functions
	Innovation capabilities	Organiza-tional innovation capacity	Share of enterprises introducing business process innovations in procedures/external relations	Eurostat, 2023, 2024	Enterprises with stronger innovation practices are more likely to reorganize processes around AI systems
		Managerial innovation capacity	Share of enterprises introducing innovations in work responsibility, decision-making, and HRM		Organizational experimentation facilitates AI-related restructuring of internal governance
AI adoption mecha-nisms	General AI adoption	AI use intensity	Share of enterprises using at least one AI technology	Eurostat, 2026c	Greater AI adoption intensifies organizational transformation pressures
	Administ-rative AI integration	AI use in manage-ment and administra-tion	Share of AI-adopting enterprises using AI for business administration processes or management	Eurostat, 2026d	AI integration into management processes contributes to restructuring of coordination and control functions
Organiza-tional restructur-ing	Organizational centraliza-tion	Centralized coordination systems	-	-	-
	Hierarchi-cal restructur-ing	Changes in organiza-tional procedures	-	-	-
	Labor reallocation	Changes in managerial employment structure	ISCO-08 groups 12–13 employment share	Eurostat, 2026e	AI may reduce routine supervisory roles while increasing demand for hybrid coordination and oversight functions
	Role of middle manage-ment	Middle-manage-ment transforma-tion			

Source: elaborated by the authors based on Figure 2 and Eurostat data.

The proposed conceptual and methodological framework therefore allows the study to move from abstract theoretical assumptions about AI-driven organizational transformation toward a systematic empirical assessment of enterprise-level restructuring processes within the European Union. By combining indicators of

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internal organizational capabilities, AI adoption mechanisms, and restructuring-related outcomes, the framework makes it possible to examine not only the diffusion of AI technologies, but also their potential implications for organizational coordination, managerial architecture, and labor reallocation. On this basis, the following section presents the data sources, indicator construction procedures, and methodological approach used for the empirical analysis of AI-driven corporate organizational restructuring across EU countries.

4. Data and Method

The empirical analysis is based on comparative Eurostat datasets covering EU countries and focusing on three analytically interconnected dimensions of AI-driven organizational transformation: internal enterprise-level capabilities, AI adoption mechanisms, and organizational restructuring outcomes. In line with the conceptual framework presented in Figure 2 and operationalized in Table 1, the study combines indicators reflecting digital and innovation capabilities, the diffusion of AI technologies in enterprises, and structural organizational changes.

Tables 2–5 therefore present the empirical indicators corresponding to the main dimensions of the conceptual model and provide the basis for examining how AI adoption may be associated with broader organizational transformation processes within enterprises across the EU.

Table 2. Enterprises Using Enterprise Resource Planning (ERP) Software and Business Intelligence (BI) Software, % of All Enterprises, EU Countries, 2023 and 2025

EU country	ERP 2023	ERP 2025	ERP Δ 2025/23	BI 2023	BI 2025	BI Δ 2025/23
EU-27	43.4	46.5	3.1	15.4	16.3	0.9
Austria	40.1	37.5	-2.6	17.8	17.2	-0.6
Belgium	59.5	62.5	2.9	31.2	32.5	1.3
Bulgaria	21.7	26.6	4.9	4.2	6.8	2.7
Croatia	25.4	21.9	-3.5	12.0	11.6	-0.4
Cyprus	41.6	41.0	-0.6	20.8	22.1	1.3
Czechia	29.0	49.7	20.7	10.9	17.1	6.2
Denmark	67.3	66.3	-1.0	40.3	41.7	1.4
Estonia	31.2	35.1	4.0	15.9	17.9	2.0
Finland	56.9	58.1	1.2	38.9	43.4	4.5
France	47.3	53.9	6.6	10.7	10.7	0.0
Germany	43.7	43.5	-0.2	14.2	13.2	-1.0
Greece	45.3	54.8	9.5	8.7	9.5	0.8
Hungary	35.2	30.9	-4.4	7.9	9.3	1.3
Ireland	30.2	33.8	3.6	21.3	25.9	4.6
Italy	42.3	49.5	7.3	17.6	16.0	-1.6
Latvia	34.0	32.1	-1.9	9.4	12.9	3.5
Lithuania	41.9	41.3	-0.6	11.6	25.2	13.6
Luxembourg	43.8	49.4	5.5	19.6	23.6	4.0
Malta	46.5	46.3	-0.2	22.0	24.4	2.5
Netherlands	51.9	52.6	0.7	31.1	35.9	4.7
Poland	36.0	39.1	3.1	10.5	11.7	1.2
Portugal	47.2	48.3	1.1	11.8	13.0	1.2
Romania	22.6	29.3	6.7	7.5	8.2	0.7
Slovakia	26.2	26.7	0.5	13.0	14.5	1.5
Slovenia	37.0	35.5	-1.5	13.2	13.7	0.5
Spain	54.6	60.4	5.8	18.0	23.0	5.0
Sweden	58.6	28.1	-30.5	22.2	22.0	-0.2

Source: compiled by the authors based on Eurostat (2026a, 2026b).

At the EU-27 level, the share of enterprises using ERP software increased from 43.4% to 46.5%, while BI software usage rose from 15.4% to 16.3% (Table 2). This suggests a gradual strengthening of enterprise-level digital integration capacities and data-driven management practices within the European economy. However, substantial cross-country variation remains evident. Northern and Western European countries generally demonstrate the highest levels of ERP and BI diffusion, reflecting more advanced digital infrastructures and organizational capabilities. Denmark, Finland, Belgium, and the Netherlands exhibit particularly high ERP

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adoption rates, exceeding 50% of enterprises in 2025, while Denmark and Finland also show exceptionally high BI usage. In contrast, several Central and Eastern European countries continue to display comparatively lower levels of digital integration, although some of them demonstrate rapid growth dynamics. Czechia represents one of the most notable cases, with ERP usage increasing by 20.7 percentage points between 2023 and 2025, accompanied by a significant rise in BI adoption. Lithuania also demonstrates substantial growth in BI diffusion, increasing from 11.6% to 25.2% (Table 2).

From the perspective of the conceptual framework, these indicators suggest important differences in enterprise-level digital capabilities across EU countries. Since ERP and BI systems facilitate organizational coordination, information standardization, and data-driven managerial control, their diffusion may increase enterprises' capacity to integrate AI technologies into administrative and decision-making processes. At the same time, the uneven distribution of these capabilities across countries indicates that the organizational preconditions for AI-driven restructuring remain structurally differentiated within the EU.

Table 3. Enterprises that Introduced Business Process Innovations in Procedures / External Relations and Work Responsibility / Decision-Making / HRM, % of All Enterprises, EU Countries, 2018–2020 and 2020–2022

EU country	Procedures / external relations 2018–2020	Procedures / external relations 2020–2022	Δ 2020–2022 / 2018–2020	Work responsibility / decision-making / HRM 2018–2020	Work responsibility / decision-making / HRM 2020–2022	Δ 2020–2022 / 2018–2020
EU-27	15.2	16.9	1.7	20.5	21.5	1.0
Austria	31.4	25.7	-5.7	33.2	26.5	-6.7
Belgium	25.8	33.3	7.5	10.1	19.3	9.2
Bulgaria	9.2	10.5	1.3	8.3	11.0	2.7
Croatia	16.8	18.7	1.9	23.3	24.3	1.0
Cyprus	39.2	36.4	-2.8	39.0	38.1	-0.9
Czechia	13.5	38.6	25.1	19.2	20.4	1.2
Denmark	23.9	22.9	-1.0	13.8	16.6	2.8
Estonia	14.6	14.1	-0.5	25.6	24.3	-1.3
Finland	16.1	17.6	1.5	25.1	27.0	1.9
France	14.6	17.5	2.9	20.6	25.0	4.4
Germany	19.8	19.6	-0.2	32.1	30.7	-1.4
Greece	31.6	37.3	5.7	36.9	43.9	7.0
Hungary	6.3	9.0	2.7	8.4	9.1	0.7
Ireland	22.6	21.1	-1.5	20.9	16.1	-4.8
Italy	21.0	18.6	-2.4	27.7	25.6	-2.1
Latvia	7.7	7.9	0.2	12.3	13.7	1.4
Lithuania	11.4	15.3	3.9	13.9	16.3	2.4
Luxembourg	16.3	12.7	-3.6	17.4	14.4	-3.0
Malta	19.4	18.3	-1.1	27.2	24.6	-2.6
Netherlands	12.3	12.5	0.2	13.6	16.1	2.5
Poland	8.8	14.2	5.4	10.5	14.4	3.9
Portugal	18.2	20.8	2.6	22.2	29.9	7.7
Romania	2.8	2.2	-0.6	4.2	3.6	-0.6
Slovakia	10.0	12.7	2.7	8.5	10.7	2.2
Slovenia	10.4	14.7	4.3	13.9	16.4	2.5
Spain	4.3	4.3	0.0	6.8	7.0	0.2
Sweden	6.8	6.6	-0.2	16.4	16.9	0.5

Notes: Procedures / external relations refers to new business practices for organizing procedures or external relations. Work responsibility / decision-making / HRM refers to new methods of organizing work responsibility, decision-making or human resource management.

Source: compiled by the authors based on Eurostat (2023, 2024).

The data from Table 3 demonstrate a moderate overall increase in organizational innovation activity across the European Union, suggesting that enterprises increasingly experiment with new coordination mechanisms, managerial practices, and internal governance structures. At the EU-27 level, the share of enterprises introducing innovations in procedures and external relations increased from 15.2% to 16.9%, while innovations related to work responsibility, decision-making, and HRM rose from 20.5% to 21.5%.

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At the country level, however, organizational innovation dynamics remain highly uneven. Several countries demonstrate particularly strong growth in organizational restructuring-related practices. Czechia recorded the largest increase in innovations related to procedures and external relations, rising by 25.1 percentage points, while Belgium and Greece also exhibited substantial growth in both dimensions of organizational innovation. Portugal demonstrated one of the strongest increases in innovations related to work responsibility, decision-making, and HRM, rising from 22.2% to 29.9%. These patterns may indicate intensified organizational adaptation processes associated with digital transformation and the growing integration of AI-related managerial practices.

At the same time, a number of countries experienced stagnation or decline in some organizational innovation indicators. Austria, Ireland, Italy, Luxembourg, and Malta recorded decreases in at least one of the observed dimensions, suggesting that organizational restructuring processes remain uneven and context-dependent across the EU. Such variation may reflect differences in digital maturity, institutional conditions, managerial traditions, or sectoral composition of national economies.

From the perspective of the conceptual framework, the indicators presented in Table 3 can be interpreted as indirect evidence of organizational restructuring capacity and managerial adaptation. Innovations in procedures, coordination mechanisms, decision-making practices, and HRM are closely related to the transformation of enterprise governance structures and may constitute organizational preconditions for broader AI-driven restructuring processes. In this sense, the data suggest that organizational transformation within the EU is occurring not only through technological adoption itself, but also through gradual changes in managerial architecture and internal coordination practices.

Table 4. Enterprises Using at Least One AI Technology and AI-Adopting Enterprises Using AI for Business Administration or Management, EU Countries, % of All Enterprises, 2023 and 2025

EU country	AI use 2023	AI use 2025	AI use Δ 2025/23	AI for administration /management 2023	AI for administration /management 2025	AI for administration /management Δ 2025/23
EU-27	8.0	20.0	12.0	21.3	31.0	9.8
Austria	10.8	30.0	19.2	29.6	37.9	8.3
Belgium	13.8	34.5	20.7	25.6	39.6	14.0
Bulgaria	3.6	8.6	5.0	19.2	32.5	13.4
Croatia	7.9	15.2	7.3	15.3	23.5	8.2
Cyprus	4.7	9.3	4.6	28.0	45.3	17.3
Czechia	5.9	17.6	11.7	24.7	40.0	15.3
Denmark	15.2	42.0	26.8	23.0	23.8	0.8
Estonia	5.2	23.4	18.2	31.4	48.7	17.3
Finland	15.1	37.8	22.7	16.0	26.4	10.4
France	5.9	18.2	12.3	11.0	: (u)	-
Germany	11.6	26.0	14.4	19.9	27.6	7.8
Greece	4.0	8.9	4.9	16.9	26.1	9.1
Hungary	3.7	10.4	6.7	22.7	31.6	8.9
Ireland	8.0	19.6	11.6	22.3	38.7	16.4
Italy	5.0	16.4	11.4	19.9	25.7	5.8
Latvia	4.5	12.2	7.7	19.5	36.2	16.8
Lithuania	4.9	21.3	16.4	22.1	34.3	12.1
Luxembourg	14.4	33.6	19.2	18.7	27.2	8.6
Malta	13.2	21.6	8.4	14.3	21.3	7.0
Netherlands	13.4	33.2	19.8	29.0	39.3	10.3
Poland	3.7	8.4	4.7	26.4	42.9	16.5
Portugal	7.9	11.5	3.6	31.5	40.8	9.3
Romania	1.5	5.2	3.7	18.5	35.2	16.7
Slovakia	7.0	18.0	11.0	14.5	14.8	0.3
Slovenia	11.4	21.6	10.2	19.6	35.2	15.7
Spain	9.2	20.3	11.1	24.2	28.6	4.4
Sweden	10.4	35.0	24.6	20.3	35.0	14.7

Note: (u) – low reliability.
Source: compiled by the authors based on Eurostat (2026c, 2026d).

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Data in Table 4 demonstrate a rapid expansion of AI adoption across the European Union. At the EU-27 level, the share of enterprises using at least one AI technology increased from 8.0% in 2023 to 20.0% in 2025, representing a growth of 12 percentage points. At the same time, the share of AI-adopting enterprises using AI specifically for the organisation of business administration processes or management increased from 21.3% to 31.0%, indicating that AI integration increasingly extends beyond technical experimentation toward managerial and organizational functions.

Considerable differences between EU countries remain visible. Denmark, Belgium, Finland, Sweden, Luxembourg, and the Netherlands demonstrate some of the highest levels of overall AI adoption, suggesting relatively advanced digital ecosystems and stronger enterprise-level technological capabilities. Denmark recorded one of the most substantial increases, with AI adoption rising from 15.2% to 42.0% between 2023 and 2025. Similarly strong growth dynamics can be observed in Sweden, Belgium, and Finland. Several Central and Eastern European countries continue to display lower absolute levels of AI adoption, although some of them demonstrate rapid relative growth. Estonia, Lithuania, Latvia, and Czechia experienced particularly notable increases in AI integration into management and administrative processes.

The second dimension of Table 4 - AI use in business administration and management - is especially relevant from the perspective of organizational restructuring. In many countries, the growth of administrative AI integration exceeds the growth of general AI adoption, suggesting that enterprises increasingly apply AI technologies not only to technical or operational tasks but also to coordination, analytical and managerial functions. Countries such as Cyprus, Estonia, Poland, Latvia and Romania exhibit especially strong increases in managerial AI usage, indicating a gradual embedding of algorithmic systems into organizational governance and administrative decision-making processes. This management-related AI indicator is central because it captures the embedding of AI into coordination, analytical and administrative functions rather than only technical experimentation (Hansen et al., 2024; Talaei-Khoei et al., 2024; Nguyen & Elbanna, 2025; Maknickienė et al., 2026).

From the perspective of the conceptual framework, these trends suggest that AI adoption is becoming an increasingly important mechanism of enterprise-level organizational transformation within the European Union. The growing use of AI in management-related activities may contribute to changes in organizational coordination, decision-making centralization, and managerial roles, thereby creating structural pressures for broader organizational restructuring processes. At the same time, the uneven diffusion of AI technologies across EU countries indicates that the intensity and forms of AI-driven transformation remain highly differentiated across national economic systems and organizational environments.

Table 5. Employment in Middle-Management Occupations, % of Total Employment within 15–64, ISCO-08 Groups 12–13, EU Countries, 2023 and 2025

EU countries	2023	2025	Differences, 2025/23
EU-27	3.1	3.3	0.2
Austria	3.9	3.8	-0.1
Belgium	5.0	6.3	1.3
Bulgaria	3.0	4.3	1.3
Croatia	3.8	4.5	0.7
Cyprus	2.8	3.0	0.1
Czechia	3.8	3.9	0.1
Denmark	1.8	2.4	0.6
Estonia	5.8	5.5	-0.3
Finland	2.3	2.9	0.6
France	4.5	4.8	0.3
Germany	2.4	2.5	0.1
Greece	1.6	1.5	-0.1
Hungary	2.8	3.7	0.9
Ireland	5.8	6.2	0.4
Italy	1.5	1.6	0.1
Latvia	5.2	5.1	-0.1
Lithuania	5.7	6.3	0.6
Luxembourg	2.5	:	-

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EU countries	2023	2025	Differences, 2025/23
Malta	5.2	5.6	0.3
Netherlands	3.9	4.2	0.3
Poland	4.0	4.2	0.3
Portugal	2.9	3.3	0.4
Romania	1.3	1.5	0.2
Slovakia	3.6	3.6	0.0
Slovenia	2.8	2.7	0.0
Spain	2.4	2.5	0.1
Sweden	5.4	5.2	-0.2

Note*:* ISCO-08 groups 12–13 (ILO, 2026) are used as an operational proxy for middle-management occupations. ":" – data not availablTABLE

Source: authors' calculations based on Eurostat (2026e); the indicator is calculated as (ISCO-08 OC12 + OC13) / TOTAL employed persons × 100

At the aggregate EU-27 level, the share of employment in these occupational groups increased slightly from 3.1% to 3.3% (Table 5), indicating that no large-scale displacement of managerial occupations is observable at the macro level during the analysed period. Instead, the data suggest a more gradual and differentiated transformation of managerial structures within European enterprises.

Significant cross-country variation nevertheless remains evident. Several countries recorded relatively strong increases in middle-management employment shares, including Belgium, Bulgaria, Hungary, Croatia, Finland, and Lithuania. Belgium and Bulgaria demonstrated the largest increases, both rising by 1.3 percentage points. These trends may indicate that AI adoption and digital transformation do not necessarily eliminate managerial roles, but instead generate demand for new forms of coordination, supervision, and hybrid managerial-analytical functions associated with technologically intensified organizational environments.

At the same time, a number of countries experienced stagnation or moderate decline in middle-management employment shares. Estonia, Sweden, Austria, and Greece recorded small decreases, while Slovakia and Slovenia remained largely unchanged. Such variation suggests that the organizational effects of AI adoption may differ substantially depending on national institutional contexts, sectoral structures, labor market characteristics, and enterprise-level managerial models. In some organizational environments, AI integration may compress hierarchical layers and reduce routine supervisory functions, whereas in others it may increase the need for coordination between digital systems, operational units, and strategic management.

From the perspective of the conceptual framework, the data presented in Table 5 provide indirect evidence that AI-driven organizational restructuring does not produce a uniform reduction of managerial occupations across the European Union. Rather, the observed dynamics support the interpretation that AI transformation may simultaneously centralize analytical and decision-making functions while also creating new coordination-intensive managerial roles. Consequently, organizational restructuring appears to involve not only labor substitution, but also the reconfiguration and hybridization of middle-management functions within digitally transforming enterprises.

To further examine the potential relationship between AI adoption and organizational restructuring within the EU, the study applies a combination of cluster analysis and linear regression analysis. The methodological objective is not merely to describe the diffusion of AI-related indicators, but to assess whether differences in enterprise-level digital capabilities and AI adoption mechanisms are systematically associated with changes in middle-management employment structures across EU countries.

At the first stage, cluster analysis is used to identify relatively homogeneous groups of EU countries based on key explanatory variables related to internal enterprise-level capabilities and AI adoption mechanisms (Figure 2). This approach allows the study to account for structural heterogeneity within the EU and to distinguish between countries with relatively advanced and less advanced AI-driven organizational transformation environments.

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At the second stage, linear regression analysis is employed to evaluate the statistical relationship between AI-related explanatory variables and organizational restructuring outcomes. The dependent variable is operationalized as the share of employment in middle-management occupations (ISCO-08 groups 12–13), which serves as a proxy indicator for changes in managerial architecture and labor reallocation processes within enterprises (Table 1). Independent variables include indicators reflecting enterprise-level digital and innovation capabilities, and AI adoption mechanisms: general AI adoption and administrative AI integration (Table 1).

Within this framework, the empirical analysis seeks to test whether higher levels of AI integration – combined with digital / innovation organizational capabilities – are associated with measurable changes in middle-management structures across EU countries. Although the available data do not allow direct observation of all dimensions of organizational restructuring, the proposed methodological approach provides an indirect quantitative assessment of AI-driven corporate organizational transformation within the EU.

5. Results and Discussion

The empirical analysis begins with a K-means cluster analysis aimed at identifying relatively homogeneous groups of EU countries according to the level of development of AI-driven organizational transformation environments. The clustering procedure includes six variables reflecting the key dimensions of the conceptual framework: the share of enterprises using ERP software and BI software in 2023 (Table 2); the share of enterprises that introduced business process innovations in the areas of procedures / external relations and work responsibility / decision-making / HRM during 2020–2022 (Table 3); and the share of enterprises using at least one AI technology together with the share of AI-adopting enterprises using AI for business administration processes or management in 2023 (Table 4).

Based on these indicators, the K-means procedure generated two clusters representing different levels of enterprise-level digital capabilities, organizational innovation intensity, and AI integration. The first cluster includes countries characterized by comparatively lower levels of digital integration and AI-driven organizational transformation, while the second cluster consists of countries demonstrating relatively more advanced organizational transformation environments associated with stronger digital capabilities and higher AI adoption intensity. The results of the clustering procedure, including final cluster centers and cluster membership, are presented in Table 6.

Table 6. Results of K-Means Cluster Analysis: Final Cluster Centers and Cluster Membership, EU Countries, n = 27

Clustering variables	**Cluster 1: less advanced environments, n = 12**	**Cluster 2: relatively advanced environments, n = 15**
Share of enterprises using ERP software, 2023	30.9	49.8
Share of enterprises using BI software, 2023	11.5	21.7
Share of enterprises that introduced business process innovations in the area of procedures / external relations, 2020–2022	14.9	20.3
Share of enterprises that introduced business process innovations in the area of work responsibility / decision-making / HRM, 2020–2022	15.0	24.1
Share of enterprises using at least one of the AI technologies, 2023	5.6	10.3
Share of AI-adopting enterprises using AI for the organisation of business administration processes or management, 2023	21.3	21.9
Cluster membership	Bulgaria, Croatia, Czechia, Estonia, Hungary, Ireland, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia	Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Italy, Luxembourg, Malta, Netherlands, Portugal, Spain, Sweden

Source: authors' calculations based on the data from Tables 2–4 using IBM SPSS Statistics software

The results presented in Table 6 demonstrate a clear structural differentiation between the two identified clusters of EU countries. Cluster 1, consisting primarily of Central and Eastern European countries, is characterized by comparatively lower levels of ERP and BI diffusion, weaker organizational innovation activity, and lower

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overall AI adoption intensity. In contrast, Cluster 2 includes mainly Western and Northern European countries demonstrating substantially higher levels of enterprise digital integration, organizational innovation, and AI adoption. For example, the average share of enterprises using ERP software reaches 49.8% in Cluster 2 compared to 30.9% in Cluster 1, while the share of enterprises using at least one AI technology is almost twice as high in Cluster 2 (10.3%) as in Cluster 1 (5.6%). Similar differences are visible in organizational innovation indicators related to managerial practices, decision-making, and business process transformation.

At the same time, the differences between clusters appear less pronounced in the indicator reflecting the use of AI for business administration and management among AI-adopting enterprises. This may suggest that once enterprises adopt AI technologies, the integration of AI into managerial and administrative functions becomes relatively widespread across different organizational environments. Nevertheless, the overall cluster structure indicates that EU countries remain highly heterogeneous in terms of the organizational and technological conditions associated with AI-driven transformation processes.

From the perspective of the conceptual framework, these findings support the assumption that AI-driven organizational restructuring develops within broader configurations of enterprise-level digital and innovation capabilities rather than through isolated technological adoption alone. The clustering results therefore provide an empirical basis for examining whether differences in these organizational transformation environments are associated with differences in middle-management restructuring dynamics across EU countries. Accordingly, Table 7 presents comparative indicators of changes in middle-management employment structures between 2023 and 2025 for the identified country clusters.

Table 7. Differences in Employment Rates in Middle-Management Occupations, EU Countries, 2025/2023

Set of countries	Minimum value	Maximum value	Mean value
EU, n = 26*	-0.3	+1.3	+0.3
Cluster 1: countries with less advanced AI-driven organizational transformation environments, n = 12	-0.3	+1.3	+0.3
Cluster 2: countries with relatively advanced AI-driven organizational transformation environments, n = 14**	-0.2	+1.3	+0.3

Notes: * Luxembourg is excluded due to missing data for calculating changes in middle-management employment. ** Without Luxembourg.
Source: authors' calculations

The results presented in Table 7 indicate that differences in the average dynamics of middle-management employment between the two identified clusters remain relatively limited at the aggregate level. Both clusters demonstrate a positive mean change of approximately +0.3 percentage points in the share of employment in middle-management occupations between 2023 and 2025. At the same time, the internal variation within each cluster remains substantial, with both groups including countries that experienced either increases or decreases in middle-management employment shares. The minimum values range from –0.3 in Cluster 1 to –0.2 in Cluster 2, while the maximum value reaches +1.3 in both clusters.

These findings suggest that AI-driven organizational restructuring does not manifest itself through a simple or uniform reduction of middle-management employment across countries with more advanced digital and AI capabilities. Instead, the observed dynamics appear considerably more differentiated and may reflect multiple organizational adaptation pathways. In some cases, AI integration may contribute to the compression of traditional supervisory layers, while in others it may stimulate demand for new coordination-intensive managerial functions associated with digital governance, analytical oversight, and hybrid organizational control structures.

Importantly, the similarity of average cluster-level outcomes also indicates that broad macro-level comparisons alone may be insufficient for identifying the organizational effects of AI adoption. The relationship between AI-driven transformation environments and changes in middle-management structures may therefore depend on the specific interaction between individual explanatory variables rather than on cluster membership itself. For this reason, the next stage of the analysis applies linear regression models separately within each cluster in order to examine whether particular dimensions of digital capabilities, organizational innovation, and AI

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adoption are statistically associated with differences in middle-management employment dynamics across EU countries.

For Cluster 1, the regression procedure did not identify any statistically significant explanatory variables suitable for inclusion in the regression equation. As indicated by the SPSS output, no predictor variables met the criteria for entry into the model for the countries belonging to Cluster 1. This result suggests that, within the group of countries characterized by comparatively lower levels of digital integration and AI-driven organizational transformation, the selected indicators of enterprise-level digital capabilities, organizational innovation, and AI adoption do not demonstrate a statistically significant relationship with changes in middle-management employment structures during the analysed period.

From the perspective of the conceptual framework, this may indicate that AI-driven organizational restructuring processes in less digitally advanced organizational environments remain either relatively weak, institutionally fragmented, or insufficiently developed to produce measurable and systematic changes in managerial employment structures at the macro level. Alternatively, the absence of statistically significant relationships may reflect the influence of additional contextual factors not captured within the present model, including sectoral composition, labor market structures, institutional arrangements, or time-lag effects associated with organizational transformation processes.

The regression results for Cluster 2 demonstrate that only one explanatory variable – the share of enterprises using Business Intelligence (BI) software – was statistically significant and therefore retained in the final regression model. The variable exhibits a positive standardized coefficient (Beta = 0.581) and remains statistically significant at the 5% level ($p = 0.030$), indicating a moderate positive relationship between BI software diffusion and changes in middle-management employment structures within the countries characterized by relatively advanced AI-driven organizational transformation environments.

The positive coefficient suggests that higher levels of enterprise analytical and data-processing capabilities are associated with increases in the share of employment in middle-management occupations. From the perspective of the conceptual framework, this finding may indicate that digitally advanced organizational environments do not necessarily eliminate managerial roles, but instead generate demand for new coordination-intensive and analytical managerial functions. In such environments, middle management may increasingly perform hybrid roles connected with data interpretation, coordination between operational units and AI systems, and organizational oversight of digital infrastructures.

At the same time, the remaining explanatory variables – including ERP software diffusion, organizational innovation indicators, general AI adoption, and AI use for business administration and management – were excluded from the final model due to statistical insignificance. This result suggests that, within relatively advanced AI-driven organizational environments, enterprise analytical capability represented by BI diffusion may play a more direct role in managerial restructuring processes than general AI adoption intensity itself. In other words, organizational transformation may depend less on the mere adoption of AI technologies and more on the development of analytical coordination infrastructures capable of embedding AI into managerial decision-making processes.

Based on the unstandardized coefficients presented in the regression output, the regression equation for Cluster 2 can be expressed as:

$$y = -0.212 + 0.022xBI$$

where:

y – difference in employment in middle-management occupations between 2023 and 2025;
xBI – share of enterprises using BI software in 2023.

According to the model, an increase of one percentage point in the share of enterprises using BI software is associated, on average, with an increase of approximately 0.022 percentage points in the share of employment

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in middle-management occupations within Cluster 2 countries. The numerical effect is modest, but theoretically meaningful because it links managerial restructuring not to AI adoption as a formal technological indicator, but to the presence of analytical infrastructures that make AI-enabled coordination organizationally usable.

The empirical findings generally support the capability-based interpretation of AI-driven organizational transformation developed in the literature. The cluster analysis shows that EU countries with higher levels of ERP and BI diffusion, stronger organizational innovation indicators, and higher AI adoption form a distinct group of more advanced AI-driven organizational transformation environments. This is consistent with Arroyabe et al. (2024), who argue that internal digital and innovation capabilities are crucial enabling conditions for AI adoption. However, the present study extends this argument by showing that these capabilities are not only associated with AI adoption itself, but also form broader national environments in which organizational restructuring processes may become more visible.

At the same time, the regression results refine the assumption that AI adoption directly produces restructuring. In Cluster 2, only BI software diffusion demonstrated a statistically significant positive relationship with changes in middle-management employment, while general AI adoption and AI use in administration were excluded from the final model. This finding suggests that organizational restructuring is not driven simply by the presence of AI technologies, but by the analytical and managerial infrastructures that allow enterprises to embed data-driven systems into decision-making processes. This result corresponds with Fan (2025), who emphasizes the role of data analytics in strategic decision-making, and with Cheng et al. (2025), who show that digital innovation depends on configurations of capabilities rather than on a single technological factor. It also supports the broader argument that productivity and organizational gains from AI depend on complementary capabilities, workflow redesign and diffusion conditions rather than on formal adoption alone (Wamba, 2022; Wamba et al., 2024; Talaei-Khoei et al., 2024; Filippucci et al., 2024).

The positive relationship between BI diffusion and middle-management employment also complicates the widespread expectation that AI necessarily reduces managerial layers. Instead of confirming a straightforward substitution effect, the results suggest that in more digitally advanced environments, AI-related transformation may increase demand for hybrid managerial-analytical roles. This partially agrees with Vacek (2026), who conceptualizes AI systems as occupying functional roles within organizations, thereby redistributing rather than simply eliminating responsibility. It also aligns with Birkstedt et al. (2023), Papagiannidis et al. (2025) and Bankins et al. (2022), who argue that AI governance requires organizational structures, rules and coordination mechanisms; such governance may actually reinforce the need for specialized middle-management functions rather than eliminate them.

The absence of significant predictors in Cluster 1 further suggests that AI-driven restructuring is context-dependent. In countries with less advanced digital and organizational environments, the selected indicators do not yet produce measurable changes in middle-management employment. This finding is consistent with Lanne et al. (2025), who describe AI implementation as a socio-technical process shaped by organizational tensions, institutional readiness, and adaptation capacity. It also supports the argument by Arroyabe et al. (2024) that internal capabilities condition the effectiveness of AI adoption: where these capabilities are weaker, the organizational effects of AI may remain fragmented, delayed, or statistically invisible.

The results only partially correspond to critical perspectives on algorithmic management and labor substitution. Minotakis (2025) emphasizes that AI may intensify surveillance, reinforce power asymmetries and transform labor control. The present findings do not directly contradict this view, but they do not provide evidence of broad middle-management displacement either. Rather, they suggest that AI-driven restructuring may occur through reconfiguration and hybridization of managerial roles, not only through reduction. Recent occupational-exposure evidence similarly indicates that generative AI is more likely to transform task content and administrative work than to produce immediate and uniform job disappearance across all managerial categories (Kellogg et al., 2020; Stark & Vanden Broeck, 2024; International Labour Organization, 2025).

Overall, the findings support the existing literature in three ways: first, they confirm the importance of internal digital and innovation capabilities for AI-related transformation; second, they show that AI adoption alone is

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insufficient to explain organizational restructuring; and third, they indicate that managerial restructuring may take the form of role reconfiguration rather than direct displacement. The main contribution of the study is therefore to shift the discussion from AI adoption as a technological outcome toward AI-driven organizational restructuring as a capability-dependent, analytically mediated, and institutionally differentiated process across EU countries.

6. Conclusions

The present study examined whether the growing adoption of artificial intelligence technologies is associated with measurable organizational restructuring processes within enterprises across the European Union, with particular attention to changes in middle-management structures. Overall, the findings suggest that AI-driven corporate organizational restructuring is not a uniform or technologically deterministic process, but rather a differentiated transformation conditioned by enterprise-level digital and innovation capabilities, organizational environments, and analytical infrastructures.

The empirical analysis demonstrated substantial heterogeneity among EU countries in terms of digital integration, organizational innovation, and AI adoption intensity. The K-means cluster analysis identified two relatively distinct groups of countries characterized by different levels of AI-driven organizational transformation environments. Countries belonging to the more advanced cluster generally exhibited higher levels of ERP and BI diffusion, stronger organizational innovation activity, and greater AI adoption intensity, indicating that AI-driven transformation develops within broader configurations of organizational and technological capabilities rather than through isolated technological adoption alone.

At the same time, the results of the regression analysis suggest that the organizational consequences of AI adoption are more complex than assumptions about direct labor substitution or automatic hierarchical reduction. In the cluster of more digitally advanced countries, only BI software diffusion demonstrated a statistically significant positive relationship with changes in middle-management employment structures. This finding indicates that enterprise analytical capabilities and data-driven coordination infrastructures may play a more important role in organizational restructuring than general AI adoption intensity itself. Rather than eliminating managerial roles, AI-driven transformation may contribute to the emergence of hybrid managerial-analytical functions associated with coordination, oversight, and governance of digital systems. In contrast, no statistically significant relationships were identified within the cluster of less advanced organizational transformation environments, suggesting that the organizational effects of AI adoption may remain fragmented, delayed, or institutionally constrained in contexts with weaker digital and innovation capabilities.

Thus, the study achieved its main research objective by providing an indirect quantitative assessment of AI-driven corporate organizational restructuring within the EU and by demonstrating that higher levels of AI integration combined with stronger organizational capabilities may be associated with measurable changes in middle-management structures. Importantly, the findings indicate that organizational restructuring related to AI adoption should be interpreted not only in terms of labor substitution, but also as a broader process of managerial reconfiguration and transformation of organizational coordination mechanisms.

The study contributes to the existing literature in several ways. First, it shifts the analytical focus from AI adoption itself toward the organizational consequences of AI integration. Second, it develops a capability-based conceptual framework linking internal enterprise-level capabilities, AI adoption mechanisms, and organizational restructuring outcomes. Third, it proposes an original methodological approach combining cluster analysis and regression analysis in order to examine organizational transformation processes across heterogeneous EU environments. In this sense, the study contributes to bridging the gap between research on technological adoption, digital transformation, and organizational restructuring.

At the same time, several limitations should be acknowledged. The study relies primarily on aggregate Eurostat indicators and therefore cannot directly observe internal organizational processes, governance structures, or firm-level managerial practices. Several dimensions of organizational restructuring were operationalized through indirect proxy indicators, which limits the precision of causal interpretation. In addition, the relatively

short time horizon may not fully capture long-term restructuring effects associated with AI integration, especially given potential institutional and organizational time lags. Finally, the analysis focuses on macro-level cross-country patterns and does not account for sectoral heterogeneity, firm size differences, or industry-specific organizational models, which may substantially influence the relationship between AI adoption and organizational restructuring. Future research may therefore extend the present analysis through longitudinal firm-level datasets, sector-specific studies and qualitative organizational case studies examining how AI technologies reshape coordination mechanisms, managerial authority, task exposure, capability development and governance structures within enterprises over longer periods of time.

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BUSINESS ENTERPRISE EXPENDITURE ON RESEARCH AND DEVELOPMENT IN THE EUROPEAN UNION IN AN INTERNATIONAL CONTEXT*

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Abstract. This study examines the development of business enterprise expenditure on research and development (BERD) in the European Union between 2014 and 2024 and compares it with trends in selected global economies, namely the United States, Japan, China, and South Korea. The research employs descriptive time-series analysis and ordinary least squares (OLS) regression in a log–log specification to identify long-term trends, structural differences, and factors influencing business R&D investment. In addition, the study assesses environmental protection expenditure in selected European countries as a complementary indicator of sustainable competitiveness. The results show that although BERD in the European Union has increased steadily in absolute terms, the EU continues to lag behind all analysed economies when measured relative to economic performance. The regression analysis confirms a statistically significant positive relationship between economic size and BERD, while the estimated elasticity indicates that business R&D expenditure grows at a slower rate than the economy itself. Environmental protection expenditure also demonstrates an upward trend across the analysed countries, although the pace of growth differs considerably between individual states. The findings point to a persistent structural weakness within the European innovation system and highlight the need for more effective policy measures aimed at stimulating business investment in research and development. At the same time, the results emphasise the importance of supporting environmental investments as part of a broader strategy for strengthening the long-term competitiveness and sustainability of the European economy.

Keywords: business enterprise expenditure on research and development (BERD); European Union; innovation system; international comparison; OLS regression; competitiveness; research and development intensity; sustainability

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JEL Classifications: O30, O31, O38, O57, F21

1. Introduction

Investment in research and development (R&D) is widely recognised as one of the key determinants of long-term economic growth and business competitiveness. In the context of a global economy characterised by rapid technological change and fluctuations in the prices of various materials, the ability of firms to systematically allocate resources to the development of new knowledge, processes, and products has become increasingly important (Cui et al., 2021; lmeida et al., 2023; Arabi, 2025). Empirical studies indicate that firms with higher levels of R&D investment achieve greater productivity, respond more flexibly to market changes, and perform more successfully in international competition (Boeing, Eberle & Howell, 2022; Bataineh et al., 2024; Saharti,

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2025). Consequently, Business Enterprise Expenditure on Research and Development (BERD) serves as an important indicator of technological advancement and the innovation potential of an economy.

Within the European Union, research and innovation have long held strategic importance. R&D policy has been shaped by initiatives such as the Lisbon Strategy, the Europe 2020 Strategy, and, more recently, the Cohesion Policy framework and the Horizon Europe programme, all of which emphasise the importance of strengthening investment in innovation as a means of achieving sustainable growth and technological sovereignty (Degirmenci & Yavuz, 2024; Pellens et al., 2024). Progress in this area is regularly monitored through indicators such as BERD, the share of R&D expenditure in gross domestic product (GDP), and the innovation capacities of Member States (Caglar et al., 2025). These frameworks reflect the European Union's efforts to enhance business competitiveness and promote a transition towards a knowledge-based economy.

In the international arena, the European Union faces growing competition from other major economies, particularly the United States, Japan, South Korea, and China. These countries consistently demonstrate high levels of business R&D expenditure and frequently achieve greater BERD intensity relative to GDP than the European Union average (Ersin et al., 2022; Arana-Barbier, 2023). A distinctive feature of the European Union is the considerable heterogeneity among its Member States. While countries such as Germany, Sweden, and Denmark rank among global innovation leaders, others exhibit lower investment levels and slower growth dynamics. This internal diversity affects the overall position of the Union within the global innovation landscape and slows the process of convergence towards the world's most advanced economies. Given the current challenges facing the European innovation system, a comprehensive analysis of business-sector investment in research and development within a broader international context is required.

The aim of this study is to evaluate the development of Business Enterprise Expenditure on Research and Development (BERD) in the European Union during the period 2014–2024, to assess the factors associated with the dynamics of these investments, and to compare the position of the European Union with selected major global economies, namely the United States, Japan, China, and South Korea. Based on these findings, conclusions are drawn regarding the development of the competitiveness of the European business sector.

To achieve this objective, the following research questions are formulated:
RQ1: How did business-sector expenditure on research and development (BERD) in the European Union evolve between 2014 and 2024 compared with the international average? Addressing the first research question enables the identification of both current and long-term trends in business R&D expenditure and places developments within the European Union in an international context.

RQ2: What relationship exists between economic size (GDP) and the level of business expenditure on research and development (BERD) in the selected economies (the European Union, the United States, Japan, China, and South Korea) during the period 2014–2024? Addressing this research question facilitates an analysis of the relationship between economic size, measured by gross domestic product (GDP), and the level of business expenditure on research and development (BERD).

RQ3: How did the position of the European Union in the global landscape of business expenditure on research and development (BERD) evolve between 2014 and 2024 compared with other major economies (e.g., the United States, Japan, South Korea, and China), and how did environmental protection expenditure develop across European countries during the same period as a complementary dimension of sustainable competitiveness? Addressing the third research question enables an assessment of the European Union's position within the global R&D environment and its level of competitiveness relative to other major economies. It also considers the development of environmental protection expenditure in European countries as part of the transition towards a sustainable and innovation-driven economy.

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2. Theoretical background

Business Expenditure on Research and Development (BERD) is widely regarded as one of the key components of modern innovation systems and serves as an important indicator of the technological and innovative performance of economies (Biel, 2023; Vetsikas & Stamboulis, 2023). Sarpong et al. (2022) and Wyrwa (2022) interpret BERD as a fundamental instrument through which firms develop their innovation capacity, strengthen their ability to generate new knowledge, and transform such knowledge into innovative products, processes, and services (Kollmann et al., 2024; Fu, Li & Wu, 2024; Ferreira, Fernandes & Veiga, 2025). Baruk (2022) further argues that these activities contribute not only to enhancing business competitiveness but also to increasing productivity and supporting long-term economic development.

Leung and Sharma (2021) emphasise that the importance of business expenditure on research and development lies not only in its absolute volume but also in the stability and long-term continuity of such investments. According to the authors, the systematic implementation of R&D activities enables firms to accumulate knowledge more effectively and utilise it more efficiently over time, resulting in greater innovation performance and more favourable long-term economic outcomes. Maintaining such continuity, however, is often challenging for firms, as R&D investments are exposed to a range of economic and organisational constraints (Link & Sardar, 2023; Park & Lee, 2023; Nguyen & Nguyen, 2024). Based on an empirical analysis, Beladi et al. (2021) demonstrated that cash-flow uncertainty leads firms to adopt more cautious investment behaviour and reduce R&D expenditure, while financial constraints further amplify this negative effect. Similarly, Milani and Neumann (2022) conclude that even globally innovative firms experience reductions in R&D intensity due to financial limitations, with information asymmetry and firms' ability to mitigate it, for example through patent activity, playing a crucial role. Beyond financial constraints, Coad et al. (2021) highlight the existence of non-financial barriers, particularly the high uncertainty associated with research outcomes, the lengthy duration of research projects, and the limited availability of qualified human resources, all of which increase the complexity of corporate decision-making regarding the scale and continuity of R&D activities. Taken together, these findings suggest that firms' investment behaviour in research and development cannot be explained solely by financial constraints but rather results from the simultaneous influence of multiple interconnected factors (Kollmann et al., 2024). The strategic importance of business expenditure on research and development has recently been reinforced at the level of European Union policy by the Draghi report on European competitiveness (Draghi, 2024). The report identifies the persistent innovation gap between the European Union and its main global competitors, the United States and China, as one of the principal causes of Europe's slowing productivity and weakening competitive position. A central element of this diagnosis is the long-term underfunding of research and development by European firms; the report notes that in 2021 EU companies invested approximately EUR 270 billion less in research and innovation than their counterparts in the United States, and it argues that the Union's repeated failure to reach the long-standing target of devoting 3 % of GDP to R&D is a fundamental reason for this lag.

3. Research objective and methodology

The input data for the analysis of Business Expenditure on Research and Development (BERD) were obtained from the Eurostat database (Eurostat, 2025), which ensures the methodological comparability of indicators both within the European Union and across other global economies. The analysed period covers the years 2014–2024, with values reported in current prices and expressed in millions of euros. The selection of this time horizon enables the identification of long-term investment trends, including structural changes associated with exogenous shocks, particularly those observed in 2020. To assess the international position of the European Union, data from leading economies, namely the United States, China, Japan, and South Korea, were incorporated into the analysis. Based on these data, an international average was calculated and used as a benchmark for evaluating global competitiveness. A supplementary analysis of environmental protection expenditure was conducted using data from the OECD database (OECD, 2025). The dataset covers selected European countries for the period 2014–2022. To ensure comparability across countries, all values were converted into an index with the base year 2014 (= 100). An overview of all variables included in the analysis, together with their sources and units of measurement, is presented in Table 1.

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Table 1. Overview of Variables Used in the Analysis

Variable	Description	Source	Unit
BERD	Business expenditure on research and development	Eurostat	EUR million
GDP	Gross domestic product	Eurostat	EUR million
BERD_intensity	BERD intensity as a share of GDP	Eurostat	% of GDP
BERD_avg	International average BERD	Author's calculation	EUR million
EPE_index	Environmental protection expenditure index	OECD	2014 = 100

Source: Authors' own elaboration

Descriptive Analysis

Descriptive time-series analysis is employed to identify long-term trends, structural breaks, and differences in the dynamics of BERD across the analysed economies. Through graphical representation of both the absolute values of BERD and its intensity relative to GDP, the relative position of the European Union within the global context is assessed, together with the extent of its convergence towards or divergence from the world's most technologically advanced economies.

All visualisations were produced using the Python programming language, which is widely utilised in scientific computing and data analysis due to its extensive ecosystem of specialised libraries. The Pandas library was employed for data loading, transformation, and manipulation, enabling efficient processing of tabular time-series data. Numerical computations and matrix operations were performed using the NumPy library. Graphical outputs were generated with Matplotlib, which provides extensive capabilities for producing publication-quality visualisations, including multi-line time-series charts that facilitate a clear comparison of developments across economies throughout the analysed period (Ono, Feire & Silva, 2021).

Regression Analysis

To examine the relationship between economic size, measured by gross domestic product (GDP), and the level of business expenditure on research and development (BERD), a simple linear regression model estimated by the Ordinary Least Squares (OLS) method is applied. Given the substantial variation in the magnitude of both variables and in order to linearise their relationship, both variables were transformed using natural logarithms, resulting in the following log–log model specification:

$$\log(BERD) = \beta_0 + \beta_1 \cdot \log(GDP) + \varepsilon$$

where:

- log(BERD) represents the dependent variable, expressed as the natural logarithm of business expenditure on research and development;
- log(GDP) denotes the independent variable, representing the natural logarithm of gross domestic product;
- β_0 is the intercept term;
- β_1 is the regression coefficient measuring the elasticity of BERD with respect to GDP; and
- ε represents the random error term.

Within the log–log specification, the coefficient β_1 has a direct elasticity interpretation, indicating the percentage change in BERD associated with a one-percent change in GDP, ceteris paribus.

4. Results and discussion

To address the research questions, an analysis of the development of business expenditure on research and development (BERD) in the European Union over the period 2014–2024 was first conducted. BERD represents a key indicator of innovation activity within the business sector and reflects the technological sophistication of an economy.

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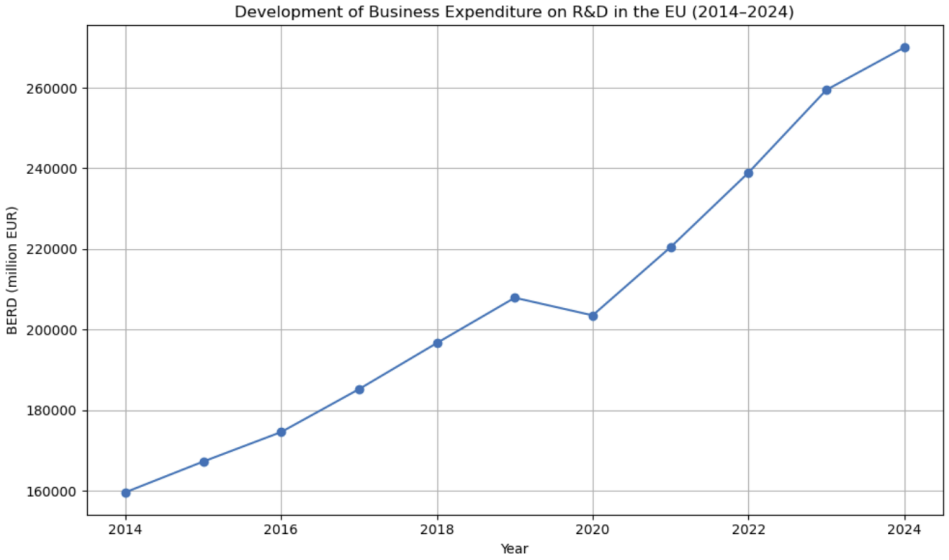


Figure 1. Development of BERD, 2014–2024
Source: Authors' own elaboration based on Eurostat data

Figure 1 illustrates a substantial increase in business expenditure on research and development within the European Union between 2014 and 2024. The only exception was a slight decline in 2020, attributable to the COVID-19 pandemic, after which growth resumed. Overall, the results indicate a long-term upward trend in investment in research and innovation across the European Union. This development suggests that European firms increasingly prioritise innovation and technological advancement. The growth in R&D expenditure may be associated with several factors, including public-sector support, increasing competition in global markets, and the need to keep pace with rapidly evolving technologies. The long-term increase in BERD represents an important indicator of future economic prosperity and competitiveness within the European Union, as innovation frequently contributes to the development of new products, services, and market opportunities.

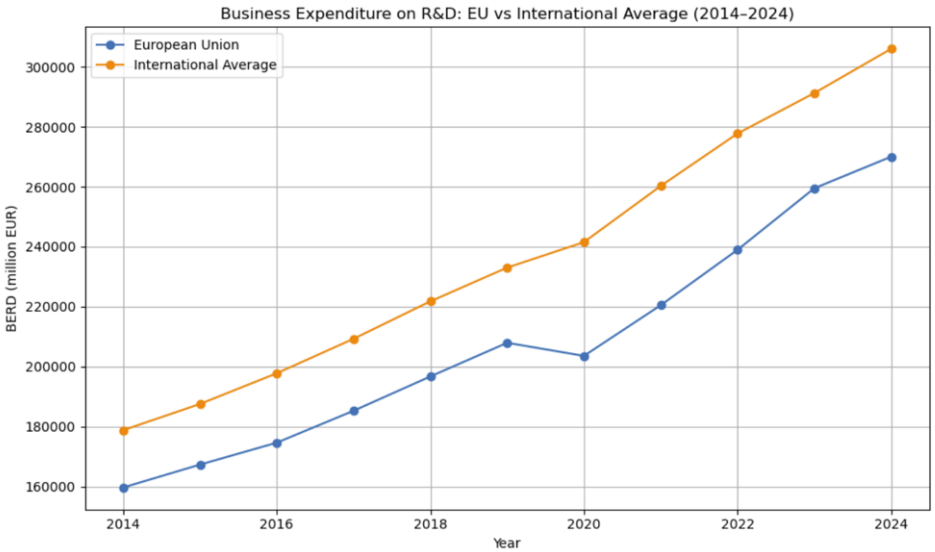


Figure 2. Comparison of the European Union and the Average of Selected Economies
Source: Authors' own elaboration based on Eurostat data

Figure 2 presents the development of BERD in the European Union compared with the average of selected global economies (the United States, Japan, China, and South Korea) between 2014 and 2024. Both groups exhibit a continuous increase in business-sector investment in research and development. However, the international average remained consistently above the European Union throughout the entire period. A moderate decline was observed in 2020 as a consequence of the COVID-19 pandemic, followed by renewed growth, particularly among the selected global economies. The temporary downturn was more pronounced in the

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European Union than in the comparison group. These findings point to persistent differences in the intensity of business investment in research and development between the European Union and technologically advanced economies, which may have important implications for the long-term competitiveness of the European innovation system.

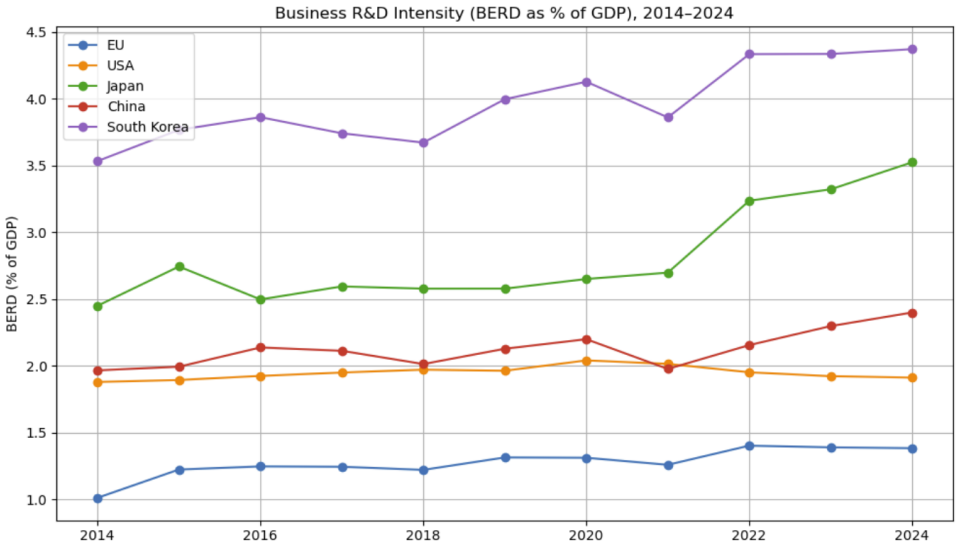


Figure 3. BERD Intensity as a Percentage of GDP, 2014–2024
Source: Authors' own elaboration based on Eurostat data

Figure 3 illustrates BERD intensity measured as a share of GDP, enabling comparisons across economies of different sizes. South Korea occupies a dominant position, with BERD intensity ranging from approximately 3.5% to 4.3% of GDP and exhibiting a generally upward trend. Japan records values between 2.5% and 3.5% of GDP and demonstrates a notable increase towards the end of the analysed period. China has strengthened its position considerably, with BERD intensity rising from approximately 2.0% to 2.4% of GDP, reflecting sustained governmental support for innovation. The United States displays relatively stable values around 2.0% of GDP. In contrast, the European Union remains behind these economies, with BERD intensity fluctuating between 1.0% and 1.4% of GDP and showing only gradual growth. These findings indicate that the challenge faced by the European Union is not merely the absolute level of business R&D expenditure but, more importantly, its relatively low intensity in relation to the size of the economy. This represents a structural weakness of the European innovation system with potentially significant consequences for long-term competitiveness.

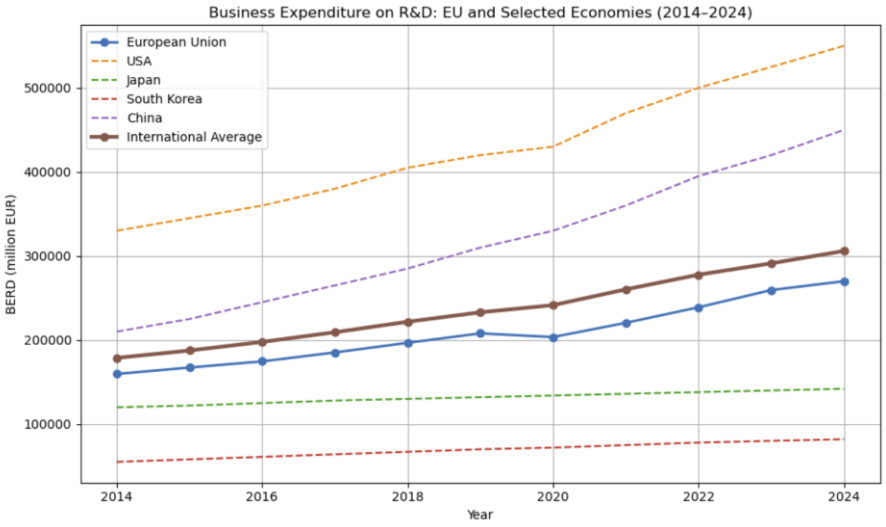


Figure 4. Business Expenditure on Research and Development in the European Union and Selected Economies – Detailed Comparison (2014–2024)
Source: Authors' own elaboration based on Eurostat data

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Figure 4 extends the comparison presented in Figure 2 by supplementing the international average with the individual trajectories of the analysed economies, thereby providing a more detailed perspective on the structure of the global R&D environment. The results reveal that the international average shown in the previous figure is driven primarily by the exceptional performance of the United States and the rapid growth of China. While the United States maintained the highest absolute levels of BERD throughout the analysed period, China exhibited the strongest growth dynamics and progressively narrowed the gap with the United States. Japan and South Korea occupied relatively stable but considerably lower positions. The European Union remained between Japan and South Korea; however, its growth trajectory was noticeably slower than those of both China and the United States. Consequently, the findings provide further evidence of the investment gap identified in Figure 2 and demonstrate that this gap is largely shaped by the performance of two dominant economies against which the European Union continues to lag in absolute terms.

Table 2. Results of the OLS Regression Model

OLS Regression Results			
Dep. Variable	log_BERD	R-squared	0.900
Model	OLS	Adj. R-squared	0.899
Method	Least Squares	F-statistic	479.3
Date	Mon, 16 Mar 2026	Prob (F-statistic)	3.24e-28
Time	10:39:18	Log-Likelihood	8.1752
No. Observations	55	AIC	-12.35
Df Residuals	53	BIC	-8.336
Df Model	1		
Covariance Type	nonrobust		

Source: Authors' own elaboration based on Eurostat data

Table 2 presents the results of the regression analysis estimated using a log–log specification, the purpose of which was to examine the relationship between economic size and the level of business expenditure on research and development. The estimated model demonstrated a high explanatory power, with a coefficient of determination of $R^2 = 0.900$, indicating that 90% of the variation in the dependent variable, log(BERD), is explained by variation in log(GDP). The overall statistical significance of the model is confirmed by an F-statistic of 479.3 ($p < 0.001$). The model was estimated using 55 observations, with one degree of freedom for the model and 53 residual degrees of freedom. The log-likelihood value equals 8.175, while the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) attain values of −12.35 and −8.336, respectively, indicating a good fit of the model to the data. The adjusted coefficient of determination $R^2 = 0.899$ further confirms that the high explanatory power of the model is not the result of over-parameterisation. More detailed results of the estimated parameters and diagnostic tests are presented in Table 3.

Table 3. Estimated Parameters and Diagnostic Tests of the OLS Model

	coef	**std err**	**t**	**P>|t|**	**[0.025**	**0.975]**
const	6.3680	0.896	7.110	0.000	4.572	8.164
log_GDP	0.6585	0.030	21.893	0.000	0.598	0.719
Diagnostic Tests						
Omnibus	6.923		Durbin-Watson		0.249	
Prob(Omnibus)	0.031		Jarque-Bera (JB)		6.644	
Skew	-0.850		Prob(JB)		0.0361	
Kurtosis	3.077		Cond. No.		932.	

Source: Authors' own elaboration based on Eurostat data

The estimated regression coefficient for the variable log(GDP) is $\beta_1 = 0{,}6585$ ((std. err. = 0,030; t = 21,893; $p < 0{,}001$), with a 95% confidence interval ranging from 0.598 to 0.719. The intercept term is estimated at $\beta_0 = 6{,}368$ (std. err. = 0,896; t = 7,110; $p < 0{,}001$). Within the log–log specification, the estimated coefficient can be interpreted as an elasticity measure. Specifically, a 1% increase in GDP is associated with an approximately 0.66% increase in BERD, ceteris paribus (Figure 5). The fact that the estimated elasticity is lower than one suggests that business expenditure on research and development grows at a slower rate than the economy itself.

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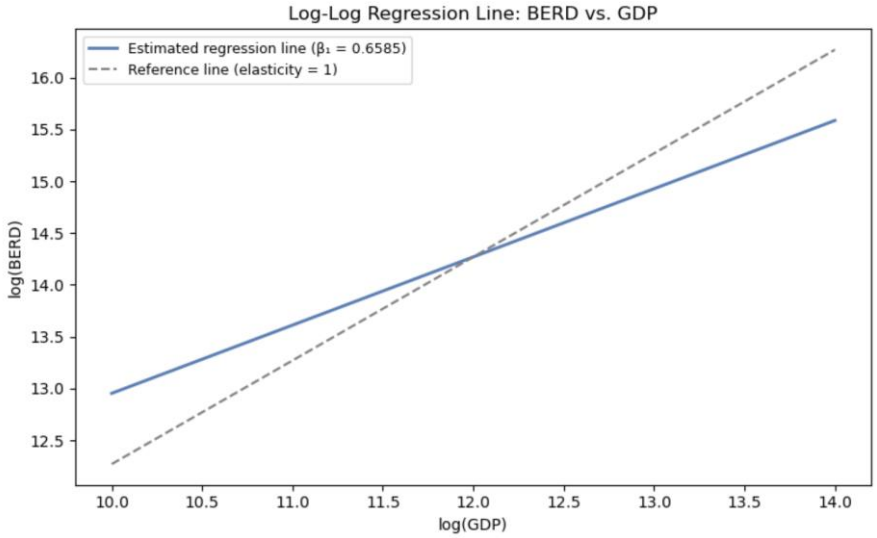


Figure 5. Interpretation of Elasticity
Source: Authors' own elaboration based on Eurostat data

The diagnostic tests indicate several limitations that should be considered when interpreting the results. The low value of the Durbin–Watson statistic (0.249) suggests the presence of positive autocorrelation in the residuals, which is expected given the time-series structure of the data. Furthermore, the Jarque–Bera test (p = 0.036) indicates a moderate deviation of the residuals from a normal distribution. Despite these limitations, the overall explanatory power of the model remains high.

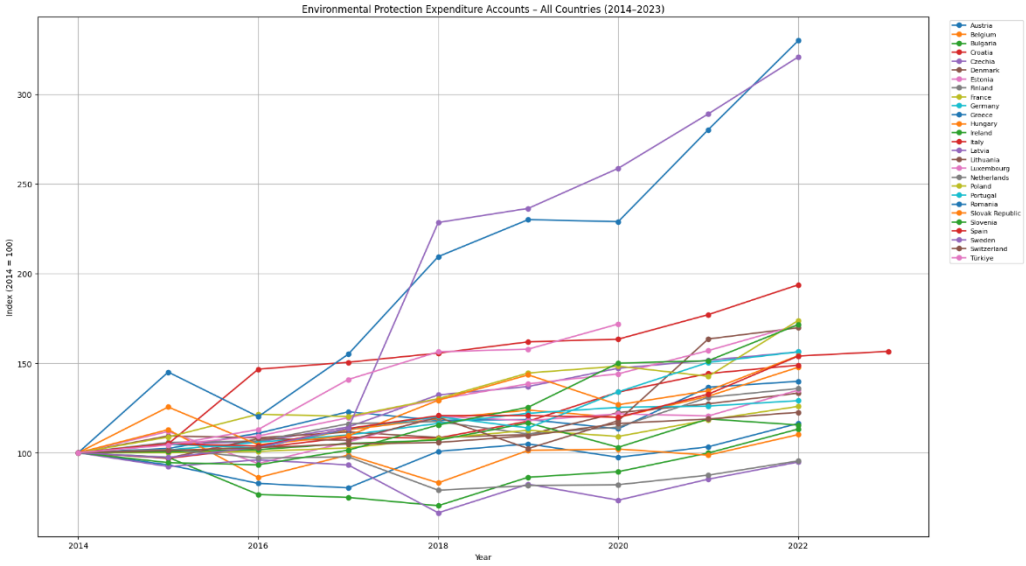


Figure 6. Growth Dynamics of Environmental Protection Expenditure in Selected European Countries (Index, 2014 = 100)
Source: Authors' own elaboration based on OECD data

Using OECD data on national environmental protection expenditure, the growth dynamics of environmental spending in selected European countries were analysed for the period 2014–2022 (Figure 6). To ensure comparability across countries, all values were converted into an index with the base year 2014 set equal to 100. The resulting index therefore reflects the relative change in environmental protection expenditure compared with the baseline year. The findings suggested that environmental expenditure generally increased across most of the analysed countries, indicating a gradual strengthening of activities related to environmental protection and sustainable development. However, the growth of environmental expenditure varied considerably among countries.

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The most pronounced growth dynamics were observed in Sweden and Romania. In Sweden, the indicator increased sharply, particularly after 2017, with the index exceeding 320 in 2022. This represented more than a threefold increase in environmental expenditure compared with 2014. A similar trend was identified in Romania, where the index reached approximately 330 in 2022. Such substantial growth may have been associated with increased support for environmental projects, infrastructure modernisation, and the utilisation of European Union financial instruments aimed at facilitating the green transition.

Significant growth was also evident in Italy, Poland, and the Czech Republic. In the Czech Republic, the index exhibited steady growth throughout the analysed period, increasing from approximately 102 points in 2014 to more than 160 points in 2022. This development suggested a gradual strengthening of investments in environmental protection activities, particularly in waste management, wastewater treatment, energy efficiency measures, and the adoption of environmentally friendly technologies.

In contrast, Germany, France, Belgium, and Austria displayed more moderate growth patterns. Index values in these countries generally ranged between 130 and 150 points. Although the growth dynamics were less pronounced than in many Central and Eastern European countries, these findings should not be interpreted as evidence of low levels of environmental investment. The more moderate pace of growth may reflect the fact that these countries already possessed relatively high levels of environmental expenditure at the beginning of the analysed period, resulting in more gradual increases over time.

Among some smaller economies, such as Latvia, Bulgaria, and Greece, more substantial year-to-year fluctuations in index values were observed. This volatility may have been influenced by lower overall investment volumes, greater sensitivity to individual large-scale projects, or variations in the utilisation of public funding programmes.

The results of the analysis provide an empirical basis for addressing the three research questions and allow the findings to be interpreted within the broader context of the existing literature.

RQ1: How did business-sector expenditure on research and development (BERD) in the European Union evolve between 2014 and 2024 compared with the international average?
The first research question focused on the development of business expenditure on research and development in the European Union between 2014 and 2024 in comparison with the international average. The descriptive analysis revealed that BERD in the EU followed an upward trend throughout the analysed period, interrupted only by a temporary decline in 2020 as a consequence of the COVID-19 pandemic. This finding is consistent with Pellens et al. (2024), who argue that economic crises typically lead to a temporary reduction in R&D investment, while the subsequent recovery depends largely on the stability of the macroeconomic environment. Although the absolute value of BERD in the EU increased steadily over time, the international average exceeded EU levels throughout the entire period, and the gap between them gradually widened. This conclusion is in line with the findings of Dachs et al. (2024), who emphasise that the European Union continues to lag behind the leading global economies in terms of business R&D expenditure despite sustained growth in investment.

RQ2: What relationship exists between economic size (GDP) and the level of business expenditure on research and development (BERD) in the selected economies (the European Union, the United States, Japan, China, and South Korea) during the period 2014–2024?
The second research question examined the relationship between economic size, measured by GDP, and the volume of business expenditure on research and development. The OLS regression analysis using a log–log specification confirmed a statistically significant positive relationship between the two variables ($\beta_1 = 0.6585$; $p < 0.001$; $R^2 = 0.900$). The estimated elasticity, which is below one, indicates that business expenditure on research and development grows at a slower rate than the economy as a whole. This finding is consistent with the conclusions of Chmielewski et al. (2025), who argue that economic size alone is insufficient to achieve high levels of BERD. The results also correspond with the findings of Santos et al. (2024), who emphasise that firms' decisions regarding R&D investment are influenced not only by economic potential but also by the availability

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of financial resources, institutional conditions, and the degree of uncertainty associated with the returns on innovation projects.

RQ3: How did the position of the European Union in the global landscape of business expenditure on research and development (BERD) evolve between 2014 and 2024 compared with other major economies (e.g., the United States, Japan, South Korea, and China), and how did environmental protection expenditure develop across European countries during this period as a complementary dimension of sustainable competitiveness?

The third research question addressed the evolution of the European Union's position within the global landscape of business expenditure on research and development. The analysis of BERD intensity as a percentage of GDP indicates that the EU lags considerably behind the analysed economies, including South Korea, Japan, China, and the United States. Furthermore, the observed growth rate appears insufficient to eliminate this structural gap. This conclusion is consistent with the findings of Moncada-Paternò-Castello and Grassano (2022), who argue that the lower BERD intensity observed in the EU is associated with a lower concentration of technologically advanced firms and weaker integration into international knowledge networks. The dynamic growth of business R&D expenditure in China, also highlighted by Fu et al. (2024), represents a significant competitive challenge and further influences the EU's position within the global innovation landscape. By contrast, the stable yet dominant position of the United States supports the conclusions of Belderbos et al. (2023) regarding the enduring technological leadership of the American business sector.

From the perspective of sustainable competitiveness, the supplementary analysis of environmental protection expenditure growth (Figure 6) revealed that European countries generally increased their environmental investments during the period 2014–2022, although with substantial variation across countries. While Sweden and Romania recorded more than a threefold increase in the expenditure index, and the Czech Republic, Italy, and Poland demonstrated steady growth, several Western European countries experienced more moderate increases from already high initial levels. This pattern reflects the growing integration of innovation and environmental policies within the framework of the Cohesion Policy and the Horizon Europe programme, as highlighted by Degirmenci and Yavuz (2024) and Caglar et al. (2025). The findings suggest that strengthening business R&D expenditure and promoting investment in the green transition constitute complementary pillars of the long-term competitiveness of the European economy.

Overall, the results are consistent with the broader literature on the determinants of business investment in research and development. The relatively low BERD intensity observed in the European Union is partly explained by structural characteristics of the European business sector, particularly the lower representation of technologically advanced industries and the high proportion of small and medium-sized enterprises, which face specific barriers to engaging in research-oriented activities, as noted by Czarnitzki and Giebels (2024) and Rajamani et al. (2022). Moreover, the persistent heterogeneity among EU Member States, emphasised by Chmielewski et al. (2025), further weakens the overall position of the European Union, as the strong performance of Northern and Western European countries is offset by substantially lower investment levels in many Southern and Central European economies. Enhancing the innovation performance of the EU therefore requires not only higher levels of business expenditure on research and development but also improvements in the institutional environment, stronger collaboration between businesses, universities, and the public sector, and more effective utilisation of public support instruments for research and innovation, as suggested by Rossoni et al. (2024), Dong et al. (2025) and Stoeber and Kanbach (2025).

Conclusions

The aim of this study was to analyse the development of Business Expenditure on Research and Development (BERD) in the European Union between 2014 and 2024, to assess the factors influencing its dynamics, and to compare the position of the EU with selected major global economies, namely the United States, Japan, China, and South Korea. To achieve this objective, descriptive time-series analysis and Ordinary Least Squares (OLS) regression in a log–log specification were applied to data obtained from the Eurostat database. The analysis was further complemented by an assessment of environmental protection expenditure in selected European countries based on OECD data, considered as a complementary dimension of sustainable competitiveness.

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The results of the descriptive analysis demonstrated that business expenditure on research and development in the European Union followed a long-term upward trend, interrupted only by a temporary decline in 2020 due to the COVID-19 pandemic. Although the absolute level of BERD in the EU increased over time, the international average derived from the selected global economies remained consistently higher throughout the analysed period, and the investment gap gradually widened. The analysis of BERD intensity as a percentage of GDP revealed that the challenge faced by the EU is not limited to the absolute volume of investment but is primarily associated with its relatively low intensity, which remained at approximately 1.0–1.4% of GDP. This contrasts sharply with South Korea, where BERD exceeded 4% of GDP, and Japan, where it approached 3.5% of GDP. This structural deficit indicates that the European Union has not fully utilised its economic potential to support business-sector innovation activities. The supplementary analysis of environmental protection expenditure further showed that European countries generally increased their environmental investments between 2014 and 2022, albeit with substantial heterogeneity. While the expenditure index more than tripled in Sweden and Romania, growth was more moderate in Western European countries that already exhibited relatively high initial expenditure levels.

The regression analysis confirmed a statistically significant positive relationship between economic size, measured by GDP, and the level of business expenditure on research and development. However, the estimated elasticity, which was lower than one, indicates that BERD grows at a slower rate than the economy itself. This finding suggests that while economic size represents an important predictor of BERD, it is not a sufficient condition for achieving high levels of business R&D expenditure. Institutional quality, industrial structure, and the availability of financing for innovation activities also play a crucial role. A particularly noteworthy finding is the exceptionally dynamic growth of business R&D expenditure in China, which is progressively approaching the level of the United States and represents an increasingly significant competitive challenge for the European Union.

The novelty of this study lies in three aspects. First, it places EU business expenditure on research and development in an international comparative framework for 2014–2024 and shows that the EU's principal weakness is not the absolute volume of R&D but its persistently low intensity relative to South Korea, Japan, and, increasingly, China. Second, by integrating environmental protection expenditure into the analysis, it provides empirical support for treating innovation investment and the green transition as complementary rather than competing pillars of sustainable competitiveness. Third, the log–log specification shows that the elasticity of business R&D with respect to economic size is significantly below unity, confirming that economic growth alone does not translate into a proportional increase in business R&D. Together, these findings offer up-to-date evidence directly relevant to the concerns raised in the Draghi report.

The findings indicate that the European Union faces a structural deficit in business expenditure on research and development, both in absolute and relative terms. Addressing this gap requires systemic measures at multiple levels. Particular emphasis should be placed on strengthening the institutional environment that supports innovation, enhancing cooperation between businesses, universities, and the public sector, improving the effectiveness of public support instruments for research and development, and reducing the structural barriers faced by small and medium-sized enterprises. At the same time, the results suggest that strengthening business R&D activities and investing in the green transition constitute complementary pillars of long-term competitiveness. Without such measures, the investment gap between the European Union and global innovation leaders is likely to widen further, potentially undermining the long-term competitiveness and technological autonomy of the European economy.

Several limitations should be considered when interpreting the results. The regression analysis is based on aggregated data at the economy level and therefore does not capture heterogeneity among individual EU Member States or differences in the sectoral structure of R&D investment. Similarly, the descriptive comparison of environmental expenditure should be regarded as indicative, as it relies on indexed values covering the shorter period of 2014–2022. Future research should focus on panel-data analysis at the Member State level in order to identify the specific factors underlying investment gaps within the European Union. Further studies should also explore the relationship between business R&D expenditure and investments in sustainability and environmental protection in greater depth.

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REFLECTING THE VALUE CHAIN IN INTEGRATED REPORTING: A TOOL FOR SUSTAINABILITY ASSESSMENT

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Abstract. At the current stage of economic development, business management and stakeholders—primarily providers of financial capital—require comprehensive information about the value created by enterprises. Such value can be effectively represented through integrated reporting, a model grounded in integrated thinking that depicts the entire value chain, from creation to preservation and erosion. The study aims to identify information related to the representation of the entire value chain process—creation, preservation, and erosion of value. It examines how enterprises utiliseutilise various types of capital (financial, manufactured, human, intellectual, natural, social, and reputational) and interact with the environment; how financial and non-financial information, including environmental, social, and governance (ESG) factors, is integrated; and how the interconnection between strategy, governance, operations, and future outlook contributes to the creation of sustainable value. The research methodology is grounded in the International Integrated Reporting Council (IIRC) Framework, the European Union's Corporate Sustainability Reporting Directive (CSRD), the European Sustainability Reporting Standards (ESRS), materials from leading international auditing and consulting firms, and scholarly literature. General scientific methods of inquiry were applied, including analysis, synthesis, generalisation, abstraction, and a systems-based approach. The study analyses the conceptual foundations of integrated reporting, including the value-creation model as defined by the <IR> Framework, its objectives, and core elements. It further examines the essence of the value chain as defined by the ESRS, highlighting the processes of value creation, preservation, and erosion; the role of value chain workers; the concepts of material impacts, risks, and opportunities; and the disclosure requirements related to value chains.

Keywords: Integrated reporting; Upstream value chain; Downstream value chain; Double materiality; European Sustainability Reporting Standards (ESRS); Sustainability disclosure

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JEL Classifications: Q56, Q58

1. Introduction

Providers of financial capital are interested not only in the value an organisation creates for itself but also in the value it generates for other stakeholders. Such information is prepared in accordance with the conceptual foundations of *Integrated Reporting (<IR>)* (IFRS, 2021) and the disclosure requirements set out in the *European Sustainability Reporting Standards (ESRS)*, which emphasise the integration of Environmental, Social, and Governance (ESG) factors.

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Integrated Reporting

The purpose of integrated reporting is to improve the quality of information available to providers of financial capital, thereby supporting effective decision-making to create sustainable value in the short, medium, and long term. Accordingly, the main task of integrated reporting is to integrate financial and non-financial information to provide a holistic view of how an organisation creates, preserves, or erodes value over time. Value is neither created, preserved, nor lost solely within the organisation itself. The process of value creation is influenced by external factors and shaped through relationships with stakeholders; it also depends on the availability and use of diverse resources. Therefore, integrated reporting requires aligning ESG factors, corporate strategy, resources, and the business model in a single report. It must also demonstrate the interconnections among various aspects of organisational activity—strategy, resources, risks, and outcomes—and disclose how value is created, preserved, or eroded for both the enterprise itself and its stakeholders (Figure 1). Ultimately, the focus is placed on long-term sustainability and on providing investors and other stakeholders (PWC, 2019) with high-quality, decision-useful information (Songini et al., 2023; de Oliveira et al., 2025).

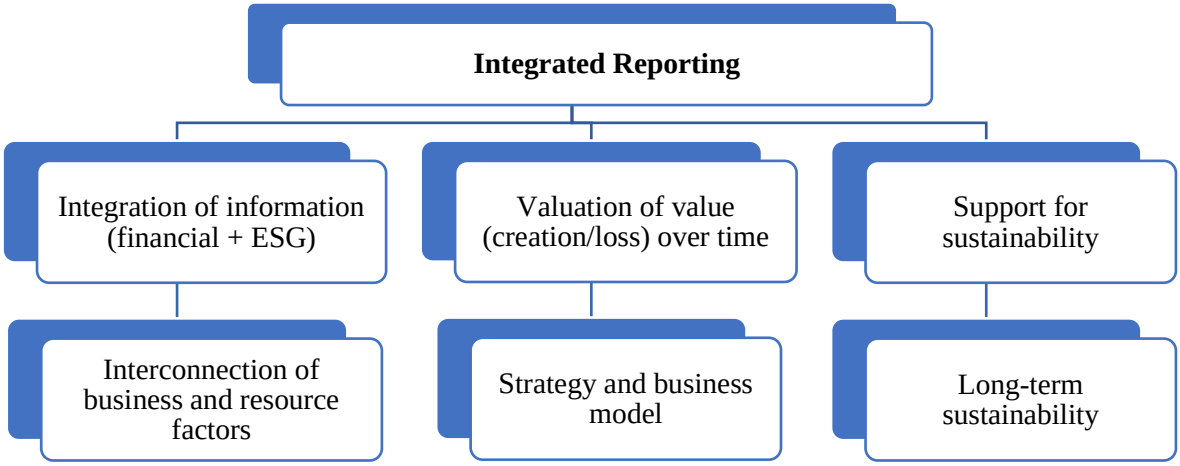


Figure 1. Key Elements of Integrated Reporting
Source: European Sustainability Reporting Standards (ESRS)

The European Sustainability Reporting Standards (ESRS) define the information that enterprises must disclose regarding their material impacts, risks, and opportunities in relation to environmental, social, and governance (ESG) matters (ESRS 1, §2). These standards introduce new requirements that obligate EU companies to report on ESG aspects of their activities. They have been developed by the *European Financial Reporting Advisory Group (EFRAG)* (European Union, 2022) and are implemented within the Framework of the *Corporate Sustainability Reporting Directive (CSRD)* (European Parliament, 2022).

The primary objective of the ESRS is to ensure that enterprises transparently disclose how they:

- affect the environment and society;
- are exposed to sustainability-related risks (e.g., climate risks);
- create sustainable value in the long term.

The value model under the CSRD requires the presentation of non-financial information. In line with the directive, the ESRS specifies the types of non-financial information (environmental, social, and governance) that organisations must disclose.

The ESRS framework is structured as follows:

1. General Standards (ESRS 1–2) – Applicable to all organisations, covering general disclosure requirements.

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2. Topical Standards:
    - Environmental standards (ESRS E1–E5): Climate, pollution, water, ecosystems, and biodiversity.
    - Social standards (ESRS S1–S4): Own workforce, value chain workers, affected communities, consumers, and end-users.
    - Governance standard (ESRS G1): Business conduct.
    - Sector-Specific Standards (Sector-Specific ESRS)

The sector-specific ESRS take into account the particular characteristics of individual industries, where risks, opportunities, and impacts may differ significantly. The purpose of these standards is to:

- ensure more relevant and accurate disclosure of information;
- reflect sector-specific risks, opportunities, and impacts.

At present, sector-specific ESRS are being developed for the following industries: energy and extractive industries, financial services, food production, construction and real estate, transport, and education (the latter primarily for public institutions). The development of sector-specific ESRS is intended to capture the unique features of different sectors in the context of sustainability reporting, with priority given to industries that have a significant impact on the environment and society—such as oil and gas, mining, transportation, and financial institutions. According to the European Sustainability Reporting Standard ESRS 1 *General Requirements*, the following structure of sustainability reporting is proposed (European Commission, 2023), see Table 1.

Table 1. Structure of European Sustainability Reporting Standards (ESRS 1)

Information	European Sustainability Reporting Standards (ESRS)
General information	ESRS 2 — General requirements for disclosure of information; Market position, strategy, business model, value chain
Environmental information	ESRS E1 — Climate change ESRS E2 — Pollution ESRS E3 — Water and marine resources ESRS E4 — Biodiversity and ecosystems ESRS E5 — Resource use and circular economy
Social information	ESRS S1 — Own workforce ESRS S2 — Workers in the value chain ESRS S3 — Affected communities ESRS S4 — Consumers and end-users
Governance information	ESRS G1 — Business conduct

2. Value Creation Model and Sustainability Reporting

The International Integrated Reporting Council (IIRC) introduced the Value Creation Model to achieve its objectives — reflecting the entire value chain by using all types of capital while protecting the interests of value chain participants. Specifically, it aims to provide more complete, transparent, and comprehensive information about the organisation's activities, strategy, management, outcomes, and prospects, taking into account not only financial but also non-financial aspects such as social and environmental impacts, corporate governance, social responsibility, and the use and preservation of capital (financial, manufactured, intellectual, human, social, and natural) (Piesiewicz & Kufel, 2025; Singhal & Goel, 2026). The creation, preservation, and erosion of value are universal processes that encompass economic activity as well as cultural, philosophical, and managerial spheres. Understanding this process is fundamental for analysing the sustainability of social systems, businesses, and society as a whole. The conceptual foundation of integrated reporting (the International <IR> Framework) includes the Value Creation Model. This model explains how an organisation creates, preserves, or erodes/loses value in the short, medium, and long term. The process of value creation, preservation, and erosion is a core concept in economics, philosophy, and management, reflecting the life cycle of economic, cultural, or moral values.

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The stages of this process are as follows:

1. **Value creation in the economy occurs through the processes of production, exchange, and consumption.** Value creation is the transformation of resources (labour, inventory, technology) into goods or services with market value. Here, value is measured by price, profit, or contribution to GDP. Key factors at this stage include labour, capital, resources, knowledge, innovation, creativity, and the demands of society and individuals.
2. **Value preservation is the maintenance of the significance or market value of an object or event over time.** This involves supporting product and company competitiveness, reducing costs, protecting against depreciation, sustainably managing the brand and corporate culture, and responding to risks and changes. Examples include the modernisation of production, the maintenance of the customer base, and the preservation of brand reputation. Methods to achieve this include risk management, marketing, corporate governance, and ESG strategies.
3. **Value erosion**. This is the decline or total loss of significance or market value. It is accompanied by decreased efficiency, loss of trust, damage to brand reputation and customer base, investor outflows, crises, bankruptcy, and more. Causes include changing market conditions, strategic errors, and weak control.

Modern governance concepts state that value is created for stakeholders and includes innovation, growth in market capitalisation, sustainability, and reputation. Value preservation involves managing strategic risks, maintaining efficiency, and investing in personnel and infrastructure. Value erosion is accompanied by reduced profitability and loss of trust from customers and investors, often caused by ineffective management, market changes, and crises.

Importance of the Value Creation Model

According to the Integrated Reporting Framework (<IR> Framework), value creation, preservation, or erosion is a process that causes growth, reduction, or transformation of capital driven by the organisation's business activities and their outcomes (Maroun, Ecim & Cerbone, 2023; Ecim & Maroun, 2025). Value creation means effective and sustainable use of capital. Value preservation results from the stable and responsible management of all types of capital. Value erosion can happen, for example, due to environmental degradation, wars, and globalisation, which may lead to identity crises and moral disorientation. Therefore, this process is important for management, strategic planning, marketing effectiveness, and understanding societal development. The value model is not linear; it is a dynamic system where the results of one period affect the input resources of the next. This way, an organisation can create, preserve, or lose value for itself and its stakeholders. The business development concept requires entrepreneurs and managers to consider not only financial indicators but also social and environmental metrics. According to this concept, business is built on the "three pillars of sustainable development" — planet, people, and profit. It is used not only as a management tool but also as a financial accounting instrument. Over the last decades, such ideas have been actively developed within the frameworks of sustainable development and integrated reporting concepts (Sabauri, 2024; Díaz et al., 2024). The process of value creation is connected not only to production and market valuation but also to the assessment of the effectiveness of organisational governance and sustainability.

Key Elements of the Value Creation Model

Core Components of the Integrated Reporting Value Creation Model (Creation, Preservation, Erosion):

I. Inputs – The Six Capitals

According to the <IR> Framework, capital refers to the resources and relationships upon which an organisation relies and which it transforms through its business activities to create value. The main types of capital through which businesses generate value include:

- Financial Capital (cash, investments, revenues);
- Manufactured capital (buildings, equipment, infrastructure, technologies);
- Social and Relationship Capital (relationships with customers, partners, and society; reputation; trust);
- Human Capital (employee knowledge, competencies, skills, motivation);
- Natural Capital (energy, water, climate conditions);
- Intellectual capital (innovation, patents, brand, IT systems, organisational culture).

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II. Business Model

According to the European Sustainability Reporting Standards (ESRS), the business model is defined as the enterprise system through which inputs are transformed into products and outcomes. It is designed to support the achievement of strategic objectives and create value in the short, medium, and long term (Glossary and acronyms, 2022).

The organisation describes how it uses its inputs to generate outcomes aligned with its strategy. This includes (EFRAG, 2022):

- business objectives;
- product and service development processes;
- risks and opportunities;
- governance mechanisms.

The objectives of the value creation model are to:

- Demonstrate business resilience and adaptability;
- Support strategic decision-making;
- Enhance transparency for investors and the wider public (Piesiewicz and Kufel, 2025; Singhal and Goel, 2026).

III. Results – Outputs

Outputs refer to the immediate products, services, and by-products resulting from the organisation's activities. These may include not only intended deliverables but also unintended consequences such as emissions, waste, and social impacts.

IV. Results – Outcomes (Impacts on Capitals)

Outcomes describe the broader effects of the organisation's operations on all six types of capital, both positive and negative. These may include, but are not limited to:

- Increase or depletion of natural resources;
- Enhancement of employee skills and competencies;
- Growth in social trust or corporate reputation;
- and other forms of value creation or erosion across capitals.

This information provides insights into how value is created, preserved, or diminished throughout the value chain — including sourcing, production, distribution, sales, and consumption.

3. The Concept of the Upstream and Downstream Value Chain

Definition of the Value Chain

According to the European Sustainability Reporting Standards (ESRS), the value chain encompasses (ESRS, 2022) the full range of activities, resources, and relationships related to the enterprise's business model and the operational context in which it operates. In other words, the value chain encompasses all processes, inputs, and interactions involved in the creation and delivery of goods and services to end users. This includes activities both within the enterprise and with external stakeholders, such as suppliers, distributors, and customers. Therefore, the value chain includes any activity, resource, or relationship that the enterprise depends on and utilises in creating products and services — from the initial development phase through to delivery, consumption, and the end of the product's life cycle.

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These activities, resources, and relationships typically include (see Figure 2, Figure 3):

- Activities, resources, and relationships used within the organisation's own operations (e.g., production, human resources);
- Activities, resources, and relationships involved in the organisation's sourcing, marketing, and distribution processes, including the identification of suppliers of materials and services, and the sale and delivery of products and services;
- The financial, geographic, geopolitical, and regulatory environment in which the enterprise operates.

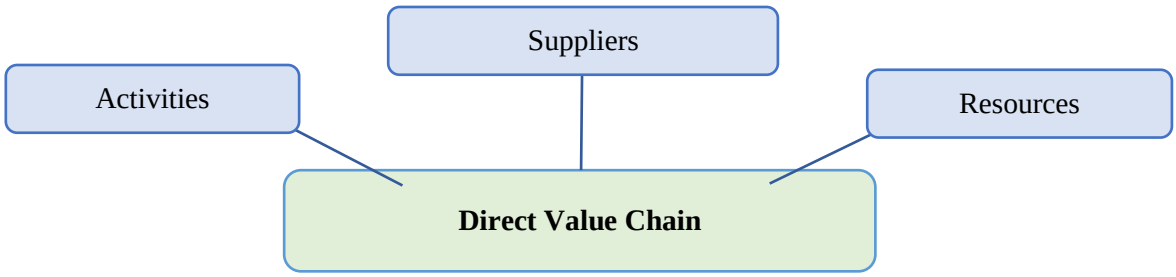


Figure 2. Direct Value Chain
Source: the author

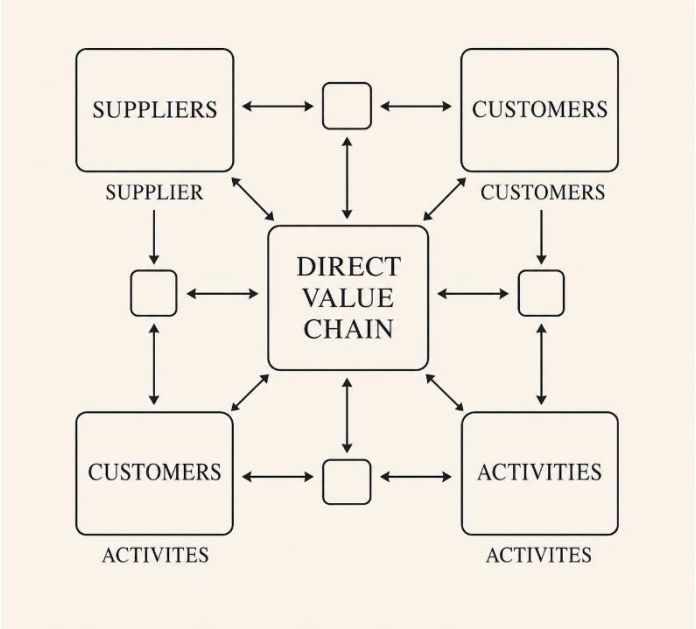


Figure 3. Upstream Value Chain
Source: the author

Upstream and Downstream Value Chain

In the context of sustainability, information on the flow of resources and value creation within the value chain is typically analysed in two segments: the upstream and downstream parts of the value chain (as defined by IFRS S1/S2 and GRI; see Figure 4 below).

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Upstream Value Chain

The upstream segment includes all activities that precede the enterprise's core production processes. These consist of sourcing, the contribution of third parties, and the procurement of resources, including:

- Raw material acquisition and transportation
- Semi-finished goods production
- Services provided by contractors
- Procurement of energy and water
- Supplier services and logistics

This stage often involves significant environmental and social risks, such as supplier carbon emissions, child labour, or unsustainable practices. As such, it is a critical focus for assessing the sustainability of the entire supply chain.

Downstream Value Chain

The downstream segment covers all processes that follow the core production or sale of the enterprise's products. This includes activities associated with distribution, consumption, and end-of-life stages of a product. Examples include:

- Logistics and distribution of finished products
- Activities of distributors and retailers
- Consumer behaviour and product usage (e.g., health impact, energy consumption)
- Product disposal, recycling, and reuse

The downstream phase is particularly important for understanding a product's life-cycle impacts, which are often analysed using Life Cycle Assessment (LCA) methodologies. This enables organisations to evaluate the sustainability of products beyond the point of sale and into post-consumer outcomes.

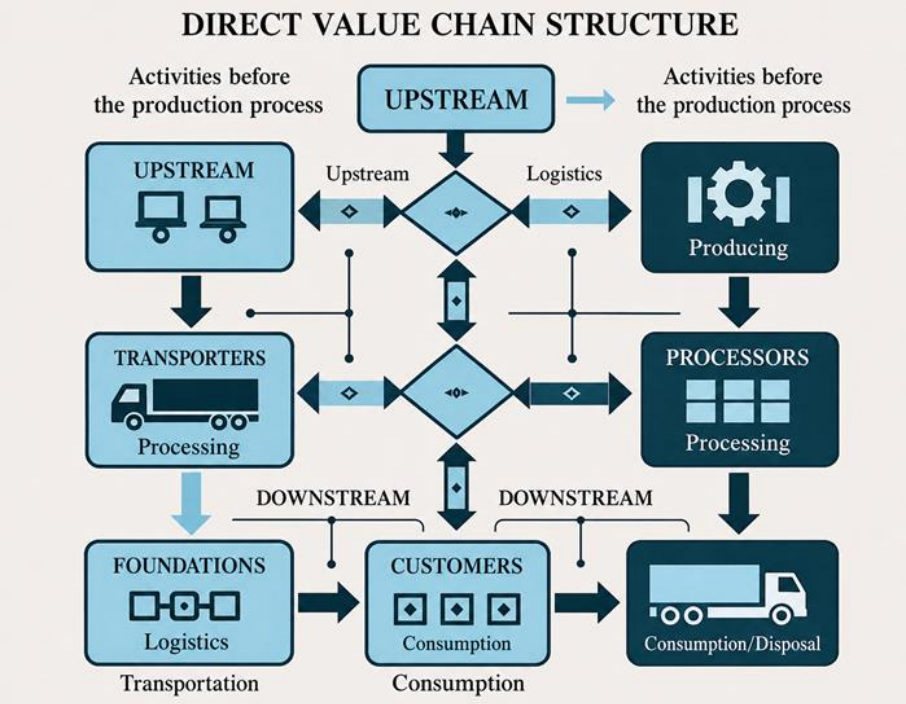


Figure 4. Downstream Value Chain
Source: the author

Value Chain Workers

The value chain encompasses both natural and legal persons. In the upstream value chain, these may include entities such as suppliers, who provide goods and services used by the enterprise in creating its own products

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and services. In the downstream value chain, they may include distributors and customers, who receive goods and services from the enterprise. Value chain workers are all individuals or entities involved in the upstream and downstream segments of the value chain on whom the enterprise has or may have a material impact. This includes impacts arising from the enterprise's own operations, its value chain (both upstream and downstream), its products and services, and its business relationships.

Material Impacts, Risks, and Opportunities

In the course of its business activities, an enterprise may exert influence—positive or negative—on people and the environment, including on human rights. These impacts are linked to its operations, value chain (both upstream and downstream), products and services, and business relationships.

Factors contributing to such impacts may include natural and anthropogenic drivers, such as:

- Air, soil, and water pollution
- Deforestation
- Use of hazardous chemicals
- Biodiversity loss
- Climate change

These impacts reflect the enterprise's contribution to sustainable development, whether adverse or beneficial. According to sustainability standards, an impact is any sustainability-related positive or negative effect associated with the enterprise's business activities and identified through a materiality assessment (see Figure 5 below). Impacts may be actual or potential.

A sustainability matter is considered material from an impact perspective when it involves actual or potential effects on people or the environment arising from (European Sustainability Reporting Standards (ESRS), 2023):

- the enterprise’s own operations,
- its upstream or downstream value chain,
- its products and services,
- or its business relationships.

In this context, impacts may relate to environmental, social, and governance (ESG) topics ((ESRS), 2023).

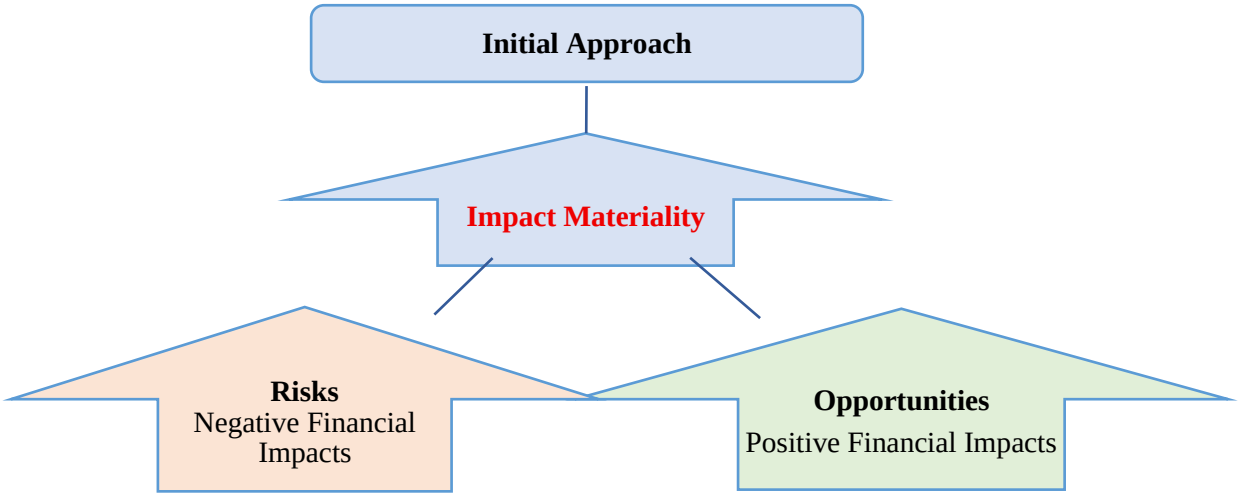


Figure 5. Double Materiality (European Sustainability Reporting Standards (ESRS), 2023

The assessment of materiality is conducted from two aspects, known as "double materiality". Double materiality has two sides: impact materiality and financial materiality. A sustainability matter meets the double materiality criterion if it is material from an impact perspective, a financial perspective, or both.

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The principle of double materiality requires the reflection of both: how an enterprise's finances impact sustainability (*impact materiality*), and how sustainability impacts financial performance (*financial materiality*). In this regard, enterprises must consider sustainability aspects from both perspectives. On the one hand, they should consider the company's impact from an "inside-out" perspective — this dimension is referred to as *impact materiality*. On the other hand, in the materiality assessment, the enterprise must include *financial materiality* from the "outside-in" perspective (Deloitte, 2024).

When assessing financial materiality, it becomes necessary to identify sustainability-related financial risks and opportunities (including those arising from dependency on natural, human, and social resources). Sustainability-related risks are uncertain environmental, social, and governance events or conditions that may negatively impact the value creation strategy and, consequently, sustainability. Material risks are sustainability-related risks with negative financial consequences, which have (or are reasonably likely to have) a material impact on the enterprise's cash flows, access to finance, or cost of capital in the short, medium, or long term. Like any other risk, sustainability-related risks are measured by the combination of impact magnitude and likelihood of occurrence.

In contrast to risks, enterprises may also face opportunities — uncertain environmental, social, and governance events or conditions that may have a material positive impact on the enterprise's value-creation strategy and, consequently, on sustainability. Specifically, material opportunities are sustainability-related opportunities with positive financial effects, which have (or are reasonably likely to have) a material impact on the enterprise's cash flows, access to finance, or cost of capital in the short, medium, or long term. Like any other opportunity, sustainability-related opportunities are measured by a combination of impact magnitude and likelihood of occurrence (see Figure 6).

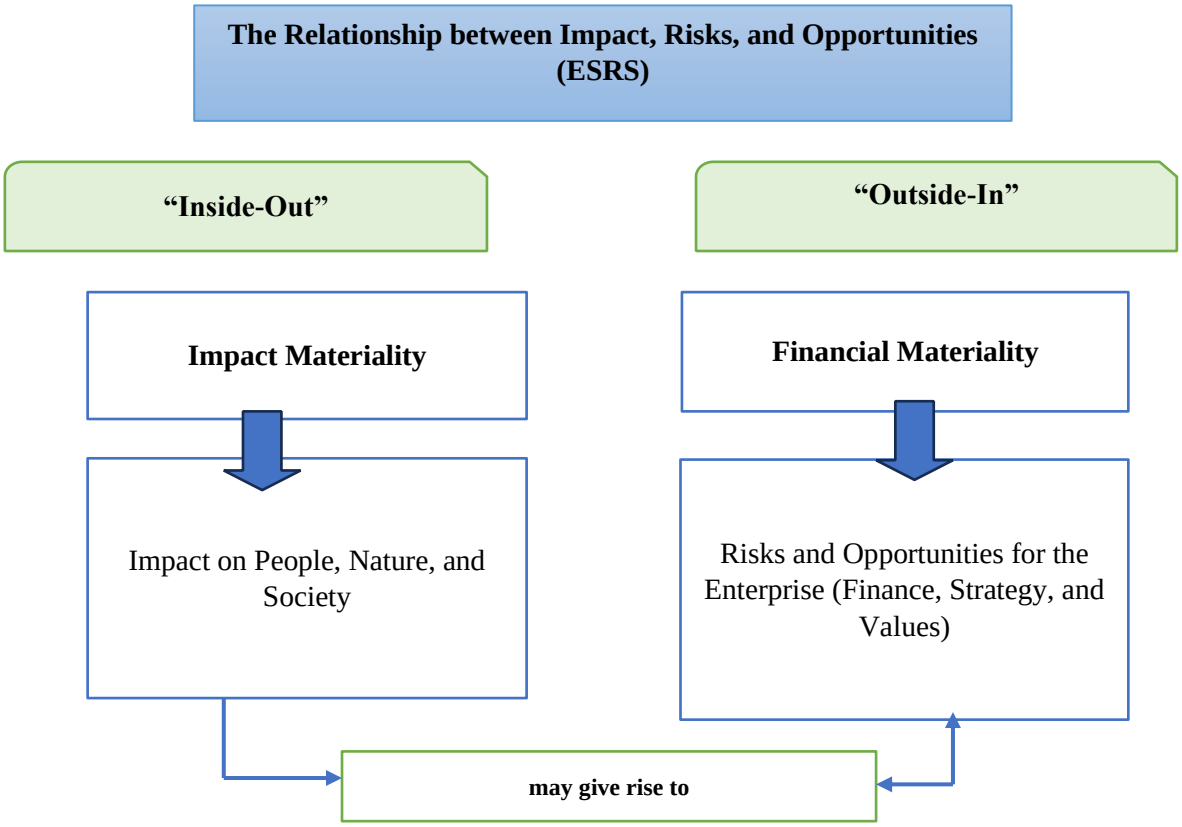


Figure 6. The Relationship Between Impact Materiality, Financial Materiality, Risks and Opportunities
Source: the authors

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For example, when an enterprise causes air pollution (a material negative impact), it may face financial risks, such as fines or the need to upgrade equipment and technologies. Alternatively, when an enterprise invests in plastic recycling (a material positive impact), it may gain opportunities such as brand enhancement and increased sales (see Table 2).

Table 2. Impacts and Related Risks/Opportunities

Impact	Financial Effect
Water pollution in production	Risk of sanctions, loss of license, and reputational damage
Violation of workers' rights in the supply chain	Risk of strikes and litigation
Investments in renewable energy	Opportunity to reduce costs and receive "green" subsidies
Promotion of gender equality	Opportunity to attract top talent and enhance brand reputation

Source: the authors

Value Chain Information

The connection between the value chain and sustainability reporting (ESRS) is fundamental, as the ESRS requires the disclosure of impacts, risks, and opportunities not only related to the organisation's own operations, but also to its value chain. Under the ESRS, the reporting scope includes not only the organisation itself but also its entire value chain. ESRS 1 *"General Requirements"* mandates that organisations disclose material impacts, risks, and opportunities associated with both their own activities and those occurring in their upstream and downstream value chains (European Sustainability Reporting Standards (ESRS), 2023). Sustainability disclosures must provide information on material impacts, risks, and opportunities related to the organisation that arise from direct and indirect business relationships within the upstream and/or downstream value chain. In other words, enterprises are expected to report "value chain information" (European Sustainability Reporting Standards (ESRS), 2023). For example, it may be necessary to disclose impacts on capital across the full value-creation chain (e.g., CO_2 emissions or labour practices among key suppliers).

4. The Link and Distinction Between Integrated Reporting and Sustainability Reporting

An enterprise moves beyond the boundaries of financial reporting by integrating sustainability and other non-financial information into its core business strategy and reporting practices. Integrated reporting should demonstrate how the enterprise creates value for all stakeholders, not just shareholders, over the short, medium, and long term. The relationship between Integrated Reporting (<IR>) and the European Sustainability Reporting Standards (ESRS) is strong and mutually reinforcing. Both are based on similar principles and aim to enhance transparency, promote sustainability, and support the creation of long-term value (Raimo et al., 2025). However, they differ in their focus areas and objectives (see Table 3).

Table 3. Comparison between Integrated Reporting (IR) and European Sustainability Reporting Standards (ESRS)

<IR> - Thinking foundations for information integration	**ESRS** - Specific disclosure requirements
Objective: Value creation over time	**Objective:** Disclosure of impacts, risks, and opportunities
Reporting type: Voluntary (in most countries)	**Reporting type**: Mandatory for EU member states
Content: Integration of financial and non-financial information	**Content:** Requirements based on specific ESRS standards
Double materiality: Partial (with the revised Framework)	**Double materiality:** Core principle – interaction between business and society
Focus: Strategy, business model, values, and linkage to capital	**Focus**: ESG factors – climate, workforce, governance, pollution, and others
Compatibility: Can apply ESRS to prepare <IR> reporting	**Compatibility:** Can use <IR> structure when preparing ESRS reports

For example, when an enterprise prepares an integrated report and discloses information prepared according to the ESRS standards regarding its impacts on climate and society, it presents this information using the logic of the <IR> Framework — that is, explaining how these factors affect the organisation's strategy, risk profile, and long-term value creation. The <IR> Framework is a conceptual structure that integrates financial and non-financial information to demonstrate how an organisation creates, preserves, and erodes value over time (Panfilo et al., 2025; Zhou & Owusu-Ansah, 2025). In contrast, the ESRS provides specific ESG disclosure standards, delivering structured and verifiable information about a company's impacts on the environment and society.

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ESG (Environmental, Social, and Governance) reporting and Integrated Reporting (<IR>) are interlinked (Haryanto et al., 2025; Hossain et al., 2025).

For example:

- ESRS provides data and metrics that can be used within the <IR> Framework to support value analysis and presentation.
- The <IR> Framework utilises ESRS-derived information to explain how sustainability factors influence an enterprise's strategy, management approach, and outlook.
- The double materiality concept of ESRS is fully aligned with the <IR> approach to risks, opportunities, and impacts (Drira et al., 2025).
- ESG reporting often leverages insights from <IR>, though its primary focus is on sustainability matters.
- ESG reporting draws on the value-creation model of <IR> to substantiate the organisation's environmental, societal, and governance-related impacts (Haryanto et al., 2025; Hossain et al., 2025).
- ESG sharpens its focus on environmental and social risks (e.g., climate change, labour conditions, reputation), considering both short-term and long-term perspectives.
- ESG reports use ESG indicators, which may be sourced from or adapted from the <IR> framework (e.g., CO_2 emissions, gender diversity, workplace incident rates).

The Relationship Between Integrated Reporting (<IR>) and ESG Reporting

Table 4 and Figure 7 illustrate which elements of integrated reporting are used in ESG reporting and how they are transformed to serve sustainability objectives.

Table 4. Mapping <IR> Components to ESG Reporting

<IR> Reporting Component (IIRC, 2021)	**Application in ESG Reporting (EFRAG, 2023)**	**Link to ESG Factors**
Value creation model	Used to analyse impacts on the environment, society, and governance	Impacts E, S, and G
Risks and opportunities	Deepens understanding of climate, social, and governance-related risks and opportunities	Linked to E, S, and G risks
Strategy and objectives	Reflected in sustainability goals and climate strategies	Primarily E and S
Governance	Assesses the role of the board and top management in ESG management	G (Governance)
Stakeholder engagement	Analyses the impacts on employees, customers, suppliers, and local communities	S (Social)
Performance indicators (KPIs)	Applied for ESG metrics: CO2 emissions, workplace injuries, staff turnover, etc.	All three components: E, S, G
Future outlook	For sustainability forecasts, climate scenarios, and regulatory adaptation	Primarily E
Types of capital (6 categories)	Focus on natural, social, and human capital	E and S, partly G

Source: EFRAG (2023); IIRC (2021)

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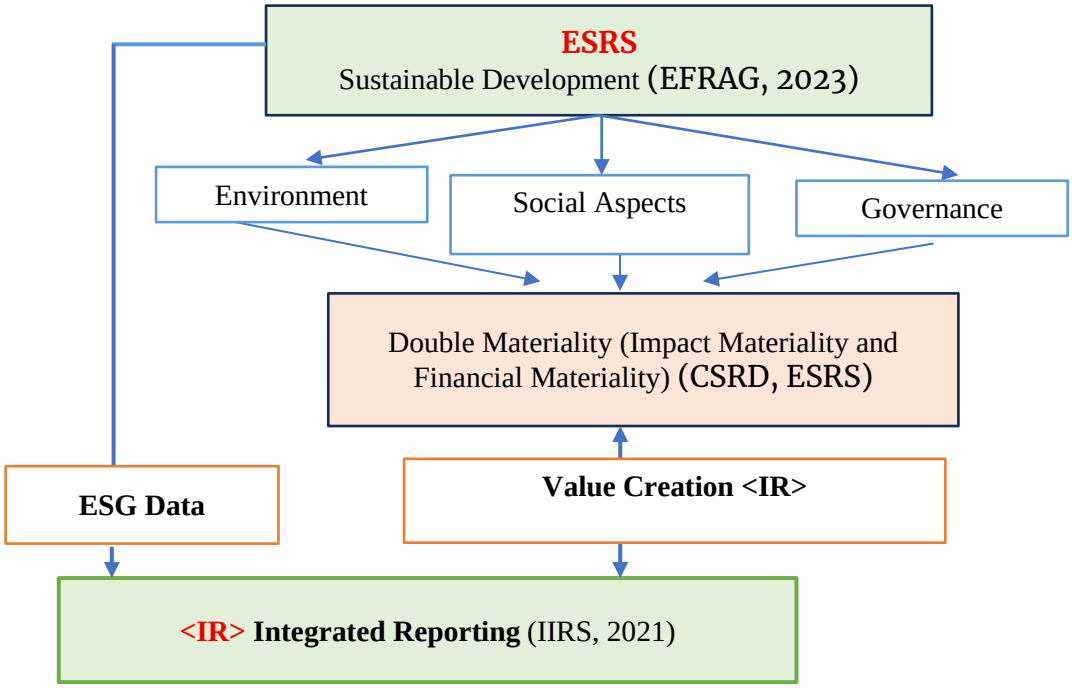


Figure 7. Diagram: The Relationship Between Integrated Reporting (<IR>) and ESG Reporting
Source: the authors

The process of value creation is not limited to production and market evaluation; it also relates to assessing the effectiveness of governance and the organisation's sustainability.

5. Conclusion

Enterprise leadership must recognise that the organisation's impact extends beyond its internal operations — both upstream (procurement) and downstream (outcomes). The enterprise must assess the impacts, risks, and opportunities across its value chain and develop disclosures aligned with ESRS requirements.

The first step is to conduct a value chain analysis, which identifies:

1) upstream value chain – who supplies what, and what risks exist (e.g., child labour, water pollution, co_2 emissions);
2) downstream value chain – what outcomes result from the enterprise's activities (e.g., for educational institutions: graduate employability, application of research, digital footprint from online learning).

By conducting an impact materiality assessment, the enterprise evaluates the positive and negative effects of its activities on people and the environment, including the value chain. This represents an outside-in perspective. Financial materiality, on the other hand, focuses on identifying risks and opportunities that affect the enterprise itself, potentially impacting future cash flows, sustainability, and the business model — this is the inside-out perspective. Therefore, material risks and opportunities represent the evaluation of both internal and external factors and may relate to climate change, biodiversity, human rights, resource dependency, and more.

Value chain information includes data related to each stage of a product or service's lifecycle — from creation and delivery to post-sale service. This information supports understanding how value is created at every step of production and logistics, including suppliers, manufacturing, distribution, sales, and consumption.

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It helps enterprises to analyse:

- environmental, social, and governance (ESG) risks and opportunities;
- environmental impacts across the supply chain (e.g., climate change);
- the resilience of the business model in the face of changing resources, regulations, or customer expectations.

Sustainability reporting is critical not only for organisations themselves but also for stakeholders — including investors, consumers, employees, and society at large (Drira et al., 2025; Pérez et al., 2025).

Key benefits:

- increased transparency and trust (PWC, 2023) –demonstrates the organisation's openness regarding its impact on the economy, environment, and society; fosters trust among investors, customers, regulators, and the public;
- improved risk management – enables identification and assessment of environmental, social, and governance (ESG) risks; strengthens preparedness for regulatory, climate, and market shifts;
- attracted investments – investors increasingly consider ESG factors in decision-making; companies with strong sustainability indicators are seen as less risky and more promising (Alatawi et al., 2025; Dhifi & Zouari-Hadiji, 2024);
- enhanced business efficiency – sustainability analysis helps identify opportunities to improve resource use and energy efficiency, which can reduce costs and drive innovation (Anschau et al., 2025; El-Deeb & Mohamed, 2024);
- strengthened reputation (PWC, 2022) – companies that publish sustainability reports are perceived as socially responsible and forward-thinking, positively impacting branding, customer loyalty, and talent attraction;
- compliance with international requirements – facilitates adherence to international standards (e.g., GRI, ESRS, IFRS S1/S2) and legal obligations; ensures access to global markets and sustainable finance;
- support for strategic planning (McKinsey Sustainability, 2020) – integrating ESG factors into strategy enables more informed, forward-looking decisions and enhances long-term business resilience and competitiveness.

Key stakeholders interested in this information:

- investors – to assess the company’s sustainability and financial reliability;
- clients – when selecting responsible suppliers;
- government agencies – for monitoring environmental and social compliance;
- employees – as indicators of corporate culture and social responsibility;
- educational and research institutions – for analysing and teaching new management practices.

The novelty of the papers lies in the original approach, which allowed for the identification and systematisation of information related to the representation of the entire value chain process—creation, preservation, and erosion of value. The created model can serve as a tool for sustainability assessment.

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STUDENT MIGRATION AS A DRIVER OF HUMAN CAPITAL DEVELOPMENT*

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Abstract. This study investigates the determinants of international student migration and their implications for human capital development in Slovakia within the broader context of increasing global mobility. As international competition for talent intensifies, understanding the factors shaping students' destination choices and post-graduation intentions becomes increasingly important for sustainable socio-economic development. The research is based on primary quantitative data collected through a questionnaire survey administered to 150 international students enrolled in Slovak higher education institutions. The data were analysed using descriptive statistics and selected non-parametric techniques to identify significant relationships between key variables. The findings reveal that linguistic and cultural proximity, together with financial considerations, represent the dominant pull factors influencing students' decisions to study in Slovakia. In contrast, the perceived quality of education plays a comparatively limited role, suggesting that Slovakia is primarily viewed as an accessible and culturally compatible destination rather than a highly competitive academic environment. The results further indicate that a substantial proportion of students consider remaining in Slovakia after graduation; however, their intentions are strongly conditioned by economic opportunities and personal factors. The study contributes to the literature on international student mobility by providing empirical evidence from an emerging destination country. It also offers policy-relevant insights to strengthen Slovakia's attractiveness and improve the long-term retention of international graduates, thereby supporting sustainable human capital development.

Keywords: student migration; international student mobility; human capital development; push and pull factors; Slovakia

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JEL Classifications: F22, I23, J24, O15

1. Introduction

Migration is a key socio-economic phenomenon influencing contemporary societies and labour markets. In recent years, youth migration has surged, with young individuals increasingly choosing to pursue educational or professional opportunities outside their region of origin. Slovakia is currently experiencing a significant outflow of young, educated individuals emigrating abroad. This "brain drain" raises concerns about the future development of the domestic labour market. Furthermore, migration profoundly influences social structures, economies, cultures, and political landscapes, affecting both countries of origin and destination. From a motivational perspective, migration is traditionally categorised into economic migration, forced displacement (refugee migration), and family reunification (Tsegay, 2023). In the contemporary era, investigating the determinants of human capital development alongside migration trends has become increasingly critical. Migration is progressively recognised as a fundamental catalyst for sustainable socio-economic progress. In this

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context, the migratory behaviour of students warrants rigorous scholarly attention, as this demographic represents a vital reservoir of intellectual and human capital. Elucidating these dynamics is essential for expanding the conceptual understanding of the phenomenon and for optimising practical management frameworks. It is imperative to address several key challenges in this field, specifically: the identification of the primary drivers underpinning students' migratory decisions; the evaluation of the temporal consequences (both short- and long-term) of such movements; the formulation and implementation of domestic policies designed to curtail population outflows. The multifaceted dimensions of migration—including motivation, magnitude, directionality, and impact—are a focal point of applied research on modern trends in human capital formation. Historically, since the nineteenth century, economic determinants have been viewed as paramount in explaining migratory trajectories (Ravenstein, 1885). These economic variables profoundly influence the processes of globalisation and the broader dynamics of population mobility. For decades, the theoretical and methodological complexities of migration as a global phenomenon have been scrutinised by an extensive range of scholars. In various national contexts, migration is predominantly conceptualised through the lens of labour mobility (Adugna, 2019; Wang et al., 2023), with particular emphasis placed on its subsequent impact on the macroeconomic landscape (Rokita-Poskart et al., 2024; Langović et al., 2024).

The objective of this research is to bridge a significant scholarly gap by investigating the push and pull dynamics that international students consider when selecting Slovakia as an educational destination, as well as their subsequent intentions regarding post-graduation residency. In essence, the study seeks to delineate the multifaceted determinants governing the relocation trajectories of international students. To achieve this, the following research questions have been formulated. Understanding the factors that influence students' migration decisions is therefore essential. In particular, it is important to identify the motivations behind their choice of study destination and their intentions after completing their studies.

RQ1: Which key push and pull factors (economic, cultural, linguistic and educational) influence international students' decision to study in Slovakia?
RQ2: Which factors significantly influence international students' intention to remain in Slovakia after graduation?

2. Theoretical background

The International Organisation for Migration (IOM) defines migration as the movement of individuals across national borders for the purpose of attaining better economic conditions. Migrants typically seek better employment opportunities or improved living conditions in the destination country. Economic migration is characterised by settling abroad for more than one year. Working and living conditions in other countries motivate Slovak citizens to establish temporary or permanent residency abroad (IOM UN Migration, Slovakia, 2023). In recent years, there has been a global increase in the number of students leaving their home countries to pursue studies at foreign universities (Vineetha et al., 2025). Simultaneously, this trend highlights the brain drain phenomenon, which refers to the migration of skilled professionals from low- and middle-income countries to higher-income nations, subsequently impacting the labour market (Mathew & Mathew, 2020; Gözüm et al., 2024). Several studies have explored the motivations behind students' decisions to study abroad and their destination selection processes, drawing on frameworks such as push-pull factor theory (Lisana, 2022; Shahrokh et al., 2025). The decision to study abroad is influenced by pull factors, such as the quality of education, and push factors, such as limited employment opportunities in home countries.

Furthermore, key reasons for studying abroad include the quality of education, career prospects, and cultural understanding (Yılmaz & Temizkan, 2022). Mazzarol and Soutar (2002) identified financial considerations, the host country's environment, geographic proximity, personal contacts, and recommendations from others as the primary factors influencing students' decisions to study abroad. Several authors highlight economic factors as a significant driver of migration (Maringe & Carter, 2007). Other scholars emphasise linguistic and cultural proximity as an important factor (Chen, 2007; Weber & Van Mol, 2023). This suggests that host-country-related, institutional, economic, and environmental factors, along with recommendations from family and friends, are the primary determinants of students' decision-making when selecting their study-abroad

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destination. As this research focuses on the Slovak context, it examines the factors that influenced international students' decision to study in Slovakia.

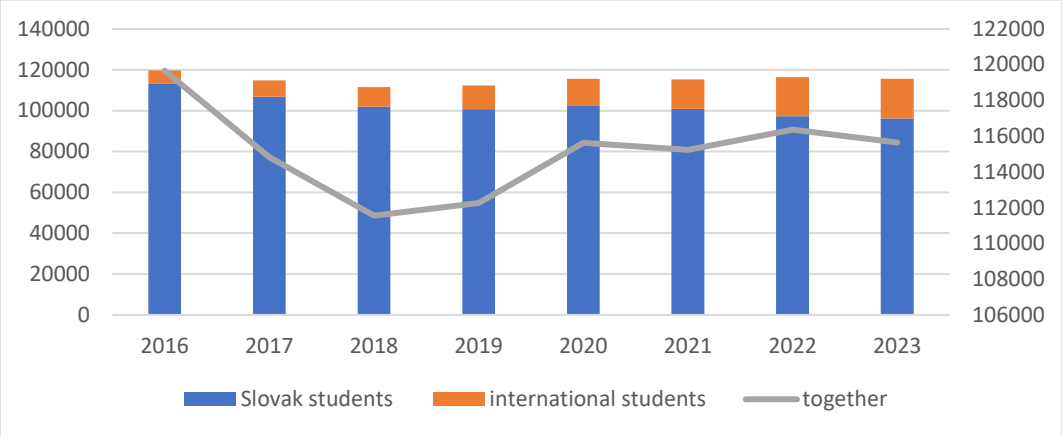


Figure 1. The Number of Slovak and International Students in Higher Education Institutions (2016–2023)
Source: Ministry of Education, Research, Development and Youth of the Slovak Republic https://vaia.gov.sk/wp-content/uploads/2023/11/Summary-Report-of-the-EDP-to-the-Strategy.pdf

As shown in Figure 1, total enrollment in higher education declined marginally, from 119,667 in 2016 to 115,642 by 2023. Crucially, the domestic student cohort experienced a pronounced reduction – from 113,092 to 96,146 over the same period – indicating a sustained long-term decline in the homegrown student population. Conversely, the international student demographic exhibited steady growth: initially recorded at 6,575 in 2016, the figure surged to 19,496 by 2023. This trend underscores a burgeoning predilection for Slovak academic institutions among foreign nationals. Consequently, a discernible demographic shift is occurring within the higher education sector, where a growing influx of international scholars is mitigating the attrition of domestic students. Student mobility exerts a profound influence on the macroeconomic stability of the country of origin. The systematic emigration of students, particularly toward prestigious global institutions, precipitates a "brain drain" phenomenon (Nghia, 2019; Prifti, 2025). This trajectory ultimately destabilises the domestic labour market, as highly skilled graduates frequently elect to remain within their destination countries. The ramifications of brain drain are systemic and multifaceted, affecting domains ranging from the fiscal sustainability of higher education to aggregate economic growth. In this context, the country of origin suffers a depletion of human capital, a factor indispensable to its global competitiveness (Bedianashvili et al., 2024). Conversely, the host nation benefits from an influx of talent, cultural diversity, and prospective professionals who serve as catalysts for socio-economic advancement. The decision to repatriate after graduation is contingent on a complex interplay of factors, including professional opportunities, remuneration structures, quality of life, and avenues for personal growth. Should graduates remain abroad, this would represent a substantial loss of state investment in human capital (Rydell et al., 2023). Extant research emphasises that pecuniary considerations – specifically labour market accessibility and the cost of living – predominantly dictate these post-scholastic migratory trajectories (Lee & Shutler, 2025). Furthermore, career development prospects within the host country are cited as a primary driver of the initial decision to study abroad (Zhai et al., 2019; Netierman et al., 2022) and serve as a significant determinant in the pursuit of post-graduation employment within that same jurisdiction (Cameron et al., 2019; Hooijen et al., 2017). Scholars also posit that familial cohesion serves as a potent influence; students often harbour a desire to maintain proximity to family members, exhibiting a marked propensity for return migration driven by these affective ties (Holloway et al., 2012; Martin, 2017; Van Schalkwyk et al., 2021). Furthermore, higher education institutions function as pivotal intermediaries in the labour market transition. Many universities integrate mandatory internships to provide requisite professional exposure, alongside comprehensive job-search training and vocational counselling (Cameron et al., 2019; Nghia, 2019; Dandi et al., 2024). Ziguras and McBurnie (2014) contend that wage differentials between the host and home nations function as a primary determinant of post-graduation residency. Elevated standards of living and competitive remuneration packages in the host country frequently incentivise long-term stay, thereby reducing the probability of immediate repatriation. This dynamic carries significant implications for human capital transfer. While the country of origin may face a shortage of qualified professionals, the host country

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capitalises on their specialised competencies and linguistic versatility. Such complexities must be meticulously accounted for in the formulation of migration and educational policy. Empirical evidence suggests that linguistic barriers can pose a substantial barrier to cultivating professional networks, even when a global lingua franca, such as English, is utilised in the host country (Zhai et al., 2019). Linguistic proficiency dictates not only the efficacy of communication but also the capacity to engage in sophisticated professional discourse and navigate complex labour market landscapes. Thus, language serves as a critical vector for integration; a lack of proficiency can severely impede both professional maturation and social acculturation. Eisenchteter (2022) maintains that the repatriation of internationally educated individuals yields significant dividends for the home country. These returnees introduce a wealth of modern competencies, global exposure, and transnational networks. By implementing innovative paradigms and operational methodologies assimilated abroad, these graduates can catalyse the modernisation of domestic enterprises. The integration of foreign technologies and pioneering practices possesses the potential to invigorate the local economy and bolster its international standing. Moreover, returnees often facilitate scientific and commercial collaborations, creating unprecedented development opportunities. Eisenchteter (ibid.) further highlights the socio-cultural shifts these individuals undergo, noting that they often return with a more cosmopolitan perspective and progressive values, which may drive positive societal evolution. Analysing these trends is therefore vital to understanding human capital development as a cornerstone of sustainable progress. Recent research conducted in Slovak organisations further emphasises that systematic human resource development practices play an important role in strengthening human capital and supporting long-term organisational sustainability. Ultimately, the propensity for migration shapes individual life paths and employability; for instance, Slovak students' mobility to the Czech Republic is instrumental in fostering autonomy and environmental adaptability (Shutaleva et al., 2022).

The push-pull framework represents one of the most frequently applied theoretical approaches in the analysis of international student mobility (Mazzarol & Soutar, 2002; Chen, 2017). According to this perspective, students evaluate a combination of economic, educational, cultural and linguistic factors when selecting a destination country. Previous studies suggest that cultural and linguistic proximity reduces adaptation costs and facilitates social integration in the host country (Weber & Van Mol, 2023). The push-pull theory represents one of the most widely used theoretical frameworks for explaining international student mobility. According to this approach, students evaluate a combination of economic, educational, cultural and linguistic factors when selecting a destination country (Mazzarol & Soutar, 2002; Chen, 2017). Previous research suggests that linguistic and cultural proximity reduce barriers to adaptation and facilitate integration into the host country (Weber & Van Mol, 2023). Furthermore, studies indicate that students who experience stronger social and cultural integration are more likely to remain in the host country after graduation (Hooijen et al., 2017; Cameron et al., 2019). Consequently, linguistic and cultural factors may influence not only destination choice but also long-term migration intentions.

Although previous studies have extensively examined international student mobility and destination choice using the push–pull framework, most empirical evidence originates from traditional host countries such as Australia, Canada, the United Kingdom, and other Western European destinations. Limited attention has been paid to emerging destination countries in Central and Eastern Europe, particularly Slovakia. Furthermore, existing research has focused primarily on students' destination choice. At the same time, less attention has been devoted to the relationship between destination-related factors and students' post-graduation intentions to remain in the host country. Therefore, a research gap exists regarding the determinants of international student migration and retention in the Slovak context. This study addresses this gap by examining the key pull factors influencing international students' decision to study in Slovakia and by analysing the factors associated with their intention to remain in the country after graduation.

To answer the first research question (RQ1), the following hypotheses were formulated:
H1: Linguistic proximity represents a significant pull factor influencing international students' decision to study in Slovakia.
H2: Cultural proximity is perceived as a stronger pull factor among Master's degree students than among Bachelor's degree students.

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To answer the second research question (RQ2), the following hypothesis was formulated:
H3: Master's degree students demonstrate a significantly higher intention to remain in Slovakia after graduation than Bachelor's degree students.

3. Research objective and methodology

The main objective of this study is to identify the key factors influencing international students' decision to study in Slovakia and to examine the determinants affecting their intention to remain in the country after graduation. The analysis focuses on economic, cultural, linguistic, and individual factors shaping students' migration behaviour.

Based on this objective, two research questions and three hypotheses (H1–H3) were formulated. These hypotheses were subsequently tested using chi-square tests of independence.

The research is based on a quantitative approach using primary data collected through a questionnaire survey. The respondents consisted of international students from various countries studying at Slovak higher education institutions. A total of 150 respondents participated in the survey. The sample was obtained using non-probability convenience sampling, as respondents were recruited through university communication channels and social media platforms. Data collection was conducted anonymously through an online questionnaire.

The questionnaire was designed to identify key pull factors influencing students' decision to study in Slovakia, as well as their post-graduation intentions. For selected questions, respondents were allowed to choose multiple answers to capture the complexity of their decision-making better.

The collected data were processed using SPSS. Descriptive statistics were applied to summarise the data, while inferential statistical methods were used to examine relationships between variables.
To test the hypotheses, chi-square tests of independence were applied to analyse relationships between categorical variables such as level of study, gender, and selected motivational factors. The Mann–Whitney U test was used to identify differences between independent groups, and measures of association (Phi coefficient and Cramer's V) were used to assess the strength of relationships. The level of significance was set at 0.05.
The basic structure of the research sample is presented in Table 1.

Table 1. Number of respondents by gender and level of study

Number of respondents	1st level (Bachelor's degree study)	2nd level (Master's degree study)	Total
Females	52	66	118
Males	10	22	32
Total	62	88	150

Source: own calculation

The data presented in Table 1 show that the research sample consisted of 150 respondents, of which 118 were female (78.7%) and 32 were male (21.3%). In terms of level of study, 62 respondents were enrolled in Bachelor's degree programmes and 88 in Master's degree programmes. The distribution indicates a higher representation of female students as well as students at the second level of study.

The research was conducted in accordance with ethical standards, including voluntary participation, anonymity of respondents, and confidentiality of the collected data.

The study has several limitations. The sample is not representative, as it is based on non-probability sampling. The data are self-reported and reflect respondents' subjective perceptions. In addition, the cross-sectional design does not allow conclusions about causal relationships or changes over time.

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4. Results and discussion

The objective was to determine the rationale behind the respondents' decision to pursue their studies in Slovakia. The findings indicate that the most prevalent pull factor is linguistic proximity, cited by 93 respondents (35% of the responses). The decision to study in Slovakia was driven by financial factors for 76 respondents (29%), while cultural proximity was identified as a key determinant by 62 respondents (23%). On the other hand, the perceived quality of education proved to be the least prevalent determinant, influencing the decision of just 33 respondents (22% of the responses).

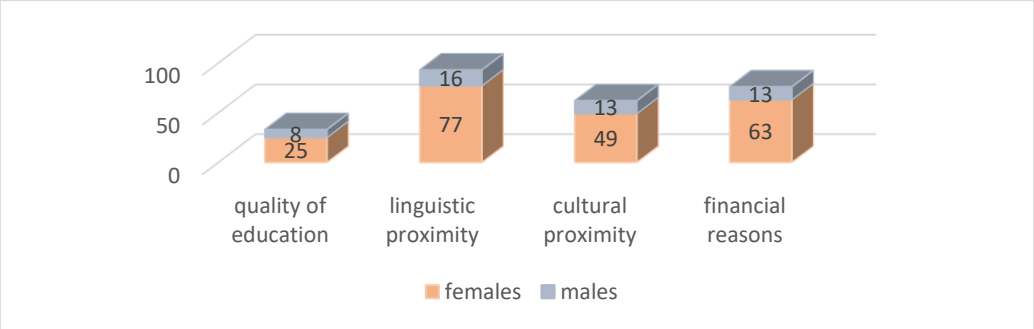


Figure 2. Respondents' pull factors
Source: own calculation

Table 2. Relationship between Level of Study and Respondents' Answers

Crosstab					
			Yes	No	Total
Level of study	1st level (Bachelor degree study)	Count	19	43	62
		Expected Count	25.6	36.4	62.0
	2nd level (Master's degree study)	Count	43	45	88
		Expected Count	36.4	51.6	88.0
Total		Count	62	88	150
		Expected Count	62.0	88.0	150.0

Source: own calculation (SPSS)

The analysis examined the Financial Reasons variable in relation to the Level of Study control variable. Pearson's Chi-square analysis resulted in a value of 0.736 (df = 1). With an asymptotic significance of 0.391, the analysis demonstrates no statistically significant association between the variables. The non-significant nature of the results was additionally validated by the continuity correction statistic of 0.479 with one degree of freedom (p = 0.489). The absence of a significant association was further supported by the Likelihood Ratio test, which produced a value of 0.737 with one degree of freedom (p = 0.391). The results of Fisher's Exact test (two-sided p = 0.412, one-sided p = 0.245) further confirm that the examined variables are not significantly related. Accordingly, the null hypothesis is retained, signifying an absence of statistically significant dependence between financial factors and the respondents' level of study. Table 2 presents the asymptotic significance values for symmetric measures, specifically the Phi coefficient and Cramer's V, which are utilised to quantify the strength of the association between two nominal variables. These coefficients operate on a scale from 0 to 1, representing no association and perfect association, respectively. The Phi coefficient and Cramer's V both indicated a very weak association (0.070); however, with an approximate significance of 0.391, this relationship did not reach statistical significance.

Table 3. Quality of Education as a Motivational Factor for Study

Crosstab					
			Yes	No	Total
Level of Study	1st level (Bachelor's degree study)	Count	16	46	62
		Expected Count	13.6	48.4	62.0
	2nd level (Master's degree study)	Count	17	71	88
		Expected Count	19.4	68.6	88.0
Total		Count	33	117	150
		Expected Count	33.0	117.0	150.0

Source: own calculation (SPSS)

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Table 3 demonstrates the relationship between the students' degree level and their selection of educational quality as a primary motivator. Only 22% of the total sample (33 students) considered the quality of education a motivating factor, standing in contrast to the 78% (117 students) who did not. Thus, the data suggest that educational quality is a secondary consideration rather than a primary driver for international students coming to Slovakia. By level of study, the quality of education, as the key pull factor, was selected by 16 first-degree respondents, just above the expected frequency of 13.6. In contrast, 17 second-degree students indicated this factor, falling slightly below the expected count of 19.4. Overall, however, the discrepancies between the observed and expected values are negligible. It follows that students in both degrees of study perceive the quality of education in Slovakia similarly – as a secondary or less significant factor in their choice of study destination.

Table 4. Motivation to Study in Slovakia – Linguistic Proximity

Crosstab					
			Reason for studying in Slovakia: Linguistic proximity		
			Yes	No	Total
Level of Study	1st level (Bachelor's degree study)	Count	39	23	62
		Expected Count	38.4	23.6	62.0
	2nd level (Master's degree study)	Count	54	34	88
		Expected Count	54.6	33.4	88.0
Total		Count	93	57	150
		Expected Count	93.0	57.0	150.0

Source: own calculation (SPSS)

The findings indicate that linguistic proximity was a decisive factor for the majority of respondents, accounting for 93 students (62%) in total. Within the Bachelor's level cohort, 39 respondents (62.9%) cited linguistic proximity as a reason for studying in Slovakia, compared to 23 (38.6%) who did not; expected values were 38.4 and 23.6, respectively. Regarding Master's level, 54 respondents (61.4%) cited this factor, while 34 (38.6%) did not, against expected values of 54.6 and 33.4. These figures indicate negligible deviations from statistical expectations. In total, 62% (93) of the sample cited linguistic proximity as a reason for their choice of study destination, while 38% (57) did not, suggesting the observed distribution closely follows the expected statistical distribution. The discrepancies between observed and expected values are negligible, indicating that the level of study does not significantly influence the role of linguistic proximity in the decision-making process. These findings suggest that linguistic proximity constitutes a primary motivational factor for both expatriate Slovaks and international students when selecting Slovakia as their study destination, irrespective of whether they are enrolled in Bachelor's or Master's programs. Furthermore, linguistic proximity may serve as a stabilising element in destination selection and could significantly enhance the overall attractiveness of the Slovak tertiary environment.

Table 5. Motivation to Study in Slovakia – Cultural Proximity

Crosstab					
			Reason for studying in Slovakia: Cultural		
			Yes	No	Total
Level of Study	1st level (Bachelor's degree study)	Count	19	43	62
		Expected Count	25.6	36.4	62.0
	2nd level (Master's degree study)	Count	43	45	88
		Expected Count	36.4	51.6	88.0
Total		Count	62	88	150
		Expected Count	62.0	88.0	150.0

Source: own calculation (SPSS)

Table 5 illustrates the relationship between cultural proximity as a motivational factor and the respondents' level of study. Within the Bachelor's degree cohort, 19 respondents cited cultural proximity as a reason for selecting Slovakia, compared to 43 who indicated it was not a factor. In contrast, at the Master's degree level, 43 respondents identified cultural proximity as a decisive factor, while 45 reported it negatively. A comparison with the expected frequencies – calculated under the assumption of a uniform distribution – reveals a noteworthy shift. At the Bachelor's degree level, 25.6 affirmative responses were expected, yet only 19 were observed, indicating that cultural proximity is a less decisive factor for this cohort. Conversely, at the Master's degree level, the observed frequency (43) exceeded the expected value (36.4), suggesting that cultural proximity plays

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a more prominent role in the decision-making process for Master's degree students. Pearson's chi-square test confirmed a statistically significant relationship between the level of study and the perception of cultural proximity as a motivational driver ($\chi^2(1) = 5,78$; $p = 0,016$). Master's degree students cited cultural proximity as a reason for selecting Slovakia more frequently than Bachelor's degree students. However, the strength of the association is weak (Phi = 0.196), indicating a modest effect size. This finding may be attributed to the greater maturity of Master's degree students, their prior international experiences, or a heightened emphasis on socio-cultural factors when selecting an environment for further education.

The study also sought to identify international students' post-graduation retention intentions. The data reveal that 62% (93) contemplate staying in Slovakia, with 28% expressing definite intent and 34% indicating probable intent. Meanwhile, 21.3% of the cohort is undecided. A minority of 16.7% expressed no desire to remain in the country, subdivided into those who responded 'somewhat unlikely' (11.4%) and 'unlikely' (5.3%).

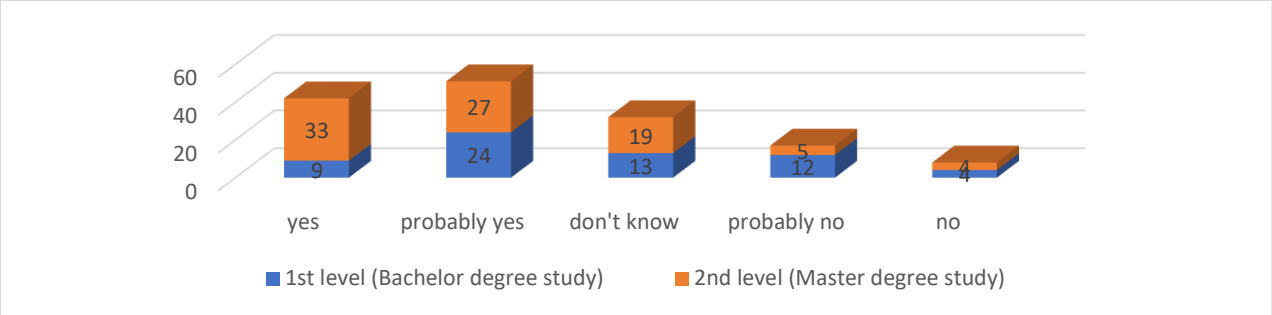


Figure 3. Post-graduation intentions
Source: own calculation

Based on the results of the Chi-square test of independence, it can be concluded that a statistically significant relationship exists between the level of study and international students' intentions to remain in Slovakia post-graduation ($\chi^2 = 13,81$; $df = 4$; $p = 0,008$). Since the p-value is below the significance threshold of 0.05, the null hypothesis of independence between the variables is rejected. This indicates that the degree level significantly influences students' decision-making regarding their stay in the country. A detailed examination of observed and expected frequencies reveals that Master's degree students expressed a definite intent to remain in Slovakia ("yes") more frequently than would be expected under the assumption of independence (observed = 33; expected = 24.6). Conversely, Bachelor's degree students provided negative responses more often than expected, particularly the "somewhat unlikely" option (observed = 12; expected = 7.0). These findings suggest that Master's degree students are more likely to remain in Slovakia after completing their studies than students in Bachelor's degree programmes. These findings suggest that higher-level students are more likely to remain in Slovakia after graduation. Consequently, these results highlight the importance of targeting retention policies specifically toward international students enrolled in advanced academic programs.

Table 6. Intention to Stay by Gender

Intention to Stay	**Gender**	**Females**	**Males**	**Total**
Yes	Count	34	8	42
	Expected Count	33.6	8.4	42
Probably Yes	Count	42	9	51
	Expected Count	40.8	10.2	51
Do Not Know	Count	26	6	32
	Expected Count	25.6	6.4	32
Probably No	Count	12	5	17
	Expected Count	13.6	3.4	17
No	Count	4	4	8
	Expected Count	6.4	1.6	8
Total	Count	118	32	150
	Expected Count	118	32	150

Source: own calculation (SPSS)

To verify the association between gender and the intent to remain in Slovakia post-graduation, a Chi-square test of independence was conducted. The analysis revealed no statistically significant relationship ($\chi^2 = 4,42$; $df =$

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4; p = 0,352). Since the p-value is greater than the 0.05 significance threshold, the null hypothesis is maintained. These findings suggest that gender is not a significant determinant of students' decision-making regarding their future residence in the host country. A comparison of observed and expected frequencies indicates that differences between male and female respondents are relatively minor. The majority of both genders expressed a positive intention to remain in Slovakia ("yes" or "somewhat likely"), which aligns closely with statistical expectations. Although slight deviations were observed in the "no" category – where the observed frequency for men (4) was higher than the expected frequency (1.6) – this discrepancy was insufficient to establish a statistically significant association. Consequently, these results suggest that international students' decision to remain in Slovakia post-graduation is not significantly influenced by gender. Instead, the most prominent driver for student retention is personal life, cited by 113 respondents (75.3%). This factor represented the highest frequency among all variables examined. This finding implies that social bonds, romantic relationships, family considerations, or overall life satisfaction play a pivotal role in the decision-making process regarding long-term residence in the host country.

Occupational prospects emerged as the second most frequently cited motive, identified by 51 respondents (34%). This finding underscores the importance of economic drivers and labour market integration as key incentives for retaining international students in Slovakia. Furthermore, linguistic and cultural affinity was cited by 31 respondents (20.6%), highlighting the role of cultural compatibility and linguistic similarity in facilitating social integration. These factors effectively lower the barriers to living abroad and increase students' propensity to remain in the country post-graduation. Conversely, the pursuit of further education was the least cited reason, reported by only 25 respondents (16.6%). This suggests that while academic progression motivates a specific subset of students, it plays a secondary role relative to personal and professional considerations. It is important to note that since respondents were permitted to select multiple answers, their decision-making process is characterised by a complex interplay of variables. The results indicate that socio-emotional and personal factors exert a more substantial influence than purely economic or academic motives. This insight highlights the necessity of prioritising integration support, fostering social ties, and cultivating a welcoming environment to encourage long-term international student retention in Slovakia.

The primary drivers behind international students' decisions to depart Slovakia post-graduation are economic factors, specifically wage differentials and superior occupational prospects abroad. Competitive remuneration in foreign markets emerged as the most prevalent motive, cited by 50% of respondents (75). This result underscores the significance of financial remuneration as a critical determinant influencing students' migratory trajectories. Similarly, superior professional opportunities abroad were identified as a significant factor by 46.6% of respondents (70). These findings suggest that international students perceive foreign labour markets as more advantageous in terms of career trajectory, vacancy availability, and professional development. This perception is a substantial push factor behind the decision to leave Slovakia upon completing their studies. Conversely, familial considerations were cited less frequently, by only 10.6% of respondents (16). While this factor influences the decision-making of a subset of students, its impact is significantly lower than that of economic variables. This indicates that the decision to emigrate is primarily motivated by pecuniary and professional incentives rather than personal or family-related circumstances.

Given that respondents were permitted to select multiple answers, it is evident that their decision-making process is the result of a synergistic combination of factors. Overall, the results indicate that the exodus of international students from Slovakia is driven primarily by economic motives. This trend emphasises the need to enhance labour conditions, career pathways, and financial incentives to bolster the retention of international graduates in the Slovak labour market.

Testing of Hypotheses

H1: Linguistic proximity is a significant pull factor influencing international students' decision to study in Slovakia.

The results demonstrate that linguistic proximity was identified by 93 respondents (62%), representing the most frequently selected motivational factor among all examined pull factors. Therefore, H1 is supported. The findings confirm previous studies suggesting that linguistic similarity significantly reduces adaptation barriers and positively influences destination choice.

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H2: Cultural proximity significantly differs according to the level of study and is perceived as a stronger pull factor among Master's degree students than among Bachelor's degree students.
Pearson's Chi-square test revealed a statistically significant relationship between cultural proximity and level of study ($\chi^2 = 5.78$; $p = 0.016$). Master's students selected cultural proximity more frequently than expected, whereas Bachelor's students reported this factor less frequently than expected. Therefore, H2 is supported.

H3: International students enrolled in Master's degree programmes demonstrate a significantly higher intention to remain in Slovakia after graduation compared with Bachelor's degree students.
The analysis revealed a statistically significant association between study level and post-graduation intentions ($\chi^2 = 13.81$; $p = 0.008$). Master's students expressed a positive intention to remain in Slovakia significantly more often than Bachelor's students. Therefore, H3 is supported.

5. Discussion

The findings of this study contribute to the existing literature on international student migration by confirming the importance of non-academic factors in the selection of study destinations. In particular, linguistic and cultural proximity were identified as key determinants of students' decision to study in Slovakia. These results are consistent with the push–pull framework, which emphasises the role of socio-cultural factors in shaping migration decisions (Mazzarol & Soutar, 2002; Weber & Van Mol, 2023). Similar findings have been reported in previous studies, where students tend to prefer destinations that offer cultural familiarity and linguistic accessibility, as these reduce the perceived risks associated with studying abroad (Chen, 2007). In addition, financial considerations were found to play an important role in students' decision-making process. This is in line with the findings Maringe & Carter (2007), who highlight that cost-related factors, including living expenses and tuition fees, are among the most influential determinants in the choice of study destination. However, the relatively low importance attributed to the quality of education in this study contrasts with some previous research (Yılmaz & Temizkan, 2022), which identifies academic quality as a primary pull factor. This discrepancy may suggest that Slovakia is currently perceived more as an accessible and affordable destination rather than a highly competitive academic hub.

The results further indicate that the level of study significantly influences students' intention to remain in the host country after graduation, with Master's degree students showing a greater propensity to do so. This finding aligns with the conclusions of Cameron et al. (2019) and Hooijen et al. (2017), who argue that advanced students are more likely to establish stronger social and professional ties during their studies, thereby increasing their chances of remaining in the host country.

At the same time, no statistically significant relationship was found between gender and students' intention to remain in Slovakia. This finding is consistent with previous research suggesting that migration decisions are more strongly influenced by structural and economic factors than by gender (Constant & Massey, 2003).

The study also highlights the importance of personal life factors in shaping post-graduation intentions. Although these factors were not analysed in depth using inferential statistics, their high frequency suggests that social ties and overall life satisfaction play a crucial role in students' decision-making. This observation is in line with the findings of Holloway et al. (2012) and Martin (2017), who emphasise the growing importance of emotional and social dimensions in international mobility. Recent research also highlights the importance of student well-being and supportive educational environments in shaping students' satisfaction and future development within higher education systems (Samašonok et al., 2026).

Overall, the results indicate that international student migration to Slovakia is driven by a combination of economic and socio-cultural factors rather than purely academic considerations. These findings provide important implications for policymakers and higher education institutions, suggesting that efforts to attract and retain international students should focus not only on improving academic quality but also on enhancing social integration, cultural accessibility, and labour market opportunities.

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However, these findings should be interpreted with caution due to the study's limitations, including a non-representative sample and reliance on self-reported data. Further research is needed to explore these relationships in more diverse contexts and using longitudinal data.

6. Suggestions and recommendations

Based on empirical findings and a multifaceted analysis of student migration behaviour in Slovakia, the following strategic suggestions and recommendations are proposed to optimise human capital development and enhance the retention of international talent. Given that educational quality was the least prevalent pull factor (22%), Slovak universities must prioritise international accreditation and research visibility. Shifting the perception from a "culturally accessible" destination to a "centre of academic excellence" is essential for long-term competitiveness. Higher education institutions should function as active intermediaries. Implementing mandatory professional internships, vocational counselling, and job-search training – specifically tailored to the Slovak legal and corporate environment – can bridge the gap between graduation and professional integration. Since Master's degree students exhibit a significantly higher intention to remain in Slovakia, universities should focus retention efforts on this cohort through graduate-specific professional networking events and research fellowships.

The primary "push" factor driving students away post-graduation is the wage differential and superior occupational prospects abroad (50%). Policymakers must incentivise local enterprises to offer competitive entry-level remuneration packages and clear career trajectories for international graduates to mitigate the "brain drain." In addition, to convert international students into a permanent skilled workforce, the government should simplify administrative procedures for transitioning from student visas to work permits, particularly in sectors facing labour shortages. As personal life was the most prominent driver for staying (75.3%), integration policies should move beyond academic support. Community-building programs, social integration initiatives, and linguistic support – even for those in English-taught programs – are vital for establishing the emotional and social ties that preclude emigration. The state should continue to capitalise on linguistic affinity (cited by 62%) as a unique pull factor. Strengthening ties with regions that share these affinities can serve as a sustainable recruitment strategy.

7. Conclusions

This study analysed the key factors influencing international students' decision to study in Slovakia and their subsequent intentions to remain in the country after graduation. Based on responses from 150 international students, the findings highlight a shift in the determinants of student migration, with socio-cultural and economic factors playing a more significant role than purely academic considerations.

The results indicate that linguistic proximity and financial factors represent the primary drivers of students' decision to choose Slovakia as a study destination. Cultural proximity was found to be particularly important for Master's level students, suggesting that the importance of socio-cultural factors increases with the level of study. In contrast, the perceived quality of education plays a less decisive role in students' decision-making. These findings suggest that Slovakia is currently perceived more as an accessible and culturally compatible destination than as a highly competitive academic hub.

The analysis further confirmed that the level of study significantly influences students' intention to remain in Slovakia after graduation, with Master's students showing a stronger tendency to do so. This may reflect deeper engagement with the host country's academic and social environment during advanced studies. At the same time, no statistically significant relationship was identified between gender and students' intention to remain, indicating that migration decisions are primarily shaped by structural and contextual factors rather than demographic characteristics.

From a human capital development perspective, these findings point to an important challenge. While Slovakia has been relatively successful in attracting international students, the long-term retention of this potential

workforce remains uncertain. Economic factors, particularly wage differentials and career opportunities abroad, continue to play a decisive role in shaping students' post-graduation decisions.

In this context, it is essential to strengthen the link between higher education and the labour market. Policymakers and universities should focus on improving employment opportunities, supporting career development, and creating conditions that facilitate the integration of international graduates into the domestic economy. At the same time, attention should be given to social and cultural aspects, as personal life factors and overall quality of life appear to significantly influence students' decisions to remain in the host country.

The novelty of this study lies in providing empirical evidence on international student migration from the perspective of Slovakia as an emerging study destination. This context has received only limited attention in the existing literature. Unlike most previous studies that focus on traditional destination countries, this research simultaneously examines the factors influencing students' choice of Slovakia and their post-graduation retention intentions. The findings reveal that linguistic and cultural proximity are more influential than educational quality in shaping migration decisions. At the same time, the level of study significantly affects students' willingness to remain in the host country. These results contribute to a deeper understanding of the links between student mobility and human capital development in smaller Central and Eastern European countries.

Overall, the study contributes to a better understanding of international student migration in the Slovak context and highlights the need for a more comprehensive approach that integrates educational, economic, and social policies. Such an approach is crucial for enhancing the country's attractiveness and ensuring the sustainable development of human capital.

However, the findings should be interpreted with caution due to the study's limitations, particularly its non-representative sample and reliance on self-reported data. Future research could expand the scope of analysis by including a more diverse sample and applying longitudinal methods to capture changes in students' migration behaviour over time.

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WAGE EXPECTATIONS AND WORK PREFERENCES OF GENERATION Z: PROFILES, DETERMINANTS, AND EMPLOYER BRANDING IMPLICATIONS

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Abstract. This paper aims to identify the wage expectations of Generation Z students in the Czech Republic, determine their key determinants, and develop wage profiles capturing specific combinations of career aspirations, competence self-concept, work preferences, and value orientations among the emerging generation of university graduates. Based on a quantitative questionnaire survey conducted among 594 university students, the study identifies the key determinants of wage expectations—gender, field of study, level of study, preferred work location, and competence self-concept—and analyses their relationship with attitudes towards employee loyalty, job stability, and willingness to deliver extra-role performance. Four distinct wage profiles of Generation Z students are identified based on expected gross starting salary: the Stability-Oriented Regional Profile, the Mainstream Stability Profile, the Corporate-Metropolitan Profile, and the High-Ambition Independent Profile. A specific combination of competence self-concept, career aspirations, employer and location preferences, and orientation towards stability characterises each profile. The paper also compares students' wage expectations with actual starting salaries offered by selected Czech and European employers, thereby assessing the degree of alignment between subjective expectations and labour-market realities. The findings show that higher wage expectations are not associated with unconditional work engagement but rather with a conditional performance orientation consistent with the logic of a reciprocal psychological contract. The study further identifies a retention paradox: the most competent and ambitious segment simultaneously reports the lowest willingness to remain with an employer over the long term. The results provide practical implications for employer-branding strategies and recruitment communication targeted at different Generation Z segments and contribute to the development of educational, remuneration, and human-resource policies in the Czech Republic and the broader European context.

Keywords: Generation Z; wage expectations; employer branding; work preferences; wage profiles; competence self-concept; employee loyalty; psychological contract; retention paradox; labour market; university students; employers; gross starting salary

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JEL Classifications: J31, J24, M51

1. Introduction

In recent years, the European labour market has undergone a major transformation driven by digitalisation, advances in artificial intelligence, demographic change, and the transition towards sustainable business models. Although economic growth has slowed in some countries (OECD, 2026), most European employers continue to face shortages of qualified workers (Pemberton-Frings & Ilie, 2026). This trend is particularly evident in technical fields, information technology, industrial production, logistics, and healthcare (Cedefop, 2024). Generation Z—young people born approximately between 1997 and 2012—is entering this environment, gradually replacing older cohorts in the labour market while bringing new work values, expectations, and approaches to employment.

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Research indicates that Generation Z places considerable importance on work–life balance, work flexibility, opportunities for professional development, and meaningful work when selecting an employer (Barhate & Dirani, 2022; Rani & Suneja, 2025). Young graduates no longer perceive employment solely as a source of income, but also as a means of personal fulfilment and development. Organisational culture, the quality of workplace relationships, and employers' emphasis on social responsibility and sustainability also play an important role (Thang et al., 2023). At the same time, members of Generation Z expect to change jobs more frequently than previous generations, and their organisational loyalty tends to be lower than that of Generations X or Y (Ravid et al., 2025).

European employers, by contrast, emphasise somewhat different priorities. In addition to professional knowledge, they increasingly require the ability to work independently, responsibility, resilience to stress, problem-solving skills, and effective communication (Līce et al., 2023; Vasilescu et al., 2026). The importance of adaptability and willingness to engage in continuous learning is also growing (OECD, 2021). In an environment of rapid technological change, employers expect graduates to acquire new knowledge and competencies throughout their careers. Many employers also report a mismatch between graduates' expectations and the realities of working life, particularly regarding starting salaries, work effort, and willingness to remain with an organisation over the long term (University of Limerick, 2025).

This paper aims to identify the wage expectations of Generation Z students in the Czech Republic, determine their key determinants, and develop wage profiles capturing specific combinations of career aspirations, competence self-concept, work preferences, and value orientations among the emerging generation of university graduates. The paper also compares these expectations with actual starting salaries offered by selected Czech and European employers. The findings are interpreted with regard to their implications for employer-branding strategies targeting different Generation Z segments, as well as for the development of educational, remuneration, and human-resource policies in the Czech Republic and the broader European context.

The research problem is therefore situated at the intersection of three dimensions: students' subjective expectations, employers' requirements, and available information on starting remuneration. This approach makes it possible to more accurately assess whether stated wage requirements reflect merely individual aspirations or are associated with the field of study, location, expected career trajectory, and self-assessed competencies. It also provides a basis for practical recommendations for both employers and higher education institutions.

2. Review of Literature: Generation Z

When Millennials entered the labour market, considerable attention was devoted to their work preferences and expectations. Today, a similar focus has shifted to Generation Z, which is gradually entering the labour market and becoming a significant component of the workforce. Although no generation can be regarded as a homogeneous group, certain common trends in values and expectations can be observed, reflecting broader social, economic, and technological changes (Rudolph et al., 2021; Kundlwana et al., 2026).

Growing up amid economic uncertainty, geopolitical change, and the ubiquity of digital technologies can be regarded as important formative influences on Generation Z (Lanier, 2017; Scholz & Rennig, 2019; Vraňaková et al., 2026). This cohort is often described as a generation of digital or mobile natives because many of its members do not remember a period without the internet and social media (Schroth, 2019). This experience affects how they search for information, communicate, and compare potential employers.

Experience of uncertainty does not, however, imply a weaker work orientation. Research suggests that Generation Z may place strong emphasis on economic security, stability, career advancement, professional development, and high-quality employee benefits (Lyons & Kuron, 2014; Pham et al., 2024; Al-Moteri et al., 2025). At the same time, this generation is sensitive to privacy protection in the digital environment (Rózsa et al., 2024), openness to diversity, and fairness in the workplace.

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Other important characteristics of Generation Z include entrepreneurial orientation, expectations of autonomy, and a need for regular feedback. Although this generation is strongly associated with digital communication, it continues to value personal contact, clear communication, and ongoing recognition of performance in the workplace.

These characteristics have direct implications for employer branding, defined as the strategic development of an employer's image to attract and retain talented employees (Vieira et al., 2024). Generation Z actively searches for information about potential employers through digital channels and evaluates not only remuneration but also development opportunities, organisational culture, the credibility of communication, and the alignment between the employer's values and its own values (Garai-Fodor & Jäckel, 2024; Thang et al., 2023; Mugunzva & Manchidi, 2024; Rani & Suneja, 2025; Iyer et al., 2026). Effective recruitment communication, therefore, requires a segmented approach that reflects Generation Z's internal diversity.

For this study, the same generational label may encompass students oriented towards stability and regional employment as well as students characterised by high mobility, strong confidence in their technical competencies, and substantial wage expectations. Understanding the wage expectations, employer preferences, and career visions of different student groups, therefore, provides an important basis for targeted recruitment communication and human-resource strategies.

This perspective is also important for interpreting wage expectations. When Generation Z students are treated as a single group, their requirements may easily be characterised as generally high or unrealistic. A profile-based approach, by contrast, makes it possible to distinguish whether a higher wage requirement arises from field-specific specialisation, geographical mobility, competence self-concept, or a broader conception of a fair employment relationship.

3. Research Methodology

The empirical part of the paper is based on primary quantitative research conducted via an online questionnaire. The research design was developed to capture selected aspects of Generation Z's transition into the labour market, particularly wage expectations, work preferences, self-assessed competencies, loyalty towards employers, and perceptions of future career development. The objective was not merely to describe respondents' stated attitudes, but also to identify relationships between expected starting salary and selected personal, educational, disciplinary, and value-related characteristics.

The questionnaire was developed in March 2026 and structured into five thematic sections. Before the main data collection, the research instrument was pilot tested with a sample of 50 respondents. The pilot study assessed the clarity of the wording, the logical sequencing of items, and the time required for completion. Minor wording adjustments were made based on the feedback received. The questionnaire consisted exclusively of closed-ended items using nominal and ordinal scales. Data were collected in May and June 2026 through online distribution of the questionnaire. The target population comprised students from different fields and levels of higher education who were approaching full entry into the labour market. The research was conducted in accordance with the ethical principles of social-science research. Participation was voluntary and anonymous, and no data that could enable the retrospective identification of individual participants were collected. Before completing the questionnaire, respondents were informed about the purpose of the study, the method of data processing, and the survey's anonymous nature.

The questionnaire included respondents' identifying characteristics; items on wage expectations and work preferences; self-assessed competences; loyalty and work attitudes; and career perspectives.

The survey was divided into four analytical areas. The first focused on wage expectations and their determinants, particularly their relationship with gender, nationality, level of study, field of study, preferred work location, and competence self-concept. The second examined work preferences and employer orientation, especially whether the expected starting salary differed by preferred employer type. The third addressed loyalty, stability,

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and performance orientation. The fourth focused on profiling respondents by their expected starting salary and interpreted wage expectations as part of a broader professional and value orientation.

This structure enabled the connection between the descriptive and analytical levels of the research. First, the basic distribution of respondents' expectations was established; relationships between variables were then tested; and finally, wage expectations were interpreted through a set of profiles. This procedure was selected so that the expected salary would not be analysed merely as an isolated economic value, but as an element of a broader work and career orientation.

The procedure is also important from the perspective of the practical use of the results. Employers do not generally work only with the broad category of "graduate"; they also consider the field of study, location, expected salary, degree of mobility, and likely stability of the employment relationship. A combination of these dimensions, therefore, corresponds more closely to actual recruitment decision-making than the isolated analysis of a single variable.

Statistical analysis was performed using IBM SPSS Statistics. Given the ordinal nature of most variables and the failure to meet the assumptions of normality, predominantly non-parametric methods were applied. Relationships between categorical variables were tested using Pearson's chi-square test and, where appropriate, Fisher's exact test. The strength of associations was expressed using Cramér's V and the phi coefficient. Differences between groups were tested using the Mann–Whitney U test and the Kruskal–Wallis test, followed by post hoc comparisons with a Bonferroni correction. Ordinal relationships were quantified using Spearman's rank correlation coefficient, and Wilson 95% confidence intervals were calculated for selected proportions.

For the profile analysis, respondents were divided into four groups according to expected gross monthly starting salary: up to CZK 35,000; CZK 35,001–45,000; CZK 45,001–60,000; and more than CZK 60,000. These groups are not the result of cluster analysis but are analytically defined wage profiles that enable systematic comparison of respondents by expected financial remuneration.

An indicative wage analysis of employers relevant to graduates in economics, management, technical disciplines, and information technology followed the questionnaire survey. Its purpose was to situate respondents' stated wage expectations within the broader context of publicly available information on remuneration in the Czech and German labour markets. The analysis did not seek to determine the exact starting salaries actually paid, but to create a comparative framework for an indicative assessment of the alignment between respondents' expectations and market data.

The wage analysis was conducted separately for economics-and-management and technical-and-IT profiles because these groups differ in the types of positions available, their sectoral setting, and demand for qualifications. Separate analysis is also important given the composition of the research sample, in which economics and management students accounted for 69.4% of respondents, while technical and IT students represented 20.2%. A combined analysis could therefore obscure field-specific differences.

Czech employers were selected based on the TOP Employers 2026 ranking and supplemented with companies relevant to graduates in the fields under examination. Germany was selected for international comparison because of its geographical proximity, economic links with the Czech Republic, and importance in students' considerations of employment abroad. Since companies generally do not publish a single standard graduate salary, the values were constructed as indicative ranges based on triangulation of job advertisements, salary portals, and sectoral benchmarks. Where company-specific information was unavailable, the range was derived from advertisements for comparable positions in the relevant sector.

Target Group and Characteristics of the Research Sample

The target group of the questionnaire survey comprised students at universities and tertiary professional schools in the Czech Republic who fell within the age definition of Generation Z. This group was selected deliberately because it is in the transition phase between education and the labour market, when perceptions of future

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employment, expected remuneration, preferred type of employer, and conditions for entering working life are being formed.

Respondents were selected using purposive sampling with elements of snowball sampling. The questionnaire was distributed through social media, student associations, academic contacts, and lecturers at cooperating higher education institutions. This approach enabled students from different institutions, fields, and levels of study to be reached. However, the sample cannot be regarded as representative of the entire population of Generation Z students in the Czech Republic.

A total of 594 valid questionnaires were included in the final analysis. Men accounted for 54.9% of respondents, women for 44.8%, and two respondents did not report their gender. The largest age group consisted of respondents aged 22–24 years (46.1%), followed by those aged 21 or younger (38.7%). Respondents aged 25–27 accounted for 13.1%, while the 28–30 age category was represented only marginally (2.0%).

By level of study, bachelor's students predominated (69.4%), while students in follow-up master's programmes accounted for 28.3%. By field, economics and management students were the dominant group (69.4%), followed by technical and IT students (20.2%) and humanities or social science students (9.1%). Czech nationals represented 87.5% of the sample, while international students accounted for 12.5%, most commonly Ukrainian and Slovak nationals.

The research sample can therefore be characterised as predominantly Czech, university-based, and strongly oriented towards economics, management, technical disciplines, and information technology. Although the sampling method limits the generalisability of the findings, the sample's size and internal differentiation provide a suitable basis for analysing relationships among wage expectations, work preferences, and attitudinal characteristics of students entering the labour market.

The selected target group is also important because it is at a stage when work expectations are still becoming established. Some respondents may already have gained experience through part-time jobs, internships, or reduced-hours employment, but most remain between the education system and full labour-market participation. The findings, therefore, capture students' perceptions at a point when they have already been influenced by contact with practice but have not yet been fully shaped by long-term professional experience.

4. Research Results

This section presents the results of the quantitative questionnaire survey on the wage expectations, work preferences, competence self-assessment, loyalty, and career orientation of Generation Z students. The presentation is organised into four analytical areas. The first focuses on wage expectations and their determinants. The second examines the relationship between wage expectations and preferred employer type. The third analyses the associations among wage expectations, loyalty, stability, and willingness to engage in extra-role performance. The fourth synthesises the partial findings into four wage profiles of Generation Z students. Conversions from Czech koruna to euros are indicative and are based on an exchange rate of EUR 1 = CZK 24.195.

4.1 Basic Characteristics of the Attitudes Examined

Respondents' wage expectations were concentrated primarily in two middle ranges. The most frequently reported expected gross starting salary was CZK 35,001–45,000, approximately EUR 1,447–1,860 (40.4%), followed by CZK 45,001–60,000, approximately EUR 1,860–2,480 (37.4%). Lower expectations of up to CZK 35,000, approximately up to EUR 1,447, were reported by 14.8% of respondents, while 7.4% indicated the highest category of more than CZK 60,000, approximately more than EUR 2,480. Most respondents, therefore, did not approach future employment with extremely high wage demands, but with expectations corresponding to qualified junior or entry-level professional positions.

This distribution is also important for interpreting the subsequent analytical section. Most respondents fall within ranges that can be considered realistic for qualified entry-level positions, yet high enough to create

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pressure for transparent salary communication by employers. The highest wage category is numerically smaller but analytically important because it concentrates specific attitudes towards mobility, performance, and stability.

Respondents generally did not perceive their own wage expectations as markedly detached from labour-market reality. A total of 41.4% stated that their expectations approximately corresponded to market conditions, 37.4% considered them slightly higher, and 7.7% regarded them as substantially higher. Salary was also an important factor in employer choice: 56.9% described it as very important, and a further 33.7% described it as one of several important characteristics of employment.

Preferences regarding employer type were divided mainly between private companies (42.8%) and multinational corporations (41.1%). Self-employment or work in a start-up was selected by 11.8%. In terms of work location, regional cities in the Czech Republic predominated (54.9%), Prague or Brno were preferred by 34.3% of respondents, and working abroad by 10.8%, most commonly in Western Europe.

This distribution indicates that respondents do not unequivocally prefer either a corporate or an entrepreneurial environment. Their perceptions combine more traditional employee career paths, an orientation towards the private sector, and interest in self-employment. This combination is important for employer branding because it shows that employer attractiveness need not be based solely on organisational size, but also on opportunities for development, autonomy, and meaningful work involvement.

Respondents assessed their competencies predominantly positively. Professional preparedness for practice was rated as medium by 43.1% and as rather high by 41.1%; digital competences were evaluated even more favourably, with 44.8% reporting an above-average and 24.9% an excellent level. Advanced language proficiency was declared by 64.3% of respondents, while most rated their soft skills as either rather or highly developed.

It should be emphasised, however, that these are subjective self-assessments rather than objective tests of competence. Their importance lies primarily in showing how students perceive their preparedness and how this perception influences the formation of wage expectations.

Loyalty and stability emerged as important but not one-dimensional work values. If satisfied with their employer, 40.4% of respondents would be willing to remain for more than ten years. Job stability was described as very important by 56.9% and as essential by 28.3%. Respondents most often associated loyalty with high-quality performance and reliability (46.5%), rather than merely with length of service. Willingness to provide extra-role performance was predominantly conditional: 50.8% would work overtime occasionally when required, while 30.3% would do so regularly if their effort was appropriately recognised.

Respondents' career visions were differentiated. The most common vision of an ideal working life in ten years was self-employment or owning a business (37.4%), followed by a stable position in a Czech company (23.6%), employment abroad (20.2%), and a managerial role in an international company (13.1%). The findings, therefore, reveal a combination of entrepreneurial, stability-oriented, international, and corporate aspirations.

4.2 Wage Expectations and Their Determinants

The first analytical area examined whether respondents' wage expectations differed according to selected individual, educational, and attitudinal characteristics. The results show that expected starting salaries are not randomly distributed across the sample, but are systematically associated with gender, nationality, level of study, field of study, preferred work location, and competence self-concept.

A key initial finding concerns the relationship between wage expectations and the importance respondents attach to salary when choosing an employer. The proportion of respondents who described salary as their highest priority or as a very important factor increased from 45.5% in the lowest wage category to 86.4% in the highest category ($\chi^2(3, N = 594) = 28.55$; $p < 0.001$; $V = 0.219$; $\rho = 0.239$; $p < 0.001$). Higher wage expectations are

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therefore not merely stated views of future income, but are associated with a greater decision-making weight assigned to salary in employer selection.

An overview of the main determinants is presented in Table 1. Median wage categories are supplemented by indicative euro equivalents.

Table 1. Wage expectations by key determinants (N = 594)

Determinant	Comparison	Test statistic	p	Effect size	Median, lower group	Median, higher group
Gender	women vs. men	$\chi^2(3) = 49.04$	< 0.001	V = 0.288	CZK 35,000–45,000, approx. EUR 1,450–1,860	CZK 45,000–60,000, approx. EUR 1,860–2,480
Nationality	Czech vs. other	$\chi^2(3) = 12.93$	0.005	V = 0.148	CZK 35,000–45,000, approx. EUR 1,450–1,860	CZK 45,000–60,000, approx. EUR 1,860–2,480
Level of study	Bachelor's vs. Master's	$\chi^2(3) = 33.36$	< 0.001	V = 0.240	CZK 35,000–45,000, approx. EUR 1,450–1,860	CZK 45,000–60,000, approx. EUR 1,860–2,480
Field of study	other vs. technical/IT	$\chi^2(3) = 28.04$	< 0.001	V = 0.217	CZK 35,000–45,000, approx. EUR 1,450–1,860	CZK 45,000–60,000, approx. EUR 1,860–2,480
Preferred location	regional cities vs. Prague/Brno	$\chi^2(4) = 27.41$	< 0.001	V = 0.152	CZK 35,000–45,000, approx. EUR 1,450–1,860	CZK 45,000–60,000, approx. EUR 1,860–2,480
Competence self-concept	lower vs. higher	$\chi^2(1) = 24.25$	< 0.001	$\varphi = 0.202$	—	—

Note: For gender and nationality, the direction of the differences was confirmed by Mann–Whitney U tests (U = 30,684; p < 0.001; U = 15,346; p = 0.003). For the level of study, U = 25,240; p < 0.001. Following the Bonferroni correction, the post hoc pairwise comparison for location confirmed a statistically significant difference only between regional cities and Prague/Brno ($p < 0.001$; $\alpha = 0.017$).

Source: Authors

Gender was the strongest individual differentiator of wage expectations. A salary above CZK 45,000, approximately above EUR 1,860, was expected by 56.4% of men compared with 30.8% of women. The highest category, above CZK 60,000 or approximately EUR 2,480, was reported by 12.3% of men and 1.5% of women ($\chi^2(1) = 24.68$; $p < 0.001$; $\varphi = 0.204$; OR = 9.16). This is a difference in expectations, however, rather than in actual earnings.

Higher expectations were also associated with nationality, level of study, and field of study. International respondents were more likely than Czech respondents to expect a salary above CZK 45,000 (59.5% vs. 42.7%) and above CZK 60,000 (16.2% vs. 6.2%; $\chi^2(1) = 9.56$; $p = 0.002$; $\varphi = 0.127$). Follow-up master's students were more likely than bachelor's students to expect more than CZK 45,000 (60.7% vs 38.8%), particularly in the CZK 45,001–60,000 range. Among technical and IT students, the category above CZK 60,000 was more frequent than among students in other fields (16.7% vs. 5.1%).

The spatial dimension was evident, particularly in relation to Prague and Brno. A salary above CZK 45,000 was expected by 55.9% of respondents preferring Prague or Brno, compared with 36.2% of those oriented towards regional cities. Respondents preferring employment abroad reported this level in 53.1% of cases, although after Bonferroni correction, the difference between regional cities and employment abroad was not statistically significant.

Competence self-concept also played an important role. Respondents who simultaneously rated their professional, digital, and language competences in one of the two highest categories expected a salary above CZK 60,000 more than four times as often as other respondents (14.2% vs. 3.3%; $\chi^2(1) = 24.25$; $p < 0.001$; $\varphi = 0.202$). Statistically significant associations were found particularly for professional preparedness, digital competences, and language skills; soft skills were not independently significant.

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In summary, higher wage expectations were concentrated among men, international students, follow-up master's students, technical and IT students, respondents oriented towards Prague or Brno, and respondents with a strong competence self-concept. Together, these characteristics suggest the existence of a group in which higher financial expectations are linked to disciplinary, spatial, and self-perceptual dimensions.

From an interpretive perspective, none of the identified determinants should be viewed in isolation. Gender, field of study, location, and competence self-concept are likely to overlap in respondents' actual decision-making. Higher expectations cannot therefore be explained by a single factor, but rather by an accumulation of characteristics that jointly reinforce graduates' perception of their higher market value.

4.3 Work Preferences and Employer Orientation

The second analytical area examined whether wage expectations differed by preferred type of employer. Given the distribution of responses, the principal comparison was between respondents who preferred a private company and those who preferred a multinational corporation. Only respondents who selected one of these two options were included in this part of the analysis (n = 498).

A statistically significant difference in the distribution of wage expectations was found between the two groups ($\chi^2(3, N = 498) = 15.31$; $p = 0.002$; $V = 0.175$; $U = 26{,}376$; $p = 0.002$). Respondents oriented towards multinational corporations most frequently reported the CZK 45,001–60,000 category, approximately EUR 1,860–2,480 (47.5%). By contrast, among respondents preferring private companies, the CZK 35,001–45,000 category, approximately EUR 1,447–1,860, predominated (42.5%). A salary above CZK 45,000, approximately above EUR 1,860, was expected by 54.9% of respondents oriented towards multinational corporations, compared with 38.6% of those preferring private companies.

The significance of this result does not lie in an association between multinational corporations and exceptionally high incomes. The proportion of respondents expecting more than CZK 60,000 (approximately EUR 2,480) was almost identical in both groups: 7.4% among those preferring multinational corporations and 7.9% among those preferring private companies. Multinational corporations are, therefore, in respondents' perceptions, associated with a higher-middle-class salary standard rather than exceptionally high remuneration. Their attractiveness is based on expectations of more predictable, stable, or standardised remuneration.

In practical terms, multinational corporations are perceived as environments offering a more predictable remuneration structure, clearer career paths, and standardised development programmes. Private companies need not be regarded as less attractive. Still, they may be associated with a different type of work experience, closer proximity to decision-making, or a different form of professional development.

4.4 Loyalty, Stability and Performance Orientation

The third analytical area examined whether wage expectations were related to respondents' perceptions of loyalty, job stability, and extra-role performance. The findings show that higher wage expectations are not automatically associated with stronger performance-based loyalty, but are linked to a different relationship with stability and a more conditional understanding of work effort.

Preference for performance-based loyalty did not differ significantly across wage groups ($\chi^2(3, N = 594) = 2.19$; $p = 0.533$; $V = 0.061$). A targeted comparison of the highest wage category likewise showed no statistically significant difference ($\chi^2(1) = 1.75$; $p = 0.186$; $\varphi = 0.054$; Fisher's exact test $p = 0.211$). Although respondents who understood loyalty in performance terms were represented somewhat more frequently in the highest wage category, the difference was not statistically significant. Performance-based loyalty, therefore, does not appear to explain higher wage demands in this sample directly.

A different pattern emerged for job stability. Stability remained important across all wage groups, but its relative importance declined as the wage profile increased. Stability was described as essential by 93.2% of respondents in the lowest category, up to CZK 35,000 or approximately EUR 1,447; 88.3% in the CZK 35,001–45,000 group, approximately EUR 1,447–1,860; 82.0% in the CZK 45,001–60,000 group, approximately EUR 1,860–

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2,480; and 68.2% in the highest category, above CZK 60,000 or approximately EUR 2,480 ($\chi^2(3, N = 594) = 18.23$; $p < 0.001$; $V = 0.175$).

A similar downward trend was found for willingness to remain with a satisfactory employer over the long term. More than ten years was reported by 45.5% of respondents in the lowest category, 47.5% in the CZK 35,001–45,000 group, 34.2% in the CZK 45,001–60,000 group, and only 22.7% in the highest category above CZK 60,000 ($\chi^2(3, N = 594) = 15.17$; $p = 0.002$; $V = 0.160$). Respondents with the highest wage expectations, therefore, did not reject stability but assigned it less weight than respondents with lower expectations.

The relationship between the highest wage expectations and willingness to provide extra-role performance was ambivalent. Respondents expecting more than CZK 60,000 (approximately EUR 2,480) were more likely to report willingness to work overtime regularly if their effort was recognised (40.9% vs 29.5%).
At the same time, they were less likely to report willingness to occasionally work overtime when required (31.8% vs 52.4%). They were more frequently represented in the limited-to-no willingness category (27.3% vs 18.2%). The difference in the distribution of responses was statistically significant ($\chi^2(2, N = 594) = 6.93$; $p = 0.031$; $V = 0.108$), but after combining regular and occasional willingness into a binary measure of overall willingness to provide extra-role performance, it was no longer statistically significant ($\chi^2(1) = 2.20$; $p = 0.138$; Fisher's exact test $p = 0.159$).

This finding suggests that respondents with the highest wage expectations are not generally more willing than others to work beyond their formal duties. Rather, they differ in how strongly they condition their work effort on recognition and corresponding reciprocity. The combination of a high importance attached to salary and conditional willingness to provide extra-role performance was reported by 36.4% of respondents in the highest wage category, 24.3% in the CZK 45,001–60,000 group, 10.8% in the CZK 35,001–45,000 group, and 15.9% in the lowest category up to CZK 35,000. As wage expectations increase, the conditional nature of work effort therefore becomes more pronounced.

Taken together, these findings can be described as a retention paradox. The group with the highest wage expectations simultaneously shows the lowest stated willingness to remain with an employer over the long term and the most strongly conditional approach to extra-role performance. For employers, this means that candidates with high wage demands and a strong competence self-concept may not automatically be the easiest to retain if their expectations of a fair and reciprocal employment relationship are not met.

The retention paradox is important for employers because it highlights the distinction between a candidate's ability to create high value and the likelihood of long-term retention. A higher wage requirement may be associated with greater self-confidence, technical specialisation, and mobility, rather than with stronger organisational loyalty. For this group, a competitive salary alone is therefore insufficient; quality of management, recognition of performance, and a clear perspective for further development are also important.

4.5 Wage Profiles of Generation Z

Based on the expected gross starting salary, respondents were divided into four analytical wage profiles: up to CZK 35,000 (approximately EUR 1,447; n = 88; 14.8%); CZK 35,001–45,000.
EUR 1,447–1,860 (n = 240; 40.4%); CZK 45,001–60,000, approximately EUR 1,860–2,480 (n = 222; 37.4%); and more than CZK 60,000, approximately more than EUR 2,480 (n = 44; 7.4%). These profiles are not the result of cluster analysis but rather an analytical classification that enables salary to be interpreted in relation to respondents' broader characteristics.

The Stability-Oriented Regional Profile, with expectations up to CZK 35,000, is associated with lower financial expectations, regional orientation, and a strong emphasis on stability. Job stability was described as essential by 93.2% of respondents in this profile, and 45.5% would remain with a satisfactory employer for more than ten years. The profile consists mainly of bachelor's students, economics and management students, and women. Competence self-concept is lowest in this group, although entrepreneurial aspirations are pronounced: 47.7% identified owning a business as their principal career vision.

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The Mainstream Stability Profile, with an expected range of CZK 35,001–45,000, represents the largest share of the sample. It is characterised by an economics-and-management orientation, regional preferences, a high emphasis on stability, and the greatest willingness to remain with a satisfactory employer for more than 10 years (47.5%). The profile combines a stability orientation with an entrepreneurial vision, reported by 44.2% of respondents. At the same time, 44.2% in this profile perceive their expectations as higher than the labour market reality, indicating potential for mismatch upon entering employment.

The Corporate-Metropolitan Profile, with an expected range of CZK 45,001–60,000, represents a transition towards a stronger corporate and metropolitan orientation. A multinational corporation was preferred by 52.3% of respondents, and Prague or Brno by 40.5%. Compared with the lower profiles, this group has a stronger competence self-concept, a greater representation of technical and IT fields, a higher proportion of follow-up master's students, and a predominance of men. Career visions are differentiated: a stable position in a Czech company, self-employment, and work abroad are all represented to a meaningful extent.

The High-Ambition Independent Profile, with expectations above CZK 60,000, is the smallest but most distinctly defined group. Men account for 90.9% of the profile [95% CI: 78.8–96.4%], a strong competence self-concept was reported by 72.7% [95% CI: 58.2–83.7%], technical and IT orientation by 45.5% [95% CI: 31.7–59.9%], and high importance attached to salary by 86.4% [95% CI: 73.3–93.6%]. The profile is associated with Prague, Brno, or employment abroad, with work abroad being the most frequent career vision (40.9%).

The absence of a managerial career vision in the highest profile is noteworthy [95% CI: 0.0–8.0%]. The highest wage expectations, therefore, do not correspond to hierarchical managerial ambition, but rather to an expert, technical, or geographically mobile career orientation. This profile also expresses the strongest conditional relationship between salary and performance: 40.9% reported regular willingness to work overtime if recognised, but 27.3% limited or rejected work beyond formal duties, and willingness to remain with an employer for more than ten years fell to 22.7%.

The synthesis of the profiles reveals two principal axes of differentiation. The first represents a transition from a stability-oriented, regionally oriented stance to a mobile, metropolitan one. Lower profiles are more strongly associated with regional embeddedness, stability, and longer expected tenure. In contrast, higher profiles are associated with Prague, Brno, employment abroad, technical and IT orientation, and lower stated willingness to remain over the long term. The second axis represents a transition from a moderate competence self-concept to a strongly stated sense of professional, digital, and language competence.

The profile classification also has practical significance because it shows that the same wage category may be associated with different types of career motivation. Lower wage expectations do not necessarily imply lower ambition, but may reflect regional embeddedness, a stability orientation, or an entrepreneurial vision. Conversely, the highest wage expectations may be linked not to managerial aspirations but to an expert self-concept, technical orientation, and mobility.

A major cross-cutting finding is the gender dimension of wage expectations. The proportion of men increases with each wage category, and the gender asymmetry is most pronounced in the highest wage category. Overall, the findings show that Generation Z students place considerable importance on salary, but their expectations are not uniform. Some respondents associate future employment with stability, regional embeddedness, and a long-term employment relationship. In contrast, others are oriented towards corporate environments, metropolitan labour markets, technical and IT specialisation, employment abroad, and greater reciprocity between performance and remuneration.

4.6 Economic Analysis of Selected Employers

The economic analysis supplements the questionnaire findings with an indicative comparison of publicly available wage data for selected employers relevant to graduates in economics, management, technical disciplines, and information technology. Its purpose is not to determine the exact starting salary at individual companies, but to create a reference framework against which respondents' wage expectations can be interpreted with appropriate caution.

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The selected employers span the main sectors where graduates from the examined fields may find employment. For economics and management graduates, these include banking, insurance, auditing, consulting, energy, the automotive industry, retail, real estate development, and consumer industries. For technical and IT graduates, the focus is on the automotive and rail industries, energy, petrochemicals, automation, information technology, construction, and aerospace.

The inclusion of the economic analysis is important because it links students' subjective expectations to indicative data on salaries offered. The questionnaire survey alone would primarily reflect respondents' perceptions, whereas the wage analysis provides a framework for a cautious assessment of the approximate reasonableness of their responses. It does not, however, verify the individual bargaining positions of particular graduates; rather, it contextualises the findings.

4.6.1 Employers Relevant to Graduates in Economics and Management in the Czech Republic

The Czech sample of employers relevant to economics and management graduates includes major organisations in financial services, auditing, consulting, energy, industry, retail, and consumer markets. It comprises both institutions traditionally associated with economics education, such as banks, insurance companies, and consulting firms, and large industrial and commercial enterprises in which economics-related competences are applied in management, controlling, finance, marketing, sales, procurement, and project coordination.

Table 2 presents selected attractive employers for economics and management graduates in the Czech Republic. The stated wage ranges are indicative and do not represent uniform starting salaries guaranteed by individual companies. Where no company-specific figure for a graduate or junior position was available, the interval was derived from comparable sectoral data.

Table 2. Selected attractive employers for graduates in economics and management in the Czech Republic: profile and an indicative gross monthly starting salary range.

Company	Sector	Brief profile	Indicative gross monthly starting salary range
Česká spořitelna	Banking	Winner of the Banking and Investment category in the TOP Employers 2026 ranking; one-year graduate programme with rotations across departments.	CZK 30,000–38,000, approx. EUR 1,240–1,571
Komerční banka	Banking	Second place in the Banking and Investment category; one-year paid trainee programme open to economics graduates.	CZK 30,000–35,000, approx. EUR 1,240–1,447
KPMG	Consulting and audit	Winner of the Consulting, Audit and Tax category; a Big Four firm with strong recruitment of economics graduates into audit and tax services.	CZK 38,000–46,000, approx. EUR 1,571–1,901
Deloitte Czech Republic	Consulting and audit	Second place in the Consulting, Audit and Tax category; junior positions in audit, tax, and consulting.	CZK 35,000–43,000, approx. EUR 1,447–1,777
ČEZ Group	Energy	Overall winner of the TOP Employers 2026 ranking; economics-related positions, particularly in finance, sales, and customer services.	CZK 38,000–48,000, approx. EUR 1,571–1,984
Škoda Auto, a.s.	Automotive industry	Winner of the Automotive and Technology Industry category; economics-related positions in finance, controlling, marketing, sales, and procurement.	CZK 38,000–46,000, approx. EUR 1,571–1,901
Generali Česká pojišťovna	Insurance	Winner of the Insurance category; trainee programme with rotations across sales, product management, and IT.	CZK 35,000–45,000, approx. EUR 1,447–1,860
IKEA	Retail and e-commerce	Winner of the Retail and E-commerce category: recruitment of graduates into retail, logistics, and store management.	CZK 32,000–40,000, approx. EUR 1,323–1,653

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Company	Sector	Brief profile	Indicative gross monthly starting salary range
CENTRAL GROUP	Real estate and development	Winner of the Real Estate and Development category, a major Czech residential developer is also recruiting for finance and project-management positions.	CZK 38,000–48,000, approx. EUR 1,571–1,984
L'Oréal	Consumer industry	Winner of the Consumer Industry category; graduate positions in marketing, sales, and finance.	CZK 35,000–45,000, approx. EUR 1,447–1,860

Note: The amounts presented are indicative ranges and do not represent uniform starting salaries officially guaranteed by individual companies. The conversion into euros is indicative and is based on an exchange rate of EUR 1 = CZK 24.195.

Source: Authors' own processing based on EduFórum (2026), Alma Career (2026), Indeed.com (2026a, 2026b, 2026c, 2026e, 2020g), Jobs.cz (2026), and Kurzy.cz (2026a, 2026b, 2026c).

The Czech sample of economics and management positions indicates that starting salary ranges extend approximately from CZK 30,000 to CZK 48,000 per month, or around EUR 1,240–1,984. The median of the midpoints of the individual ranges is approximately CZK 40,000, or EUR 1,653. Lower ranges were identified mainly in certain banking and retail graduate programmes, whereas higher ranges occurred in auditing, consulting, energy, industry, and real estate development. Differences between employers should, however, be interpreted as indicative of the general wage framework rather than as a precise ranking of individual companies by remuneration attractiveness.

4.6.2 Employers Relevant to Graduates in Economics and Management in the German Labour Market

The German labour market was selected as the reference market for international comparison. The sample includes large multinational companies operating in banking, insurance, consumer industries, information technology, energy, and manufacturing (see Table 3). These companies were included because they offer positions or graduate programmes suitable for graduates in economics, finance, business, or management.

Table 3. Selected attractive employers for graduates in economics and management in the German labour market: profile and indicative gross monthly starting salary range

Company	Sector	Brief profile	Indicative gross monthly starting salary range
Deutsche Bank	Banking and investment	One of Europe's largest banks, a structured Graduate Programme for economics and finance graduates.	approx. EUR 4,800–5,200
Allianz	Insurance	A major European insurance group headquartered in Munich; graduate programmes in finance and risk management.	approx. EUR 4,000–4,600
BNP Paribas	Banking and investment	A major European banking group; graduate programmes including corporate banking.	approx. EUR 4,200–4,800
Unilever	Consumer goods	A global corporation; graduate programmes focused on marketing, finance, and sales.	approx. EUR 3,600–4,200
Nestlé	Food industry	A global food company; graduate programmes in marketing, finance, and supply-chain management.	approx. EUR 3,600–4,200
L'Oréal	Consumer industry	A global cosmetics group; graduate positions in marketing, sales, and finance.	approx. EUR 3,600–4,200
SAP	IT and software	A major European software corporation; business positions in sales, finance, and corporate administration.	approx. EUR 4,000–4,800
Shell	Energy	A multinational energy company, business positions in finance, sales, and commodity trading.	approx. EUR 3,800–4,400
Siemens	Industry and technology	A global technology group; business positions in finance, controlling, and sales.	approx. EUR 3,600–4,300

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Company	Sector	Brief profile	Indicative gross monthly starting salary range
Volkswagen Group	Automotive industry	The parent group of Škoda Auto offers graduate and trainee programmes also available in finance, controlling, and procurement.	approx. EUR 3,600–4,200

Note: The amounts presented are indicative gross monthly salary ranges in euros. They are based on information relating to specific employers and sectoral benchmarks.

Source: Authors' own processing based on Glassdoor (2026b), PayScale (2026), Fintiba (2026), and the StepStone Salary Report 2026 (2026a).

In the German sample of economics and management positions, indicative ranges extend from approximately EUR 3,600 to EUR 5,200 per month. The median of the midpoints of the individual ranges is approximately EUR 4,025. The highest values in the compiled sample were mainly observed in banking and investment services, while lower values were particularly observed in some consumer-industry positions. It should again be emphasised that some values were derived from sectoral benchmarks and should therefore not be interpreted as exact salary figures guaranteed by individual employers.

4.6.3 Employers Relevant to Graduates in Technical and IT Fields in the Czech Republic

The Czech sample of employers relevant to technically educated graduates includes companies operating in the automotive and rail industries, energy, petrochemicals, automation, information technology, construction, and aerospace (see Table 4). The selection is based on leading positions in the relevant categories of the TOP Employers 2026 ranking. It is supplemented by companies of particular importance for the employment of technical and IT graduates.

Table 4. Selected attractive employers for graduates in technical and IT fields in the Czech Republic: profile and indicative gross monthly starting salary range

Company	Sector	Brief profile	Indicative gross monthly starting salary range
Škoda Auto, a.s.	Automotive industry	Winner of the Automotive and Technology Industry category; Tech-Trainee programme with rotations.	CZK 45,000–55,000, approx. EUR 1,860–2,273
Škoda Group	Rail vehicles	Second place in the Automotive and Technology Industry category; manufacturer of trams and trains, formerly Škoda Transportation.	CZK 42,000–50,000, approx. EUR 1,736–2,067
ABB Czech Republic	Automation and electrical engineering	Third place in the Automotive and Technology Industry category; manufacturing and technology activities in energy and automation.	CZK 40,000–46,000, approx. EUR 1,653–1,901
ČEZ Group	Energy	Winner of the Energy, Gas and Petrochemicals category and overall ranking winner; ČEZ Potentials graduate programme.	CZK 38,000–48,000, approx. EUR 1,571–1,984
ORLEN Unipetrol	Petrochemicals and energy	Second place in the Energy, Gas and Petrochemicals category, a major petrochemical group operating in the Czech Republic.	CZK 40,000–48,000, approx. EUR 1,653–1,984
Seznam.cz	Information technology	Winner of the Information Technology category, a major Czech internet company with strong recruitment of developers.	CZK 45,000–55,000, approx. EUR 1,860–2,273
Microsoft Czech Republic	Information technology	Second place in the Information Technology category, the Czech subsidiary of the global software corporation.	CZK 45,000–55,000, approx. EUR 1,860–2,273
STRABAG	Construction	Winner of the Construction category; one of the largest construction groups operating in the Czech Republic and Europe.	CZK 40,000–50,000, approx. EUR 1,653–2,067

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Company	Sector	Brief profile	Indicative gross monthly starting salary range
Metrostav	Construction	Second place in the Construction category, a major Czech construction group with a scholarship programme for technical students.	CZK 40,000–50,000, approx. EUR 1,653–2,067
Honeywell	Aerospace and automation	Winner of the Aviation and Aerospace category; research and development activities in Brno.	CZK 42,000–50,000, approx. EUR 1,736–2,067

Note: The amounts presented are indicative ranges. Where no information was available for a specific employer and graduate position, the range was derived from comparable junior positions in the relevant sector. The conversion into euros is indicative and is based on an exchange rate of EUR 1 = CZK 24.195.

Source: Authors' own processing based on EduFórum (2026), Alma Career (2026), Indeed.com (2026c, 2026d, 2026f), Kurzy.cz (2026b), DobráPráce.cz (2026), and Metrostav (2026).

In the Czech sample of technical and IT positions, indicative ranges are approximately CZK 38,000-55,000 per month, or around EUR 1,571–2,273. The median of the midpoints of the individual ranges is approximately CZK 45,500, or EUR 1,881. Higher values were recorded, particularly in information technology, the automotive industry, and selected development positions. Within the compiled sample, technical and IT positions therefore display a higher indicative wage level than economics and management positions. This finding cannot, however, be generalised to the entire Czech labour market because the employer sample was not constructed to be representative.

4.6.4 Employers Relevant to Graduates in Technical and IT Fields in the German Labour Market

The German sample of technically oriented employers includes multinational industrial, technological, automotive, aerospace, chemical, and electrical-engineering companies (see Table 5). Given the industrial structure of the German economy, these companies represent a relevant reference group for comparing employment opportunities available to technically educated graduates.

Table 5. Selected attractive employers for graduates in technical fields in the German labour market: profile and indicative gross monthly starting salary range

Company	Sector	Brief profile	Indicative gross monthly starting salary range
Siemens	Industry and technology	A global technology group; a two-year Siemens Graduate Program with international rotations for technical disciplines.	approx. EUR 3,800–4,500
Volkswagen Group	Automotive industry	The parent group of Škoda Auto offers graduate, trainee, and doctoral programmes for technical fields.	approx. EUR 3,800–4,500
BMW Group	Automotive industry	A major German automotive group; graduate programmes for mechanical and electrical engineers.	approx. EUR 4,000–4,700
Airbus	Aerospace industry	A European aircraft manufacturer; technical positions in research, development, and production.	approx. EUR 4,000–4,800
Bosch	Automotive components and technology	A global technology and industrial group headquartered in Germany, a major employer of mechanical and electrical engineers.	approx. EUR 3,800–4,400
ABB	Automation	A global technology group focused on electrical engineering, robotics, and industrial automation.	approx. EUR 3,800–4,400
Schneider Electric	Electrical engineering and automation	A French technology group with a strong position in energy management and automation.	approx. EUR 3,800–4,400
BASF	Chemical industry	A major chemical group headquartered in Ludwigshafen; graduate programmes for chemical and process engineers.	approx. EUR 4,000–4,600

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Company	Sector	Brief profile	Indicative gross monthly starting salary range
Continental AG	Automotive components and technology	A global supplier of technologies and components for the automotive industry.	approx. EUR 3,800–4,400
Rolls-Royce Deutschland	Aerospace industry	The German division of the British Rolls-Royce Group focused on the development, production, and servicing of aircraft engines; technical positions for mechanical and aerospace engineers.	approx. EUR 4,000–4,800

Note: The amounts presented are indicative gross monthly salary ranges in euros. They are based on information relating to specific employers and sectoral benchmarks.

Source: Authors' own processing based on StepStone (2026b), Glassdoor (2026a), PayScale (2026), and Fintiba (2026).

In the German labour market, indicative ranges for technical positions extend from approximately EUR 3,800 to EUR 4,800 per month. The median of the midpoints of the individual ranges is approximately EUR 4,150. Differences between individual companies are relatively small, which may partly reflect the fact that some data are derived from common sectoral benchmarks. The values should therefore be interpreted as an indication of the wage framework for technical graduate positions in Germany rather than as a precise comparison of the individual remuneration policies of the selected employers.

4.7 Comparison of the Czech and German Samples

A comparison of compiled samples indicates that technical and IT positions in the Czech Republic offer higher indicative starting salaries than economics and management positions. The median midpoint is approximately CZK 45,500, or EUR 1,881, for technical and IT positions and approximately CZK 40,000, or EUR 1,653, for economics and management positions. In Germany, the difference between the two groups is smaller: the median is approximately EUR 4,150 for technical positions and EUR 4,025 for economics and management positions.

Using the indicative exchange rate of EUR 1 = CZK 24.195, the German medians correspond to approximately CZK 100,400 for technical positions and CZK 97,400 for economics and management positions. The nominal ratio of the German to Czech value is therefore approximately 2.2 for technical positions and 2.4 for economics and management positions. These ratios cannot be interpreted as precise wage differentials because they do not account for price levels, taxation, social-security contributions, living costs, working hours, or the structure of total remuneration.

Direct comparison is also limited by differences in how wage data are defined. The German StepStone Salary Report uses total annual gross remuneration, standardised to a forty-hour working week, and may include bonuses, commissions, and other variable components, whereas Czech job advertisements generally report the basic gross monthly salary. The geographical location of positions is also important, both in Prague, Brno, and economically strong Czech regions and in German federal states such as Bavaria, Baden-Württemberg, and Hesse.

Overall, the analysed sample confirms a higher nominal wage level in the German labour market than in the Czech environment. At the same time, it shows that differences between economics-related and technical occupations are not identical across contexts: in the Czech sample, the difference between technical/IT and economics/management positions is more pronounced, whereas in the German sample, the wage ranges of the two occupational groups are relatively similar.

For interpreting Generation Z expectations, this difference is particularly important among respondents considering employment abroad. Higher nominal salaries may increase the attractiveness of international employment, but they do not in themselves indicate the net economic advantage of such a decision. Students and higher education institutions should therefore work not only with nominal salary figures but also with information on living costs, taxation, social security contributions, and career prospects.

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Limitations of the Economic Analysis

The analysis has several limitations. It is based on advertised salaries, public estimates, and sectoral benchmarks rather than on salaries actually paid. The results may be affected by differences in job content, location, applicant requirements, and remuneration structure.

Data from anonymous salary portals may not be verified or methodologically harmonised and may therefore reflect the sector's general wage level rather than the specific remuneration policies of individual employers. The companies were not selected through probability sampling. The findings cannot therefore be generalised to the entire Czech or German labour market and serve only as an indicative framework for comparing respondents' wage expectations.

5. Discussion

The findings confirm that Generation Z is not a homogeneous group, but exhibits substantial internal differentiation (Rudolph et al., 2021). Students' wage expectations are influenced by gender, level and field of study, location, nationality, and competence self-concept. Higher expectations are particularly evident among men, technical and IT students, and respondents oriented towards metropolitan centres. Gender differences in expectations may be related to disciplinary composition, confidence in wage negotiation, and labour-market information (Lyons & Kuron, 2014). The higher wage expectations of technical and IT students correspond to growing demand for digital competences (Līce et al., 2023; Vasilescu et al., 2026).

Job stability is important across all profiles, but its importance declines as wage expectations increase. The highest wage profile shows lower willingness to remain with a single employer over the long term. Stability is understood more as the sustainability of one's position in the labour market than as continued employment within one organisation (Pham et al., 2024; Al-Moteri et al., 2025). High wage requirements are associated with expectations of reciprocity, recognition, and development (Barhate & Dirani, 2022; Rani & Suneja, 2025). The findings therefore support the need for differentiated approaches to Generation Z by both employers and higher education institutions (Vieira et al., 2024).

Research Limitations and Recommendations for Further Research

The findings must be interpreted in light of several limitations. The research is cross-sectional and captures respondents' expectations at only one point in time; it therefore cannot track their development or verify how they translate into actual employment decisions after labour-market entry. A further limitation is the purposive sampling method with elements of snowball sampling, which prevents generalisation to the entire population of Generation Z students in the Czech Republic. The sample's disciplinary composition further limits representativeness. Economics and management students account for 69.4% of respondents, whereas technical and IT fields are less strongly represented despite displaying important differences in wage expectations. Another specific limitation is the small size of the highest-wage profile, which includes only 44 respondents. Findings relating to this group should therefore be regarded as indicative, even though Wilson's confidence intervals were used for selected proportions.

A further limitation is the use of competence self-assessment. The findings do not reflect objectively measured levels of professional, digital, language, or soft skills, but rather respondents' perceptions of their own preparedness. Competence self-concept is important for wage expectations, but cannot be equated with an objectively verified level of labour-market readiness.

Future research should follow respondents longitudinally and compare their stated expectations with actual working conditions after entering employment. Comparative research across types of higher education institutions, fields of study, and regions would also be beneficial, as would qualitative research focusing on the highest wage profile. Particular attention should be devoted to identifying the sources from which students construct their wage expectations and to the role played by higher education institutions, employers, social media, job portals, and personal experience.

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6. Conclusions

The aim of the paper was to analyse the wage expectations, work preferences, competence self-concept, and career orientation of Generation Z students in the context of their transition into the labour market. The study was based on a quantitative questionnaire survey conducted among university students and supplemented by an indicative economic analysis of selected employers operating in the Czech and German labour markets. The findings show that the expectations of the emerging generation of employees cannot be reduced solely to demands for higher pay or a general preference for flexibility. Wage expectations instead form part of a broader set of values, career perceptions, perceived competencies, and expectations towards employers.

The empirical findings confirm that Generation Z is not a homogeneous group. Expected starting salaries differ significantly according to gender, field of study, level of study, preferred work location, and competence self-concept. Higher wage expectations are concentrated particularly among men, follow-up master's students, technical and IT students, individuals preferring Prague or Brno, and respondents with high self-assessments of their professional, digital, and language competences. These findings suggest that any mismatch between graduates' expectations and actual labour-market opportunities is not universal but structured and differentiated by specific respondent characteristics.

A major contribution of the study is the identification of four wage profiles among Generation Z students. These profiles show that expected salary is not merely an economic figure, but also reflects different forms of career reasoning. Lower-wage profiles are more closely associated with regional embeddedness, an emphasis on stability, and a longer-term perspective with an employer. Higher profiles are more often associated with technical and IT orientation, a stronger competence self-concept, a metropolitan or international work orientation, and a more conditional relationship with extra-role performance. The highest wage profile also exhibits a retention paradox: high wage demands and a strong competence self-concept coexist with lower willingness to remain with an employer over the long term.

The indicative economic analysis of selected employers showed that respondents' wage expectations must be interpreted in the context of specific fields, employer types, and geographical labour markets. In the Czech sample, technical and IT positions displayed higher indicative starting salaries than economics and management positions. In contrast, in the German sample, the differences between the two occupational groups were less pronounced. The German labour market also showed a substantially higher nominal wage level. However, these differences cannot be interpreted without considering price levels, taxation, social-security contributions, living costs, and the structure of total remuneration.

The contribution of the paper lies primarily in linking the analysis of Generation Z wage expectations to work preferences, competence self-concept, and career visions. The findings indicate that employers should not approach the emerging generation through a uniform strategy. A segmented approach appears more effective, distinguishing between candidates oriented towards stability and regional embeddedness, candidates preferring corporate and metropolitan environments, and highly ambitious candidates who combine higher wage demands with expectations of transparent performance conditions, recognition, and reciprocity in the employment relationship.

The findings also show that managing graduates' expectations should begin before labour-market entry. Transparent information about salaries, employer requirements, and career development opportunities can help students assess their market position more accurately. It also enables employers to formulate offers that are clear, credible, and targeted towards specific applicant segments.

In conclusion, Generation Z enters the labour market with high sensitivity to remuneration, but also with differentiated conceptions of what constitutes an attractive and fair employment relationship. Employers, therefore, need to communicate salary terms, development opportunities, performance expectations, and recognition principles openly. For higher education institutions, the findings highlight the importance of career guidance, the development of a realistic competence self-concept, and the establishment of systematic links between students and practice. Further research should focus particularly on longitudinally examining how

students' stated expectations translate into actual work behaviour after labour-market entry. For employer-branding practice, the results further imply that recruitment communication aimed at the High-Ambition Independent Profile should move beyond traditional narratives of "stability and security" and replace them with a transparent definition of the psychological contract, including clear performance criteria, a direct link between performance and remuneration, and guaranteed professional autonomy. By contrast, for the Stability-Oriented profiles, location and the prospect of long-term employment remain central pillars of employer branding.

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IMPACT OF ORGANISATIONAL REPUTATION ON COMPANIES' REVENUES: AN EMPIRICAL STUDY OF SELECTED ENTITIES IN THE CZECH BEVERAGE MARKET*

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Abstract. This study examines the relationship between corporate reputation and firm-level financial performance in the Czech beverage industry (CZ NACE 11070), with particular emphasis on digitally derived reputation indicators. The primary objective is to assess whether online reputation metrics can serve as meaningful predictors of revenue performance. The analysis initially considers the ten largest firms in the sector and subsequently focuses on four companies with sufficient and comparable data. Using a mixed-methods approach, the study integrates secondary financial data with primary reputation indicators, including Total Online Reputation (TOR) scores derived from indexed web content and online ratings, as well as Advanced Sentiment Analysis (ASA) scores based on sentiment polarity and intensity. Correlation and regression analyses reveal a strong positive relationship between corporate reputation and revenues, with TOR scores demonstrating a higher correlation (r = 0.841) than ASA scores (r = 0.749). These findings suggest that multifactorial reputation measures capture broader stakeholder perceptions and provide greater explanatory power for firm-level financial outcomes. The results highlight the strategic importance of systematic reputation management, particularly in consumer-oriented industries where digital visibility, trust, and perceptions of sustainability are critical. Despite limitations related to sample size and sector specificity, the study contributes empirical evidence supporting the integration of digital reputation analytics into managerial decision-making and performance evaluation frameworks.

Keywords: corporate reputation; beverage industry; revenues; total online reputation; advanced sentiment analysis

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JEL Classifications: L14, L66, H27

1. Introduction

Corporate reputation has become an essential determinant of business success in today's highly competitive and transparent global market. Reputation management, which encompasses strategies to maintain a favourable corporate image, plays a crucial role in securing consumer trust, investor confidence, and long-term sustainability (Markovič & Pollák, 2017; Ajayi, Mmutle & Chaka, 2022; Dorčák). Beyond traditional

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performance drivers such as financial growth and innovation, companies are increasingly evaluated for their commitment to social responsibility, environmental stewardship, and ethical business practices (Sagapova, Dušek & Pártlová, 2022; Raithel & Schwaiger, 2014; Afful, 2023). This shift in stakeholder expectations underscores the importance of corporate reputation, particularly in industries that rely on finite natural resources, such as the bottled water sector. The Czech bottled water industry, CZ NACE 11070 (NACE Czech Republic, 2025), faces distinct challenges in balancing financial performance with environmental responsibility. Water scarcity, plastic pollution, and regulatory pressures are shaping consumer perceptions and influencing corporate reputations. Recent studies have highlighted growing concerns over microplastics in water supplies, with implications for both public health and industry sustainability (Lee et al., 2021; Schmidt, Krauth & Wagner, 2017; Halfar et al., 2023). Reports have even found microplastics in amniotic fluid and placental tissues, raising new concerns over long-term health effects (Reenock, Konisky & Uttermark, 2022). Additionally, reputational risks linked to environmental impact and resource mismanagement have led to significant market exits in the sector. Statistics indicate that two-thirds of companies operating under CZ NACE 11070 in the Czech Republic have either ceased operations or shifted their business focus, leaving only a third operating successfully (Kubina et al., 2019; Ministry of Finance of the Czech Republic, 2024; Ministry of Justice of the Czech Republic, 2023). This industry contraction emphasises the need for companies to adopt effective reputation management strategies to maintain competitiveness and financial stability. Given these challenges, this research examines the relationship between corporate reputation and financial performance in the bottled water industry. Specifically, it investigates how reputation metrics, Total Online Reputation (TOR) and Advanced Sentiment Analysis (ASA) scores, correlate with company revenues. The measurement approaches used in this study are based on established methodologies in reputation research. These approaches have been previously utilised in academic literature to assess corporate reputation and its financial impact (Pollák et al., 2018; Jiao, Przepiorka & Buskens, 2021). The study builds upon these existing models rather than introducing a completely new methodology. The study employs a mixed-methods approach, initially analysing the top 10 companies by financial performance before narrowing its focus to the top 4 for a more detailed examination. This approach ensures that insights are drawn from the most influential firms in the sector while allowing for a deeper exploration of reputation determinants. The following key questions guide this research: What is the relationship between corporate reputation, as measured by TOR and ASA scores, and company revenues? How do these two reputation measurement methodologies differ in their ability to capture the reputation-revenue dynamic?

By addressing these questions, the study contributes to the existing literature on corporate reputation and financial performance while offering actionable insights for companies in the bottled water industry. The findings aim to help firms optimise their reputation management strategies, enhance stakeholder trust, and improve financial resilience in a competitive and sustainability-conscious market.

2. Theoretical background

Corporate reputation is widely recognised as a crucial factor influencing financial performance, competitive advantage, and long-term sustainability. A positive corporate reputation enhances consumer trust, investor confidence, and stakeholder engagement, ultimately contributing to higher revenues and market valuation (Raithel & Schwaiger, 2014; Ajayi, Mmutle & Chaka, 2022; Straková & Kostiuk, 2023). Conversely, a damaged reputation can lead to decreased customer loyalty, increased financial risks, and a decline in profitability (Pollák et al., 2021; Gangi, Daniele & Varrone, 2020; Afful, 2023). Given the increasing significance of digital platforms and online consumer interactions, firms are increasingly relying on advanced reputation metrics to assess and manage their public perception (Pollák, Dorčák & Markovič, 2019).

Corporate Reputation and Financial Performance

Extensive research has established a strong link between corporate reputation and financial performance. A company with a strong reputation benefit from greater brand equity, enhanced customer retention, and the ability to command premium pricing for its products or services (Amy & Osiyevskyy, 2017; Lee & Lee, 2019; Világi, Konečný & Ruschak, 2022). Studies also indicate that firms with a well-managed reputation experience lower capital costs and greater access to financing due to higher investor confidence (Jiao, Przepiorka & Buskens, 2021). Reputation serves as a risk mitigation factor, as companies with strong reputations are more resilient to market fluctuations and crises (Khairat & Maher, 2015). Furthermore, corporate reputation plays a key role in

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shaping relationships with other stakeholders, including suppliers, creditors, and regulatory bodies. Businesses with positive reputations often secure favourable contract terms, better credit conditions, and higher stakeholder engagement (Nastišin et al., 2021). The reputational benefits extend beyond financial performance, as companies with strong reputations are more likely to attract and retain skilled employees, further strengthening long-term organisational success (Konečný et al., 2024; Konečný et al., 2025).

Reputation Measurement Methodologies

Several methodologies have been developed to assess corporate reputation, ranging from traditional survey-based approaches to advanced digital sentiment analysis. The Reputation Quotient (RQ), developed by Fombrun and Van Riel, is one of the most established frameworks for evaluating corporate reputation across multiple stakeholder groups (Fombrun, Gardberg & Sever, 2000). Similarly, the Corporate Reputation Index (CRI) has been widely used to measure a firm's reputation based on consumer perceptions (Loke & Lam-Lion, 2021). However, these traditional methods often rely on subjective survey data, which may not fully capture real-time changes in public perception. In response to these limitations, digital reputation measurement techniques have gained prominence. Sentiment analysis, which applies natural language processing (NLP) and machine learning to assess consumer opinions from online sources, has become a key tool for reputation evaluation. Advanced sentiment analysis methods analyse the emotional tone of online reviews, social media posts, and digital news articles to quantify reputation scores (Lee et al., 2021). These techniques offer real-time insights and reduce the biases associated with traditional survey-based approaches (Reenock, Konisky & Uttermark, 2022).

Total Online Reputation (TOR) and Advanced Sentiment Analysis (ASA)

This study utilises two specific reputation measurement methodologies—Total Online Reputation (TOR) and Advanced Sentiment Analysis (ASA) to assess the relationship between corporate reputation and financial performance. The TOR score is a multifactorial measure that aggregates various determinants of online reputation, including social media ratings, indexed web pages, and consumer sentiment across digital platforms. It is designed to provide a comprehensive overview of a company's online presence and its perceived trustworthiness in the market (Dorčák, Markovič & Pollák, 2017; Pollák & Markovič, 2022; Pollák, Markovič & Majdúchová, 2023). The ASA score, in contrast, is based on extended sentiment analysis techniques that categorise consumer sentiment into multiple emotional dimensions. By analysing online discourse and evaluating sentiment intensity, ASA scores provide deeper insights into trends in public perception (Kubina et al., 2019). Previous studies have highlighted the advantages of advanced sentiment analysis in evaluating corporate reputation, particularly in industries where online consumer engagement plays a significant role in shaping brand image (Jiao, Przepiorka & Buskens, 2021; Pollák, Dorčák & Markovič, 2021).

Reputation and the Bottled Water Industry

The bottled water industry faces unique reputational challenges due to increasing consumer awareness of environmental sustainability and corporate social responsibility (Aidarovna-Kamalova & Lenarovna-Kurbangalieva, 2020). Negative public sentiment surrounding plastic waste, resource depletion, and microplastic contamination has placed heightened scrutiny on companies operating in this sector (Schmidt, Krauth & Wagner, 2017). As a result, firms in the bottled water industry must actively manage their reputation to maintain consumer trust and long-term profitability (Halfar et al., 2023). Studies indicate that reputation management is particularly critical for small and medium-sized enterprises (SMEs) in the bottled water industry, as these firms often lack the financial and operational resources to counter negative publicity (Ministry of Finance of the Czech Republic, 2024). By leveraging digital reputation measurement tools such as TOR and ASA, businesses can gain actionable insights into consumer perceptions and develop targeted reputation management strategies (Pollák, Dorčák, & Markovič, 2019). The existing literature underscores the importance of corporate reputation as a determinant of financial performance and highlights the advantages of advanced reputation measurement methodologies. This study builds on prior research by applying TOR and ASA scores to assess the relationship between reputation and financial performance in the Czech bottled water industry. Given the sector's increasing exposure to reputational risks, adopting effective online reputation management practices is crucial for long-term success. The findings from this study aim to provide both theoretical and practical contributions to the field of corporate reputation management.

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3. Research objective and methodology

This study aims to examine the relationship between corporate reputation and financial performance in the Czech bottled water industry, classified under CZ NACE 11070 (NACE Czech Republic, 2025). Specifically, the research focuses on two reputation measurement methodologies: Total Online Reputation (TOR) scores and Advanced Sentiment Analysis (ASA) scores, assessing their correlation with company revenues. By comparing these methodologies, the study seeks to determine which reputation metric provides a more reliable indicator of financial success.

Corporate Reputation and Financial Performance
The study employs a mixed-methods approach, integrating secondary financial data with primary reputation data derived from digital platforms. The research initially analysed the top 10 companies in the Czech bottled water industry by financial performance, then narrowed its focus to the top 4 for in-depth analysis. This selection process was based on revenue rankings and data availability, ensuring that the final sample represented companies with significant market influence.

Financial data were obtained from publicly available sources, including:

- ARES (Ministry of Finance of the Czech Republic, 2024) – financial statements, revenue data, and profitability indicators.
- eJUSTICE (Ministry of Justice of the Czech Republic, 2023) – corporate reports, legal filings, and annual statements.

The following financial variables were extracted:

- Revenue (total sales from own products and services).
- Net profit (profitability measure to assess financial stability).
- Inventory levels (as an indicator of market demand and production efficiency).

Reputation-related data were collected using a digital sentiment analysis approach, incorporating:

- Google and Facebook ratings – as indicators of consumer satisfaction.
- Indexed web pages – representing online visibility and search engine authority.
- Extended sentiment analysis – measuring digital reputation trends through multi-factor NLP analysis (Lee et al., 2021).

These reputation determinants were used to compute TOR and ASA scores, which served as the basis for statistical analysis.

Reputation Measurement Methodologies
Total Online Reputation (TOR) Score- The TOR score is a multifactorial measure that aggregates various online reputation determinants, including social media ratings, indexed web pages, and digital sentiment indicators. It captures a quantitative assessment of a company's online presence and trustworthiness. The formula for TOR calculation follows an extended sentiment analysis model proposed by Dorčák, Markovič & Pollák (2017). Advanced Sentiment Analysis (ASA) Score- ASA is based on natural language processing (NLP) techniques that analyse digital content, including customer reviews, social media discussions, and online articles (Jiao, Przepiorka & Buskens, 2021).

The ASA score was computed using:

- Three sentiment keyword groups – classifying online discourse into positive, neutral, and negative sentiment categories.
- Machine learning classification models – extracting emotional intensity scores from digital conversations (Jiao, Przepiorka & Buskens, 2021).

Both TOR and ASA scores were used to quantify corporate reputation and evaluate their effectiveness in predicting financial performance.

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Statistical Methods and Analysis

To assess the relationship between corporate reputation (TOR & ASA scores) and financial performance (revenues), the study employed the following quantitative methods.

Pearson's correlation coefficient (r) was used to evaluate the strength and direction of the relationship between TOR, ASA scores, and revenues by Gangi, Daniele & Varrone (2020) or Freedman, Pisani & Purves (2007):

$$r = \frac{\sum_{i=1}^{n}(x_i - \dot{x})(y_i - \dot{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \dot{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \dot{y})^2}}$$

Where:

- x_i and y_i are individual data points for variables x and y, respectively.
- $\dot{x}$ and $\dot{y}$ are the means of variables x and y.
- The numerator represents the covariance between x and y.
- The denominator is the product of the standard deviations of x and y.

The Pearson correlation coefficient r ranges from -1 to +1:

- r > 0: A positive correlation (as one variable increases, the other also increases).
- r < 0: A negative correlation (as one variable increases, the other decreases).
- r = 0: No correlation (no linear relationship between variables).

A linear regression model was applied to assess the predictive power of TOR and ASA scores on revenues. The equation for a simple linear regression model is (Kutner et al., 2005; Montgomery, Peck & Vining, 2021):

$$y_i = \beta_0 + \beta_1 x_i + \epsilon_i$$

Where:

- $x_i, x_{1i}, x_{2i}, ..., x_{ki}$ = Independent variables (predictors).
- β_0 = Intercept, representing the expected value of y when all x variables are 0.
- $\beta_1, \beta_2, ..., \beta_k$ = Regression coefficients, representing the estimated effect of each independent variable on y.
- ϵ_i = Error term, accounting for variability not explained by the independent variables.

The final sample of 4 companies was determined based on data availability and industry representation. While the small sample size limits statistical significance, it enables an in-depth case-study approach to understanding how reputation influences financial performance in a highly specific sector (Afful, 2023).

Table 1. Dataset for regression and correlation analysis

Company	ASA (%)	GR (%)	FR (%)	NGIP	TOR (%)	Revenue (CZK)
Mattoni 1873 a.s.	40.65	82	82	100	76.16	19592716
Walmark a.s.	35.27	96	94	19	61.07	6100734
CHÂTEAU VALTICE - Vinné sklepy Valtice, a.s.	33.33	94	94	9	57.58	1274930
Ekomilk a.s.	23.01	86	46	8	40.75	2166442

Notes: ASA (%) – % score based on the advanced sentiment analysis; GR (%) – Google rating in %; FR (%) – Facebook rating in %; NGIP (Number of Google-Indexed Pages) – the absolute number of pages indexed by Google; TOR (%) – total online reputation in %.
Source: Authors' own elaboration

The impact of reputation metrics on corporate revenues is a critical area of research because corporate reputation significantly influences consumer trust, brand perception, and ultimately, financial performance. Calculation of Total Online Reputation (TOR) used the formula based on Kubina et al. (2019):

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$$TOR = \frac{R_{ASA} \sum_{i=1}^{n} Ri}{n+1}$$

Where:

- TOR – total online reputation in %;
- R_{ASA} – reputator ASA (% score based on the advanced sentiment analysis);
- R_i – reputator (% score based on a given i-th determinant of online reputation;
- n – number of indicators.

This study employs hypothesis testing to evaluate the statistical significance of the relationships between Total Online Reputation (TOR) scores, Advanced Sentiment Analysis (ASA) scores, and corporate revenues. The hypothesis tests aim to determine whether these reputation metrics have a measurable impact on financial performance. The null hypothesis (H_0) states that there is no statistically significant relationship between reputation scores (TOR and ASA) and company revenues. Conversely, the alternative hypothesis (H_1) suggests that a meaningful correlation exists, indicating that reputation scores are predictive of financial performance. To assess statistical significance, the study utilises p-values with a threshold of $\alpha = 0.05$. If the p-value is below 0.05, H_0 is rejected in favour of H_1, confirming a significant relationship. If the p-value is greater than 0.05, H_0 is not rejected, implying insufficient evidence to support a strong correlation between reputation metrics and revenues.

4. Results and discussion

This section presents the study's key findings and interprets their implications in the context of corporate reputation and financial performance. The results are structured to compare the effectiveness of Total Online Reputation (TOR) scores and Advanced Sentiment Analysis (ASA) scores in predicting company revenues within the Czech bottled water industry. Statistical analyses, including descriptive statistics, correlation analysis, and regression modelling, provide insights into the strength and direction of these relationships. The discussion contextualises the findings by comparing them with existing literature on corporate reputation management and financial outcomes. Given the increasing reliance on digital reputation metrics in business decision-making, the results contribute to ongoing debates about the validity of online sentiment analysis as a predictor of firm performance (Jiao, Przepiorka & Buskens, 2021; Pollák, Dorčák & Markovič, 2019). The Total Online Reputation (TOR) score calculations provide a quantitative foundation for analysing the impact of reputation metrics on corporate revenues:

TOR score Mattoni 1873 a.s. = $\frac{R_{ASA} + \sum_{i=1}^{n} R_I}{n+1} = \frac{40{,}65+(82+82+100)}{3+1}$ = 76.16 %

TOR score Walmark a.s. = $\frac{R_{ASA} + \sum_{i=1}^{n} R_I}{n+1} = \frac{35{,}27+(96+94+19)}{3+1}$ = 61.07 %

TOR score CHÂTEAU VALTICE - Vinné sklepy Valtice, a.s. = $\frac{R_{ASA} + \sum_{i=1}^{n} R_I}{n+1} = \frac{33{,}33+(94+94+9)}{3+1}$ = 57.58 %

TOR score Ekomilk a.s. = $\frac{R_{ASA} + \sum_{i=1}^{n} R_I}{n+1} = \frac{23{,}01+(86+46+8)}{3+1}$ = 40.75 %

Notes: TOR – total online reputation in %; RASA – reputator ASA (% score based on the advanced sentiment analysis); Ri – reputator (% score based on a given i-th determinant of online reputation; n – number of indicators.

An analysis of the ten most successful companies, as presented in Figure 1, revealed that most of these firms experienced increasing revenues up until 2019.

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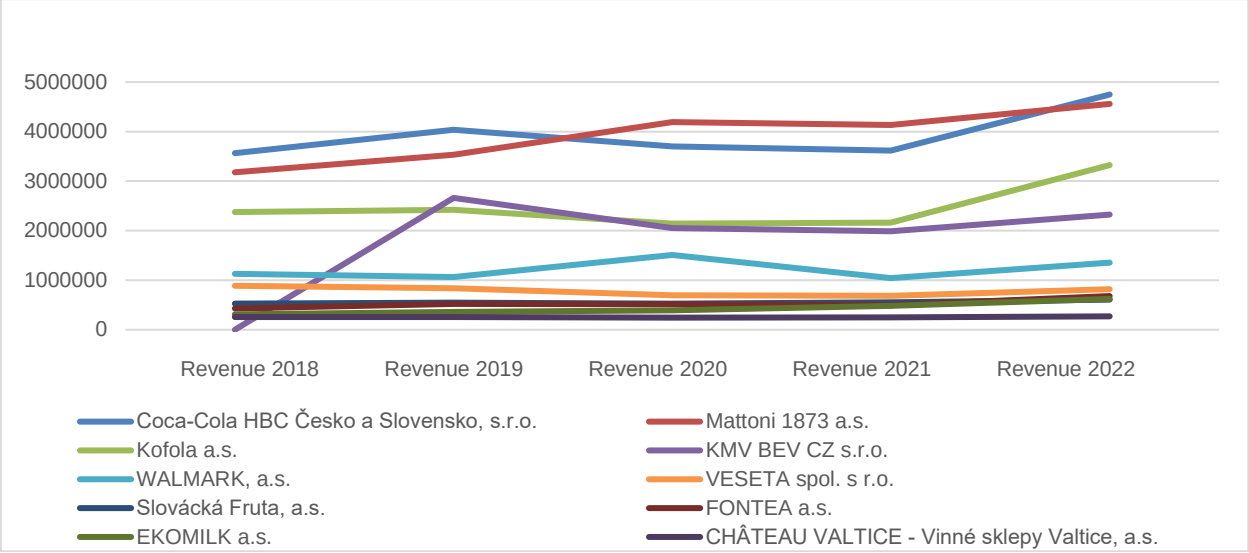


Figure 1. Overview of the 10 most successful joint-stock companies (a.s.) and limited liability companies (s.r.o.) with the business activity CZ NACE 11070 in the Czech Republic, based on revenues from 2018 to 2022
Source: Authors' own elaboration

However, a turning point occurred in 2019, after which all companies, except Mattoni, a.s., and Walmark, a.s., experienced a revenue decline that persisted until 2021. Initially, this decline was sharp, but by the end of 2020, revenues began to stabilise. The authors attribute this trend to the impact of the COVID-19 pandemic.

Table 2. Overview of the 10 most successful joint-stock companies (a.s.) and limited liability companies (s.r.o.) with the business activity CZ NACE 11070 in the Czech Republic, based on revenues from 2018 to 2022

No	Company	Revenue 2018	Revenue 2019	Revenue 2020	Revenue 2021	Revenue 2022	Total revenue
1	Coca-Cola HBC Česko a Slovensko, s.r.o. https://www.coca cola.com/cz/cs	3564500	4034034	3704138	3619257	4748224	19670153
2	Mattoni 1873 a.s. https://www.mattoni1873.cz/	3177771	3532274	4189069	4134093	4559509	19592716
3	Kofola a.s. https://www.kofola.cz/	2377422	2420387	2142716	2160404	3323934	12424863
4	KMV BEV CZ s.r.o. https://www.zaperli.cz/	2109213	2661738	2053109	1989971	2322142	9027170
5	WALMARK, a.s. https://www.walmark.cz/	1125546	1065274	1509296	1042663	1357955	6100734
6	VESETA spol. s.r.o. https://bonny-drink.cz/	887194	840778	694412	684901	817537	3924822
7	Slovácká Fruta, a.s. https://www.bapa.cz/	527555	547972	526593	556273	607852	2766245
8	FONTEA a.s. https://fontea.cz/	429724	518558	515225	496859	679981	2640347
9	EKOMILK a.s. https://www.ekomilk.cz/	310299	362333	391789	480076	621945	2166442
10	CHÂTEAU VALTICE https://www.vsvaltice.cz/	258144	255642	244222	246953	269969	1274930

Source: Authors' own elaboration

A subsequent reversal occurred in early 2021, with revenues across all companies beginning to rise, coinciding with the lifting of government-imposed COVID-19 restrictions. Supporting this observation is the fact that Walmark, a.s., which produces both dietary supplements and pharmaceuticals, benefited from increased demand for these products during the pandemic. Similarly, Mattoni 1873, a.s., which specialises in the production of mineral and medicinal waters, experienced revenue growth. These two companies uniquely benefited from heightened consumer interest in medicines, medicinal waters, and dietary supplements aimed at boosting immunity during the COVID-19 crisis. When examining the reputations of the ten most successful companies through sentiment analysis, as illustrated in Figure 2, it becomes evident that employing advanced methods

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yields a more accurate evaluation. This method assesses the sentiment of all companies' websites comprehensively by analysing three distinct groups of keywords. Conversely, utilising a basic sentiment analysis approach based solely on the keyword "name of the entity" would result in the highest sentiment scores being attributed to CHÂTEAU VALTICE - Vinné sklepy Valtice, a.s., Walmark, a.s., and Kofola, a.s., according to the data presented in Figure 2. However, the rankings differ significantly when applying the advanced sentiment analysis approach.



Figure 2. Sentiment of the 10 companies' websites based on advanced sentiment analysis
Source: Authors' own elaboration

Kubina et al. (2019) highlighted the inherent subjectivity of this type of analysis. A comparison of the TOR and ASA scores, as presented in Figure 3, supports their argument, as the rankings derived from the TOR scores differ significantly from those based on the ASA scores. Specifically, the TOR scores identified CHÂTEAU VALTICE – Vinné sklepy Valtice, a.s., Mattoni 1873, a.s., and Walmark, a.s. as the companies with the strongest reputations.

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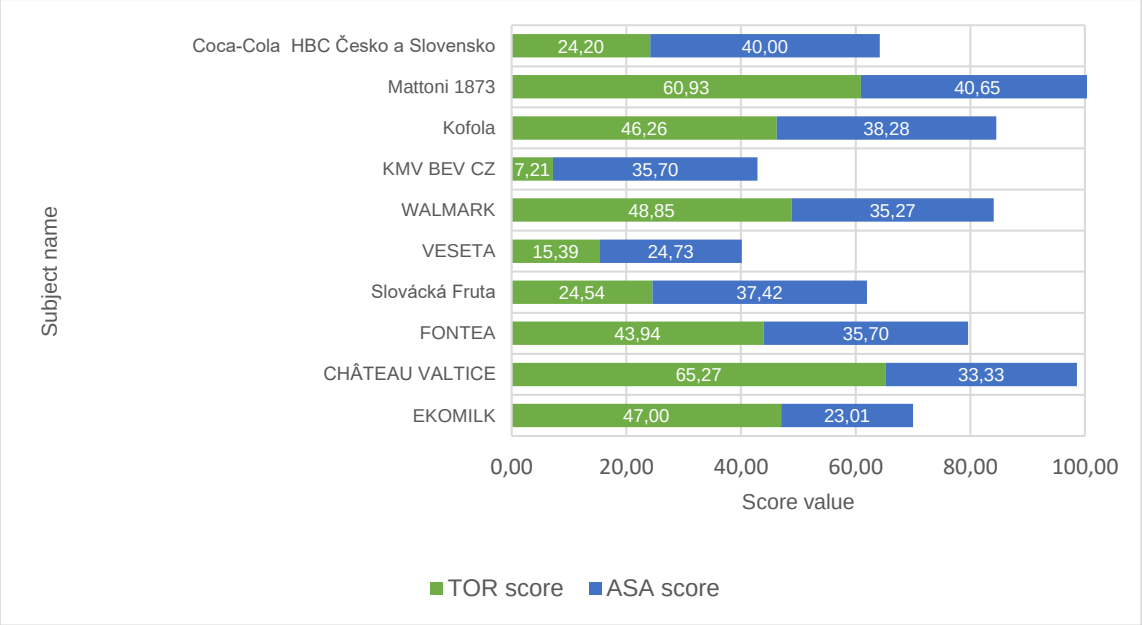


Figure 3. Comparison of TOR and ASA scores of the analysed companies
Source: Authors' own elaboration

Kubina et al. (2019) emphasised the subjective nature of this type of analysis. A comparison of the TOR and ASA scores, as illustrated in Figure 3, substantiates their claims, as the rankings derived from the TOR scores differ significantly from those based on the ASA scores. According to the TOR scores, CHÂTEAU VALTICE - Vinné sklepy Valtice, a.s., Mattoni 1873, a.s., and Walmark, a.s. were identified as the companies with the strongest reputations. However, when examining the means of ASA and TOR scores using a two-sample paired t-test for dependent samples at a significance level of $\alpha = 0.05$, it was not confirmed that the reputation calculated through ASA scores was, on average, different from the reputation based on TOR scores.

This confirmed the null hypothesis $H0$: $\mu\ ASA = \mu\ TOR$. However, when regression and correlation analysis was conducted on companies with the most common evaluation determinants—ultimately including only 4 out of the 10 companies—it was found that there is a stronger direct relationship between TOR scores and revenues compared to ASA scores and revenues, with a correlation coefficient of $r = 0.091794015$.

The problem here, however, is that none of the calculations showed statistical significance, which was always attributed to the very small sample size of companies. If the issue of the small sample size is disregarded, regression and correlation analysis confirmed a causal relationship between TOR scores and revenues from own products, which supports the assertion by Jiao, Przepiorka & Buskens (2021) that a company's reputation influences its performance in the expected direction.

Through regression analysis of TOR scores and revenues, illustrated in Figure 4, and correlation analysis, as presented in Table 1 with a correlation coefficient of r=0.841283766, it was demonstrated that the value of the correlation, approaching 1, and satisfying the condition $| r | > 0.8$, indicates a strong direct relationship between TOR scores and revenues from own products and services for 4 out of the 10 analysed companies.

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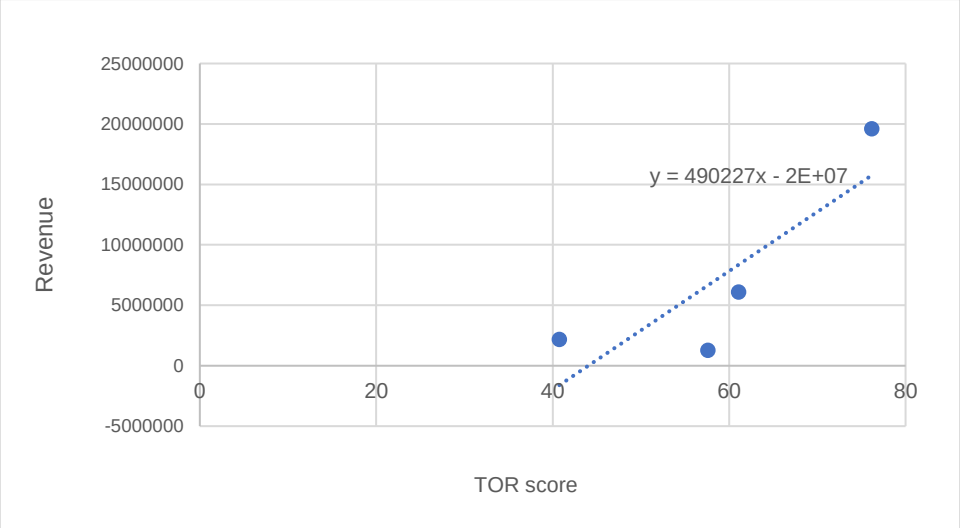


Figure 4. Regression and Correlation Analysis of TOR Scores and Revenues - Evidence of Correlation
Source: Authors' own elaboration

The hypotheses were further analysed using a paired t-test to examine the statistical significance of the correlation coefficient r. The result was a p-value of 0.183929414, indicating that, since p>0.05, the correlation analysis is not statistically significant. This is primarily due to the very small sample size of companies.

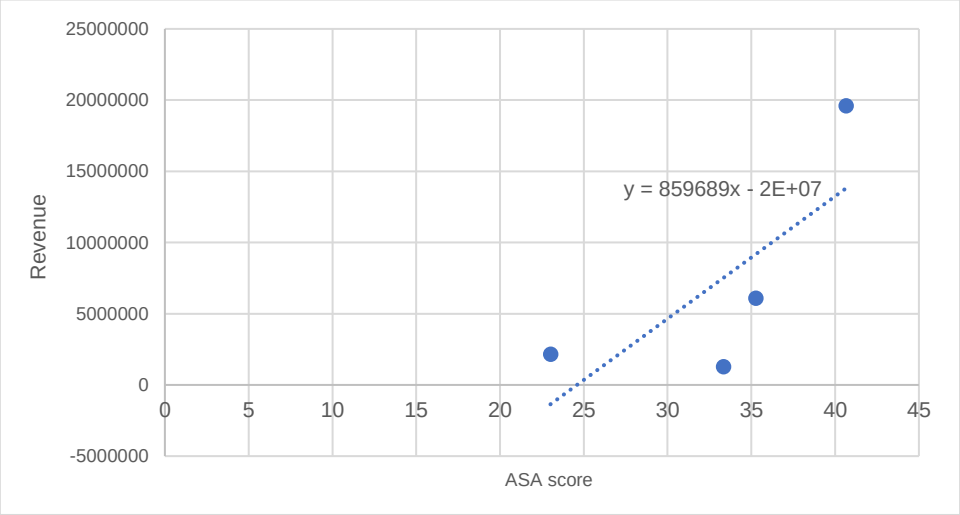


Figure 5. Regression and Correlation Analysis of ASA Scores and Revenues - Evidence of Correlation
Source: Authors' own elaboration

Although the sample size was determined to be too small to draw generalisable conclusions from the regression and correlation analysis, it was deemed necessary for this study to evaluate whether ASA or TOR provided a more effective measure. Consequently, regression and correlation analysis were performed on the same subset of 4 out of the 10 companies with the strongest reputations (see Table 1), examining the relationship between ASA scores and revenues, as depicted in Figure 5. The correlation analysis revealed a correlation coefficient of r = 0.749489751, indicating a moderate positive relationship between ASA scores and revenues. However, hypothesis testing did not confirm the statistical significance of this correlation, as the p-value was 0.18392853.

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Conclusions

This research aimed to explore the relationship between two distinct reputation measurement methodologies TOR and ASA scores and company revenues. By analysing data from ten companies, with a focused subset of four companies due to data availability, the study sought to assess how effectively these methodologies capture the reputation revenue relationship. The findings provide meaningful insights, albeit with notable limitations that warrant further investigation. The results indicate a stronger correlation between TOR scores and revenues, with a correlation coefficient of $r = 0.841$, signifying a strong direct relationship. This suggests that TOR scores are better aligned with financial outcomes, particularly revenues from own products and services. On the other hand, ASA scores showed a moderate positive correlation with revenues ($r = 0.749$), indicating that while ASA captures aspects of the reputation revenue dynamic, it is less robust compared to TOR in this context. The key difference between the methodologies lies in their approach to assessing reputation. TOR scores appear to capture determinants more directly linked to financial outcomes, while ASA scores may reflect broader sentiment less directly tied to revenue generation. This distinction is critical for businesses aiming to use reputation as a strategic tool for performance assessment and decision-making. However, the study's conclusions are constrained by the small sample size, which impacted the statistical significance of the findings. P-values for both TOR and ASA analyses exceeded the standard threshold ($p > 0.05$), underscoring the need for caution in generalising these results. The limited sample size was a primary factor affecting the reliability of the statistical analyses, as it reduced the power of hypothesis testing and regression models. Despite these limitations, the findings align with existing literature, such as Jiao, Przepiorka & Buskens (2021), which emphasises the impact of reputation on corporate performance. This study reinforces the notion that corporate reputation, when measured effectively, plays a critical role in influencing financial outcomes. The results suggest that businesses should prioritise developing and maintaining a strong reputation as it correlates positively with financial success. From a practical perspective, the study highlights the importance of selecting appropriate reputation metrics. Companies may benefit from using TOR scores for financial performance assessments due to their stronger correlation with revenues. Additionally, organisations should consider integrating these insights into broader strategic frameworks to optimise reputation management as a driver of competitive advantage. For future research, addressing the sample size limitation is paramount. Expanding the dataset to include a larger and more diverse set of companies would enable more robust statistical analyses and increase the generalizability of the findings. Moreover, exploring other variables that may mediate or moderate the relationship between reputation and revenues, such as market conditions, industry type, and consumer behaviour, could provide a more comprehensive understanding of this dynamic. In conclusion, while this research offers valuable insights into the relationship between reputation measurement methodologies and revenues, it also highlights the complexities and limitations inherent in such analyses. The study sets the stage for further exploration into reputation metrics, providing a foundation for enhancing the strategic use of corporate reputation in financial performance evaluations. The novelty of this study lies in integrating Total Online Reputation (TOR) and Advanced Sentiment Analysis (ASA) metrics with financial performance indicators in the Czech beverage industry. Unlike previous studies focusing primarily on sentiment analysis, this research demonstrates that a multifactorial online reputation metric provides a stronger explanatory relationship with company revenues. Future research should include a larger sample of companies and extend the analysis to other industries and countries. Further studies could also investigate the influence of specific reputation dimensions, stakeholder trust, ESG-related communication, and market conditions on financial performance.

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EXPLORING THE CONNECTION BETWEEN ENTREPRENEURIAL ORIENTATION AND EXPORT PERFORMANCE: THE ROLE OF INNOVATION CAPABILITIES*

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Abstract. This study aims to analyse the relationship between entrepreneurial orientation, innovation capabilities and export performance in the context of the transport sector. In addition, it aims to analyse the mediating effect of innovation capabilities on the relationship between entrepreneurial orientation and export performance. This exploratory and transversal study takes a quantitative methodological approach based on survey data from 246 top managers of Portuguese small and medium-sized enterprises (SMEs) in the transport sector, specifically those involved in road, sea, and air freight operations. The findings confirm the existence of significant direct relationships between entrepreneurial orientation and innovation capabilities, innovation capabilities and export performance, and entrepreneurial orientation and export performance. The mediating effect of innovation capabilities on the relationship between entrepreneurial orientation and export performance was also supported. This study emphasises the vital connection between entrepreneurial orientation and innovation capabilities, confirming entrepreneurial orientation as a core strategic driver of innovation within firms. Innovation capabilities mediate the relationship between entrepreneurial orientation and export performance, indicating that strategic intent must be translated into concrete innovation competencies to achieve export success. The findings also substantiate the impact of entrepreneurial orientation on export performance, aligning with theories that link entrepreneurial strategies to international growth. The study provides practical insights for transport sector managers, highlighting the importance of cultivating innovation capabilities alongside entrepreneurial practices to improve export outcomes and sustain competitiveness in global markets. This study focuses on the transport sector, a relatively underexplored industry in the study of entrepreneurial orientation, innovation capabilities, and export performance. Additionally, it investigates and confirms the mediating effect of innovation capabilities on the relationship between entrepreneurial orientation and export performance. This research contributes to existing research, as previous studies focused primarily on direct relationships rather than exploring mediating mechanisms. By focusing on Portuguese SMEs in the transport sector, the study provides empirical evidence from a regional and sectoral perspective. This localised focus enhances understanding of how entrepreneurial orientation and innovation capabilities drive performance in a specific economic and cultural environment.

Keywords: entrepreneurial orientation; innovation capabilities; export performance; transport sector; PLS-SEM

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1. Introduction

In a world of constant change, with growing interdependence between countries, firms have a progressively greater need to constantly seek solutions for their survival and adaptation to the environment, and to respond to the incessant obstacles present, by following policies, developing and applying strategies and/or adapting the instruments used by the various players. Thus, in this context, entrepreneurship and internationalisation are the answer to the widespread increase in potential competitive threats to their survival. Entrepreneurial orientation in the international context is a research topic that has been systematically developed within international entrepreneurship studies, thereby consolidating the concepts of entrepreneurship and international business.

Some researchers have analysed the impact of entrepreneurial orientation on export performance (e.g., Miller, 1983; Monteiro et al., 2019; Hossain et al., 2022) or innovation capabilities (e.g., Aljanabi, 2017), while others have found some empirical evidence that innovation capabilities have an impact on a firm's export performance (e.g., Kolbe et al., 2021; Alegre et al., 2022; Moreira et al., 2022; Zhang & Jedin, 2022). However, the effects of entrepreneurial orientation on innovation capabilities remain a topic of study that warrants further research, reflecting a gap in the literature (Aljanabi, 2017; Alshanty & Emeagwali, 2019). Furthermore, the complexity of defining export performance is a challenge, as different perspectives from various authors (e.g., Monteiro et al., 2019; Njegic & Komnenic, 2020) contribute to a multifaceted view of this concept, encompassing a variety of measurement indicators and potentially introducing subjectivity into its assessment.

The scarce resources of SMEs can also explain situations in which a particular firm lacks sufficient means to excel in innovation (Alegre et al., 2022). Firms often lack sufficient resources to bear the high costs of internationalisation; only the most productive firms become exporters. Innovation is therefore an important factor in export performance; however, firms also increase their performance and innovation capabilities after entering foreign markets (Vieira et al., 2022). It is important to note that innovation improves export performance, both directly and indirectly, by sustaining technological innovation (Zhang & Jedin, 2022). Therefore, the main objective of this study is to understand how a higher level of entrepreneurial orientation and a higher degree of innovation capabilities influence the export performance of a Portuguese exporting firm.

Although the relationship between entrepreneurial orientation, innovation capabilities and export performance has been the subject of growing interest and research, as it is intrinsically linked to firms' ability to stand out in international markets, develop their competitiveness and drive economic growth (Ferreira et al., 2020; Monteiro et al., 2019), there is still no consensus in the literature about this relationship and there is the need to develop empirical studies about these three variables, especially in ever-changing markets, to enrich theoretical advancement in this field, because resources and competencies are interlinked and underpin entrepreneurs' ability to recognise unique business opportunities and allocate resources. Studies indicate that promoting innovation capabilities in SMEs will contribute to an increase in export performance; this implies adopting innovations in various areas, including technological, commercial and logistical processes (e.g., Perera et al., 2026; Dao et al., 2026)

Furthermore, the interconnection between these three variables represents a gap in the literature and is the main motivation for this research problem. Thus, the question under study is defined as: How do innovation capabilities influence the relationship between entrepreneurial orientation and export performance in firms? As mentioned above, the main objective is to understand this relationship, but it is also essential to define specific objectives for this study, such as:
(1) To assess the impact of entrepreneurial orientation on increasing innovation capabilities in firms;
(2) To analyse the importance of innovation capabilities in the development of firms' export performance;
(3) To evaluate the contribution of entrepreneurial orientation to export performance;

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(4) To understand the extent to which entrepreneurial orientation and innovation capabilities together influence export performance.

2. Theoretical background

Entrepreneurial orientation and innovation capabilities

Entrepreneurial orientation refers to the intensive search for new market opportunities and the improvement of existing areas of operation. The objectives set and the skills of the firm's top management are essential for boosting entrepreneurial orientation (Ferreira et al., 2020).

Researchers view entrepreneurial orientation as an essential organisational resource that enables firms to differentiate themselves from others. The firm possesses a rich body of knowledge from its employees, which is shared both internally and externally, thereby fostering knowledge creation. Subsequently, this knowledge is recognised as a strategic resource that is converted into innovation to exploit market opportunities. This will enable firms to understand the demands of the market in which they operate and of their customers, and thus fulfil their needs through innovation (Miller, 1983). SMEs with a high entrepreneurial orientation are more likely to be highly proactive, with a greater predisposition to seek out and capitalise on market opportunities and trends encountered, this description being linked to the ability to respond to market signals (Aljanabi, 2017; Kang & Lee, 2025).

Associated with innovation, another dimension of entrepreneurial orientation is risk-taking, given the potential for firm failure. In this way, it must be prepared to face these adversities by creating operational knowledge rooted in entrepreneurial attitudes (Aljanabi, 2017). Innovation capabilities are recognised as a firm’s ability to develop new products or services, concepts and processes through its proactivity and speed in responding to the latest market trends (Alshanty & Emeagwali, 2019). It is important for a firm to continually acquire market information to outperform its competitors, build relationships with market players, and gain a competitive advantage (Alshanty & Emeagwali, 2019).

The relationship between entrepreneurial orientation and innovation capabilities refers to the link with a market-oriented culture, which plays a significant role in the success of business innovation; thus, entrepreneurial orientation is an essential resource for a firm to implement innovation, with a major influence on its ability to adapt to environmental changes (Ferreira et al., 2020). A high level of innovation capability allows entrepreneurial orientation to be linked to product innovation. Ko and Lu (2010) highlight the role of other dimensions of entrepreneurial orientation, such as risk-taking, which drives a firm's ability to produce new products and processes, since its nature allows for the allocation of the organisational resources needed to produce innovations.

The innovation dimension specifically reflects a firm’s propensity to support and engage in novel ideas, experimentation, and creative processes, potentially leading to the development of new products, services, or technological solutions (Miller, 1983). This dimension is primarily attitudinal, capturing the firm’s orientation or openness toward innovation, rather than its ability to execute it. It indicates how forward-looking and entrepreneurial the firm is in spirit, without necessarily reflecting the effectiveness of innovation implementation.

In contrast, innovation capabilities pertain to a firm's actual competence in developing, managing, and executing innovations. This construct emphasises the operational and process-based aspects of innovation, encompassing the organisational skills, resources, and systems required to sustain innovation in response to both internal dynamics and external market conditions. Innovation capabilities include knowledge management, R&D proficiency, a learning orientation, and the systematic integration of innovative practices into the firm's routine operations.

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Although both constructs are centred on innovation, they differ in terms of conceptual focus and practical implications. Entrepreneurial orientation, through its innovation dimension, reflects an intention or disposition toward innovation, while innovation capabilities capture the firm's capacity to realise innovation in practice. Consequently, a firm may possess a strong entrepreneurial orientation yet lack the necessary capabilities to implement innovation effectively, or conversely, may have robust innovation capabilities but a limited strategic inclination toward entrepreneurial initiatives.

We therefore intend to test the following research hypothesis:
H1: Entrepreneurial orientation has a positive and significant effect on innovation capabilities.

Innovation capabilities and export performance
Export growth depends not only on the main innovation assets (R&D, manufacturing, and marketing) but also on secondary innovation assets, such as learning, organisation, resource allocation, and strategic planning, to strengthen international competitiveness. Although innovation capabilities positively impact SME performance and innovation increases the propensity to export, these factors may not be the predominant ones for success on an international scale; international experience may play a more crucial role in this context (Oura et al., 2016). The increase in exports is closely associated with the total improvement in the dimensions of innovation capabilities. Furthermore, additional innovation capabilities (learning, organisational, resource exploitation, and strategic capabilities) enable the integration of all capabilities and the achievement of sustainable international competitiveness (Sriboonlue & Sriboonlue, 2026).

Kolbe et al. (2021) mention that product innovation can increase the likelihood of starting to export and encourage non-exporting SMEs to pursue international operations. Furthermore, exporters must identify customers who are compatible with products developed with new technologies to ensure their success. Living in an increasingly global and highly competitive market, firms must have a remarkable and efficient capacity for innovation to understand and satisfy the needs of international customers through differentiated products, improving their productivity levels (Vieira et al., 2022).

Exploratory and exploitative innovation have been shown to positively impact firm performance, whereas a mixed approach has no significant effect (Popadić & Černe, 2016). Gupta et al. (2006) suggest that exploratory innovation and exploitative innovation can be mutually reinforcing and need not necessarily be contradictory. Still, they can occur in complementary fields that do not necessarily compete for the same resources. The traditional theory of the technology life cycle argues that after the exploratory innovation phase, which is characterised by generating higher potential returns through radical innovations such as new product concepts or distribution channels, the post-design phase follows. In this phase, exploratory innovations, which are characterised by incremental improvements, can yield significant performance benefits. According to Benner and Tushman (2003), it is possible to find both high and low levels of exploratory innovation in a given field, coexisting with high or low levels of exploitative innovation in a complementary field.

We therefore intend to test the following research hypothesis:
H2: Innovation capabilities have a positive and significant effect on export performance.

Entrepreneurial orientation and export performance
The literature is extensive on the role of entrepreneurial orientation in the firm's search for opportunities, as well as its multifaceted outcomes that enable superior performance (Monteiro et al., 2019). According to Miller (1983), a firm that adopts an entrepreneurial orientation invests in product and/or market innovation, takes on some risk, and takes a proactive stance towards its competitors. To some scholars (e.g., Miller, 1983), firms with an entrepreneurial orientation tend to be successful, since there is a positive relationship between entrepreneurial

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orientation and business performance, and it is an indispensable condition for firms seeking to develop in increasingly demanding competitive environments.

Entrepreneurial orientation is a multidimensional concept with three key dimensions: innovativeness, risk-taking and proactivity (Miller, 1983). The most common dimensions in research are the three mentioned by Miller (1983), in which firms with a high level in these three dimensions are considered potentially entrepreneurial, with a greater likelihood of making strategic decisions to combine adequate resources, foster sustainable capabilities and perfect essential capabilities to succeed in international markets (Monteiro et al., 2019).

As part of their differentiation strategy, firms consider innovation to offer different solutions across markets. Thus, innovation is a dimension of entrepreneurial orientation and an instrument that enables the exploration of new opportunities, despite greater risk due to the possibility of not achieving the expected return on investment (Monteiro et al., 2017). SMEs with a higher level of international entrepreneurial orientation tend to perform more effectively in international markets, as they proactively adopt new technologies and take on the risks inherent in strategies focused on product adaptation to the needs of foreign customers (Hossain et al., 2022).

The literature on internationalisation points out that innovation is important for obtaining competitive advantages in global markets and that many international firms have greater learning opportunities that can lead to innovation. Given the growing global competitiveness, a proactive stance is an important driver of firm survival and strong commercial performance. International entrepreneurial orientation induces SMEs to adopt innovative, risky and proactive behaviours in international markets (Jin & Cho, 2018).

For many born-global firms, internationalisation is becoming a crucial necessity. The scarcity of resources available for this purpose often means that international operations are conducted through flexible organisational measures, such as partnerships and export networks, without entailing a significant increase in the firms' administrative costs. According to Jin and Cho (2018), a high level of international entrepreneurial orientation in SMEs leads to the search for innovative products and services oriented towards foreign markets, viewing these as opportunities rather than risks and seeking business opportunities and partners abroad.

The relationship between entrepreneurial orientation and performance remains controversial. The vast majority of studies have found a significant influence of entrepreneurial orientation on business performance, while others report an insignificant association (Hossain et al., 2022). Because of this, various conclusions have called for a third variable to find the nature of this relationship (Hossain et al., 2022), such as mediating effects (Monteiro et al., 2017).

This link is based on both the firm's overall performance and its success in the international market. Entrepreneurial orientation contributes favourably to export performance. Firms with a stronger entrepreneurial orientation achieve higher levels of international sales than total sales and operate in a greater number of foreign countries (Celec et al., 2014). Entrepreneurship is closely associated with the adoption of a marketing leadership strategy and with the intensity of response to the opportunities and threats of globalisation, increasing firm performance.

Possible differences in customer needs, competition, and the environment require product, channel, and organisational innovations to overcome barriers to market entry and establish a superior position (Celec et al., 2014). In addition, uncertainties related to market acceptance and local competition require a willingness to take risks. Achieving a competitive advantage in export markets requires a proactive approach that involves developing market knowledge, creating a distinctive range, and entering the market as a first mover.

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We therefore intend to test the following research hypothesis:
H3: Entrepreneurial orientation has a positive and significant effect on export performance.

The mediating effect of innovation capabilities on the relationship between entrepreneurial orientation and export performance

Entrepreneurial orientation refers to the organisational attitude that drives the firm to act on identified opportunities, using its resources and skills, so the firm's ability to exploit opportunities depends on its ability to recognise them, its ambition to take action and its effectiveness in responding (Celec et al., 2014). Entrepreneurial orientation plays an essential role in driving decisions and activities related to the proactive utilisation of resources and capabilities for entrepreneurial purposes, as well as accompanying reactive activities, as highlighted by Celec et al. (2014). In the context of internationalisation, entrepreneurial orientation is a significant factor in shaping the relationship between organisational resources and competencies and the performance of export activities, depending on the purpose for which these resources and competencies are applied. By way of example, the firm's market and innovation-oriented capabilities can be directed towards acquiring in-depth knowledge of existing customers, resulting in the development of improved solutions. In addition, they can be used to explore new customers and markets, leading to the creation of solutions that are considerably different from those offered in its existing portfolio (Celec et al., 2014). However, these scholars point out that it is possible to support the idea that entrepreneurial orientation can neutralise the resources allocated to administrative and routine tasks, such as export activities. For example, a significant change in customer service capabilities can lead to a temporary reduction in service quality due to reduced efficiency. As a result, entrepreneurial orientation can mitigate the positive relationship between superior service capacity and export performance.

Finally, we intend to test the last research hypothesis defined:
H4: Innovation capabilities mediate the relationship between entrepreneurial orientation and export performance.

Figure 1 presents the research model, highlighting the complex dynamics among the constructs studied (Entrepreneurial Orientation, Innovation Capabilities, and Export Performance).

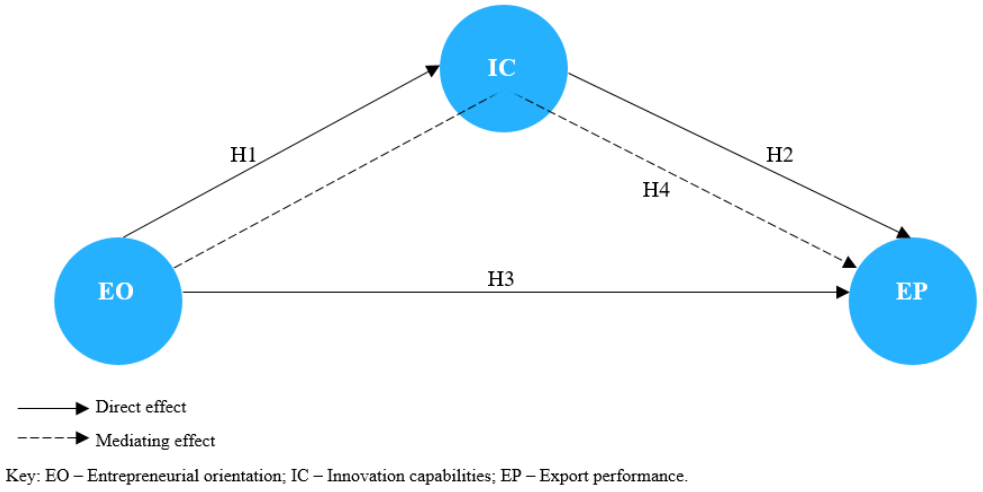


Figure 1. Research model and hypotheses
Source: own work based on the conducted study

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3. Methodology

Sample and data collection

The sample for this empirical study consists of top managers from Portuguese SMEs in the transport sector, specifically those involved in road, sea, and air freight operations. A questionnaire was used as the primary data source. The data collection was carried out between August 1, and February 29, 2023. The firms were identified using the SABI database. The database includes 1,642 SMEs.

In this study, we used non-probabilistic and convenience sampling. The following inclusion criteria guided the sampling process to ensure relevance and consistency with the study's objectives: (1) Firm size: Only SMEs were included, defined according to the European Commission criteria as firms with fewer than 250 employees and an annual turnover not exceeding €50 million, (2) Industry sector: Eligible firms operated within the transport sector, specifically in freight operations by road, sea, or air. Passenger transport firms and firms in unrelated sectors were excluded, (3) Geographic location: Only firms legally registered and operating in Portugal were considered, to ensure consistency with the national context of the study, (4) Respondent profile: Participants had to be top-level managers, such as CEOs, managing directors, or senior executives, directly involved in strategic decision-making processes, particularly those related to innovation, internationalisation, or export performance, and the unit of analysis was the individual, and (5) Operational status: Firms needed to have been in continuous operation for a minimum of three years to ensure respondents could provide informed and reliable insights into the firm's strategic orientation and performance trends.

The research survey was sent to the top manager's professional email, and the addresses in the SABI database were verified and validated. The participants were informed about the survey content to enhance response efficiency, and they provided consent. Whenever one of the following situations occurred, the responses were discarded to avoid possible bias: (1) surveys that did not include all of the responses, (2) when the firm did not have a manager designated for this purpose, and (3) surveys passed on to another type of manager.

A total of 246 fully completed and validated questionnaires were returned. This return corresponds to a response rate of 15%, considered entirely satisfactory, given that the average response rate for top management surveys is 15–20%. Hair et al. (2022) argued that this sample size is suitable for data analysis using partial least squares structural equation modelling (PLS-SEM).

Instrument and measures

The questionnaire was structured into five different sections, each dedicated to a topic: (1) entrepreneurial orientation, (2) innovation capabilities, (3) export performance, (4) the firm's data and (5) the managers' sociodemographic data. Before being distributed to the sample, it underwent a pre-test phase to assess its organisation, formatting, and possible improvements to the wording for clearer interpretation.

This study will use the variables of entrepreneurial orientation (its five dimensions: innovation, risk-taking, proactivity, autonomy, and competitive aggressiveness), innovation capabilities, and export performance. Entrepreneurial orientation comprises 10 items in total, two for the innovation dimension, two for the risk-taking dimension, two for the proactivity dimension, two for the autonomy dimension and two for the competitive aggressiveness dimension (Al Mamun et al., 2017). Innovation capabilities comprise 15 items (Mir et al., 2016). Export performance comprises five items (Zou & Stan, 1998). All these items are based on previous studies by Sariol and Abebe (2017) and Popadić and Černe (2016). Table 1 shows the items of the constructs.

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Table 1. Items of the constructs

Construct / Items	Author(s)
Entrepreneurial orientation (EO): E1. Usually, the top management of my company prioritises R&D, technological leadership, and innovation. E2. In my company, we are consistently pioneers in introducing new management techniques, operational technologies, and other advancements. E3. Top managers in my company often show a strong preference for high-risk projects that offer prospects of high returns but involve significant uncertainty. E4. Employees in the company have complete freedom to present ideas or suggestions at any time and are encouraged to make decisions without restrictions. E5. We adopt a reactive posture in response to competitors' actions, aiming to strengthen our market position and reduce our rivals' competitiveness. E6. The top management of my company regularly prioritises marketing existing products and services. E7. My company closely monitors changes initiated by competitors in the market. E8. Top managers at my company often prefer low-risk projects that offer predictable, guaranteed returns. E9. Employees in the company face restrictions when presenting ideas or suggestions and are not encouraged to make decisions freely at any time. E10. My company takes a passive stance toward competitors' actions, weakening its competitive ability.	Covin & Slevin (1989); Al Mamun et al. (2017).
Innovation capabilities (IC): IC1. Innovation projects are aligned with the company's overall strategy. IC2. The company has excellent knowledge of the competitive market environment. IC3. A precise, early definition of the tasks and objectives to be developed is required. IC4. Communication of the information required for innovation projects is especially clear, transparent, and integral. IC5. Mistakes made during innovation projects are seen as opportunities for learning and systematic improvement. IC6. The innovation vision is considered when making strategic decisions in the company. IC7. Innovation projects follow a properly documented innovation process that considers all areas of activity and is carried out according to the planned schedule and budget. IC8. Through innovation, the company has gained larger market shares than its competitors. IC9. Market-oriented distribution channels are identified early in the innovation process. IC10. A budget is allocated for innovation projects that are not directly financed by customer orders. IC11. Coordination with external research sources is maintained to stay informed of relevant technological and research developments. IC12. Members of the management bodies show strong interest in participating in new projects (such as openness to new markets and technologies). IC13. Employees from different backgrounds can work together in innovation project teams. IC14. Risks in innovation projects are systematically controlled using methods and tools such as SWOT analysis. IC14. Clearly defined and precise criteria are used to evaluate and select potential projects for implementation.	Mir et al. (2016).
Export performance (EP): EP1. Our international market has proven to be highly profitable. EP2. We have observed a substantial increase in sales in our international market. EP3. Over the past 3 years, we have experienced significant growth in our international activities. EP4. Over the past 3 years, we have expanded our operations. EP5. Overall, the company's international performance has been highly satisfactory.	Zou & Stan (1998); Kuivalainen et al. (2007)

Source: own work based on the conducted study

Data were collected using the questionnaire, which included scales that were previously adapted, validated, and used in prior studies. Each variable section was assessed using a 10-point Likert scale, allowing respondents to indicate their degree of agreement or disagreement with the statements presented (0 = Strongly disagree; 10 = Strongly agree). Furthermore, the independent variable in this study is entrepreneurial orientation, while the dependent variables are innovation capabilities and export performance.

4. Results

Descriptive analysis

The reliability analysis was performed using Cronbach's alpha, which ensured the consistency and stability of the responses while accounting for respondent heterogeneity and opinion differences (Pestana & Gageiro, 2008). The sample reliability was excellent for all variables (0.958). Table 2 shows the descriptive statistics of the sample's demographics.

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Table 2. Descriptive analysis

Managers	
Item	**%**
Gender:	
Male	**59.3**
Female	**40.7**
Age (years old):	
< 25	**7.7**
25-30	**13.8**
31-40	**23.1**
41-50	**53.8**
> 50	**1.5**
Academic qualifications:	
vocational qualification	33.9
professional qualification	9.2
bachelor degree	**44.6**
master degree	**12.3**
PhD	**0.0**
Professional experience (**years):**	
< 5	23.1
5-10	23.1
11-15	15.4
16-20	13.8
> 20	24.6
Firms	
Item	**%**
Firm age (years):	
< 5	**20.0**
5-10	**12.3**
11-15	**15.4**
16-20	**7.7**
> 20	**44.6**
Firm dimension**:**	
Micro	38.5
Small	36.8
Medium	24.7
Markets**:**	
North America	4.6
South America	6.2
Central America	3.1
North-East Asia	1.5
Northern Europe	12.3
Southern Europe	30.8
Western Europe	35.4
Eastern Europe	4.6
Middle East	1.5
Activity area**:**	
Air freight	10,8
Sea freight	6.2
Road freight	83.1

Source: own work based on the conducted study

Partial least square structural equations modelling (PLS-SEM)

PLS-SEM was used to test the hypotheses with SmartPLS 3.0 software (Hair et al., 2022). PLS-SEM was best suited to estimate the research model as (1) this research focuses on prediction and explanation of the variance of the model's constructs (in this case, four); (2) the research model has a complex structure; (3) the relationship between open innovation and competitive advantage can be measured directly and indirectly; (4) the study uses first and second-order reflective constructs; and (5) the sample (n = 251) is relatively small. Reflective constructs were used to estimate PLS parameters to maximise the variance explained in observed measures (Anderson & Gerbing, 1988).

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Evaluation of the measurement model

The results showed that the measurement model met all general requirements. First, all reflective items have a factor loading greater than 0.707, indicating that the reliability of individual indicators (loadings) was greater than 0.5. Second, all composite reliability values and Cronbach's alpha values were above 0.7, indicating acceptable model reliability. Third, the average variance extracted (AVE) values of all constructs were higher than 0.50, indicating adequate convergent validity and implying that the indicators represent the same underlying constructs (Hair et al., 2022).

In addition, the composite reliability coefficient was used to test the constructs' validity (Chin, 1998). Gefen and Straub (2005) advocate a minimum of 0.6 when the variables exceed the reference value. Fornell and Larcker's (1981) criterion was used in this study, proposing that AVEs must have a minimum value of 0.5 to prove convergent validity. All the constructs reached this value (Table 3).

Table 3. Standardised factor analysis loadings, CR, AVE, Mean and SD

First-order constructs	Items	Loadings	CR	AVE	Mean	SD
Entrepreneurial Orientation			.958	.696		
(α = 0.951)	EO1	.758			7.35	2.287
	EO2	.854			6.71	2.367
	EO3	.840			6.93	2.373
	EO4	.838			7.21	2.201
	EO5	.876			6.71	2.377
	EO6	.832			6.68	2.388
	EO7	.836			6.51	2.316
	EO8	.840			6.95	2.126
	EO9	.841			6.81	2.101
	EO10	.823			6.78	2.157
Innovation capabilities			.965	.655		
(α = 0.960)	IC1	.555			6.52	2.306
	IC2	.669			7.13	1.594
	IC3	.596			7.12	1.559
	IC4	.718			6.95	1.727
	IC5	.845			6.97	1.677
	IC6	.845			6.96	1.651
	IC7	.748			7.22	1.579
	IC8	.884			7.03	1.649
	IC9	.931			7.01	1.655
	IC10	.848			7.14	1.562
	IC11	.901			7.07	1.611
	IC12	.834			6.97	1.601
	IC13	.885			7.15	1.581
	IC14	.868			6.95	1.689
	IC15	.893			7.00	1.662
Export Performance			.921	.704		
(α = 0.890)	EP1	.899			7.01	1.609
	EP2	.942			7.04	1.551
	EP3	.733			7.20	1.296
	EP4	.676			7.26	1.495
	EP5	.911			7.07	1.595

Source: own work based on the conducted study

The discriminant validity of the model was demonstrated, as the results showed that constructs with no theoretical relation were indeed not significantly correlated; this can be gauged from the principle that cross-loadings cannot exceed the loading of each indicator (Hair et al., 2022). Based on Chin's (1998) classification of explanatory power as moderate/substantial, the data in Table 3 indicate that the discriminant validity results were satisfactory; that is, the construct measures were significantly different. The Fornell-Larcker (1981) criterion (FLC) specifies that the AVE should be greater than the variance between constructs of the same model. Henseler et al. (2015) proposed a new and advanced criterion (Heterotrait-Monotrait Ratio - HTMT) to assess discriminant validity. They accept that the FLC is still an acceptable method for evaluating discriminant validity. However, the FLC

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fails to assess the lack of discriminant validity in various research situations. Therefore, the present study used the HTMT to evaluate the constructs' discriminant validity; these values are presented in Table 4. All values were less than 0.9.

Table 4. Discriminant validity and HTMT

FLC	**1.**	**2.**	**3.**
1. Entrepreneurial orientation	.665		
2. Export performance	.486	.950	
3. Innovation capabilities	.846	.476	.805
HTMT	**1.**	**2.**	**3.**
1. Entrepreneurial orientation			
2. Export performance	.440		
3. Innovation capabilities	.906	.488	

Source: own work based on the conducted study.

Evaluation of the structural model

The significance of the model was assessed based on path coefficients, t-values and standard errors. The hypotheses were tested for main and indirect effects through the bootstrapping procedure (Ringle et al., 2005). Based on Chin's (1998) criterion that the minimum structural coefficient should be 0.2, the effects proposed in the hypotheses were shown to be significant. Entrepreneurial orientation has a direct effect on innovation capabilities (β=.223, t=4.648; LL=.098, UL=.293), so H1 is supported, as the lower and upper limits include the value zero, indicating that the relationship is significant. Innovation capabilities have a direct effect on export performance (β=.604, t=12.856; LL=.507, UL=.689); therefore, H2 is supported. On the other hand, entrepreneurial orientation also has a direct effect on export performance (β=.997, t=53.050; LL=.961, UL=.1.035); thus, H3 is supported. We used the bootstrap technique to test the research hypothesis that there is a mediating effect (Preacher & Hayes, 2008). Mediation exists when the indirect effect is positive (Hair et al., 2022). Thus, innovation capabilities present a mediating effect on the relationship between entrepreneurial orientation and export performance (β=.603; t=11.458; LL=.496, UL=.701); consequently, Hypothesis 4 is supported. Table 4 and Figure 2 show the effects demonstrated.

Table 5. Results of the structural equations modelling: Direct and indirect effects

Hypotheses	**Original Sample (O)**	**Sample Mean (M)**	**Standard Error (STERR)**	**T-Statistics (O / STERR)**	**L.L.**	**U.L.**	**Results**
Direct Effects							
H1. EO→ IC	.223	.223	.027	4.648*	.098	.293	Supported
H2. IC→ EP	.604	.605	.047	12.856*	.507	.689	Supported
H3. EO→ EP	.997	.998	.019	53.050*	.961	1.035	Supported
Indirect Effect							
H4. EO→ IC→ EP	.603	.604	.053	11.458*	.496	.701	Supported

Notes:
* *t-values* significant at $p<0.001$.
* *t-values* significant at $p<0.05$.

Source: own work based on the conducted study

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Figure 2 shows the structural model assessment, considering both direct and indirect effects.

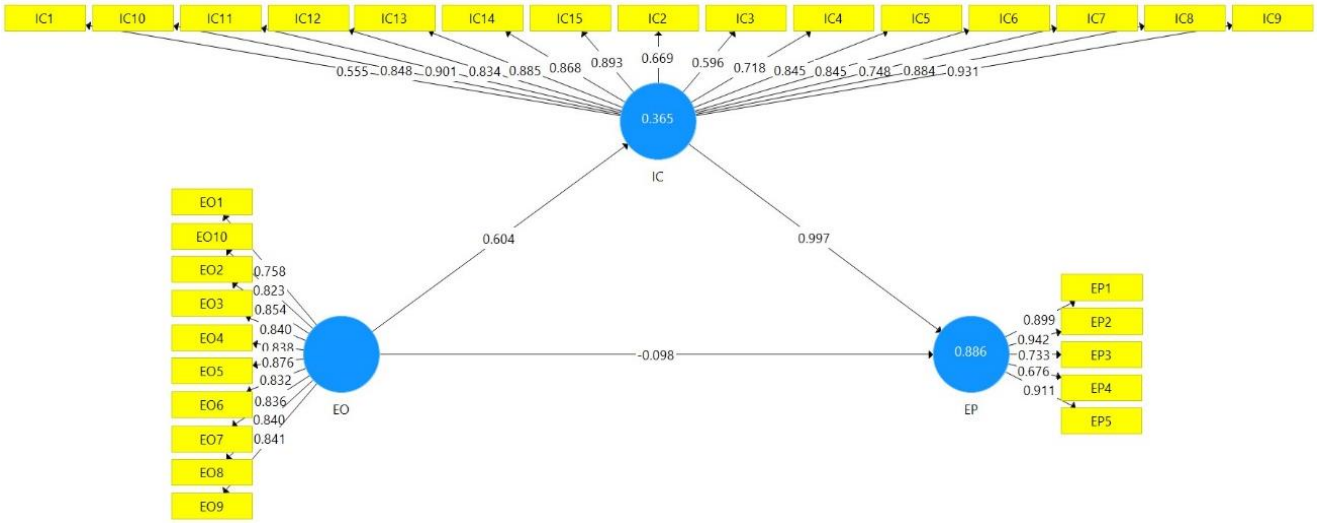


Figure 2. Structural model assessment
Source: own work based on the conducted study.

The explanatory power of the model was assessed by examining the coefficient of determination R-square (R^2) for the endogenous constructs. As presented in Table 5, entrepreneurial orientation explains 36.5% of the variance in innovation capabilities and 88.6% in export performance**.** According to Chin's (1998), these R^2 values suggest a moderate level of explanatory power for innovation capabilities (>0.33) and a **s**ubstantial explanatory power for export performance (≥0.67), indicating a very strong model fit for this outcome. Furthermore, the model's predictive relevance was assessed using PLS predict**,** which generated Q^2 values**.** Table 5 indicates Q^2 (Stone-Geisser's Q^2) values of 0.207 for innovation capabilities and 0.676 for export performance, both of which are above zero, thereby confirming the model's predictive capability in line with the standards outlined by Hair et al. (2022). Hence, we conclude that our research model demonstrates a high predictive relevance.

Table 5. R^2 and Q^2 predict values

Constructs	R^2	Q^2 predict
Innovation capabilities	.365	.207
Export performance	.886	.676

Source: own work based on the conducted study

Competing models fit measures

Paulraj et al. (2008) advocate that the proposed model should be compared with others to assess which one presents the best fit whenever the structural equation model is used. In our case, the proposed model, expressed in the previous figures, corresponds to Model 1. Next, we established Model 2, corresponding to the direct relationships between entrepreneurial orientation and export performance and innovation capabilities and export performance. The following criteria were adopted to determine the model that presents the best fit: SRMR with a value less than .10 or of .08 (Hu & Bentler, 1999) and NFI with a value between zero and one (Hair et al., 2022). Model 1 is the one that presents the best fit. Although there are no significant changes between the SRMR and NFI values, this model is the one that shows the most significant relationships (p≤.001) between the model constructs (Table 6).

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Table 6. Competing models

Hypotheses	Proposed Model (Model 1)	Direct Model (Model 2)
EO→ IC	3.648*	--
IC→ EP	12.856*	54.627*
EO→ EP	53.050*	2.912**
EO→ IC→ EP	11.458*	--
SRMR	.096	.095
d_ULS	4.259	4.329
d_ULS	3.234	3.216
Chi-square	3263.701	3254.375
NFI	.671	.670

Notes:
* *t-values* significant at $p<0.001$.
* *t-values* significant at $p<0.05$.

Source: own work based on the conducted study

5. Discusion

The results of this study corroborate those of previous studies (e.g., Aljanabi, 2017; Alshanty & Emeagwali, 2019; Ferreira et al., 2020), supporting the direct relationship between entrepreneurial orientation and innovation capabilities (H1 supported). Innovation capabilities are considered a dimension of entrepreneurial orientation (Miller, 1983). Alshanty and Emeagwali (2019) validated the convergence and divergence of their constructs, emphasising the relevance of market perception and customer needs in acquiring knowledge and thus boosting innovation capabilities. Both exploratory and exploitative innovation affect innovation, with the latter standing out, indicating the progress of Portuguese firms in the European innovation ranking (Ferreira et al., 2020). These two types of innovation are essential for understanding the creative process, as they incorporate past success as an influencing factor in the propensity to explore new ideas. In addition, Ferreira et al. (2020) highlighted the mediating influence of entrepreneurial orientation on the relationship between self-efficacy and business performance, i.e., firms that adopt proactive and innovative strategies are more likely to explore new ideas and products. Aljanabi (2017) emphasised that entrepreneurial attitudes drive technological innovation and the adoption of external knowledge, highlighting the importance of entrepreneurial orientation and its dimensions in strengthening SMEs' innovation capabilities.

As highlighted by Zhang and Jedin (2022), there is a solid direct correlation between innovation capabilities and export performance, since firms' distinctive capabilities provide positive results in international markets (H2 supported). Furthermore, acquiring these capabilities in advance of the competition gives firms a significant advantage in export performance. Vieira et al. (2022) reinforce this relationship, arguing that the assessment of innovation in international contexts seeks to capture the firm's ability to adapt to market changes, whether in response to uncertain contextual situations or in identifying and exploiting new opportunities. Similarly, several scholars (e.g., Alegre et al., 2022; Kolbe et al., 2021; Moreira et al., 2022) share the view that innovation capabilities play a crucial role in exporting firms, promoting stronger performance in international markets by enabling adaptation to customer needs, the development of multiple dimensions of innovation capability and the creation of a multidimensional construct that reflects the unique characteristics of the innovation activities of exporting firm. This broad convergence of evidence supports the validity of hypothesis H2 and reinforces the importance of innovation capabilities in improving export performance.

In this study, the results also support the existence of a direct effect of entrepreneurial orientation on export performance (H3 supported). This conclusion is in line with a wide range of studies that have traditionally supported this relationship (Miller, 1983). It is based on the idea that an entrepreneurial orientation focused on internationalisation stimulates international growth, innovation, and exports in foreign markets, with reinforcement coming from firm size and organisational culture. According to Monteiro et al. (2017), export

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performance is positively affected, directly and indirectly, by entrepreneurial orientation. Monteiro et al. (2019) also found support for the impact of entrepreneurial orientation on export performance. It is important to note the lack of specific studies that verify this dimension of internationalisation, in contrast to the relationship between entrepreneurial orientation and performance in general. However, Jin and Cho (2018) point out that, despite previous studies highlighting the crucial role of international entrepreneurial orientation in export performance, this effect only manifests itself when entrepreneurial orientation promotes technological and marketing capabilities, which, in turn, directly influence export performance.

Innovation capabilities are theorised to mediate the relationship between entrepreneurial orientation and export performance. Entrepreneurial orientation, encompassing dimensions such as innovativeness, proactivity, and risk-taking, provides a strategic foundation for developing innovation-related competencies within the firm. Innovation capabilities refer to the firm's ability to systematically generate, manage, and apply new knowledge to develop products, services, or processes that create value. These capabilities are essential for firms seeking to adapt to dynamic international markets and enhance their competitive positioning abroad. While entrepreneurial reflects a firm's strategic intent toward entrepreneurial behaviour, it does not inherently ensure improved export performance. Rather, translating entrepreneurial intentions into tangible performance outcomes often requires robust innovation capabilities. Therefore, innovation capabilities serve as a mediating mechanism through which entrepreneurial orientation influences export performance. Firms with a strong entrepreneurial orientation but lacking innovation capabilities may be limited in their ability to respond effectively to external opportunities or challenges in international markets. This conceptualisation underscores the importance of internal dynamic capabilities in leveraging strategic orientations for superior performance outcomes (H4 supported).

Celec et al. (2014) refer that innovation and market capabilities have a positive and significant impact on export performance, especially when entrepreneurial orientation reaches high levels. This emphasises the importance of ambition and the ability to identify and exploit opportunities. This positive effect is also supported by Monteiro et al. (2019), who highlight the contribution of both dynamic capabilities and entrepreneurial orientation to export performance. Monteiro et al. (2017) reinforce this relationship, showing that export performance benefits directly and indirectly from dynamic capabilities and entrepreneurial orientation. Furthermore, as in our study, the relationship between entrepreneurial orientation and export performance manifests directly, but is established indirectly when innovation capabilities are included as a mediating effect. This shows that the continuous search for new opportunities strengthens entrepreneurial orientation, allowing firms, especially SMEs, to direct their entrepreneurial strategies towards innovation, risk-taking and proactivity, resulting in superior export performance. Ferreira et al. (2020) emphasise that an entrepreneurial orientation values innovation capabilities, which contribute significantly to improving business performance, especially in SMEs. Therefore, innovation capabilities play a vital role in enabling SMEs to proactively exploit opportunities, which are essential for successful export performance.

6. Conclusion

Final remarks

SMEs represent more than 99 per cent of Portugal's firms and play an essential role in the economic, social and financial growth of their country. In an increasingly competitive global context, improving their competitiveness and providing added value to their customers is becoming a necessity. In turn, it is important to achieve greater overall and sustainable performance in the long term.

This study contributes to understanding the importance of the interaction between entrepreneurial orientation, innovation capabilities and export performance in exporting firms in the air, sea and land transport sectors in Portugal. Firms that demonstrate proactivity in the continuous search for opportunities, as well as the competence to conceive and develop new ideas, taking associated risks, mainly in financial terms, while responding to the

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actions of the competition, play a leading role in the development of innovation capabilities. These, in turn, have a positive and significant impact on export performance.

These conclusions are in line with previous studies and emphasise the importance of the complementary roles that each variable plays in the development of exporting firms. First, it examines the relationships between entrepreneurial orientation, innovation capabilities, and export performance within the transport sector, an industry that has received limited attention in previous research compared with manufacturing and technology-intensive sectors. By focusing on road, sea, and air freight SMEs, the study extends the applicability of entrepreneurial orientation and innovation theories to a distinct service-based and logistics-oriented context. Second, the study advances existing knowledge by empirically testing and confirming the mediating role of innovation capabilities in the relationship between entrepreneurial orientation and export performance. While prior research has predominantly focused on direct effects, the present findings demonstrate that entrepreneurial orientation enhances export performance not only directly but also indirectly through the development of innovation capabilities. This provides a more comprehensive understanding of the mechanisms through which entrepreneurial strategies generate international competitive advantages. Third, the research offers original empirical evidence from Portuguese SMEs operating in the transport sector. The regional and sectoral focus enriches the literature by providing insights from a specific economic and cultural context that remains underrepresented in international studies. The results show that innovation capabilities constitute a critical pathway by which entrepreneurial orientation translates into superior export outcomes, thereby highlighting the strategic importance of innovation for international business success.

Overall, the study contributes theoretically by integrating entrepreneurial orientation, innovation capabilities, and export performance into a single explanatory framework and empirically validating this framework in an underexplored sector and geographical setting.

Implications for theory and practice

The study contributed to the literature regarding the relationship between entrepreneurial orientation and export performance. Limited scholarly attention has been paid to examining this relationship, particularly regarding the mediating role of innovation capabilities between the two constructs. Additionally, this study contributes to the theoretical advancement of the export performance construct, which remains conceptually underdeveloped and lacks a universally accepted definition.

The results obtained make a relevant contribution to clarifying how entrepreneurial orientation and innovation capabilities influence the export performance of transport SMEs in the sectors mentioned above in northern Portugal. This research underscores the significant link between entrepreneurial orientation and innovation capabilities, affirming the proposition that entrepreneurial orientation functions as a core strategic orientation that propels innovation processes. Innovation capabilities, which include both exploratory and exploitative dimensions, are vital for maintaining a sustainable competitive edge, particularly within volatile environments that demand continuous adaptation to evolving market conditions and customer expectations. Furthermore, innovation capabilities act as a mediator in the entrepreneurial orientation-export performance nexus, indicating that the strategic intentions inherent in entrepreneurial orientation must be effectively transformed into concrete innovation competencies to yield measurable export outcomes. As such, innovation capabilities constitute dynamic resources that enable firms to respond agilely to global uncertainty and shifting consumer demands, thereby enhancing their international competitiveness.

The findings also corroborate the influence of entrepreneurial orientation on export performance, aligning with perspectives that regard entrepreneurial strategies focused on international market engagement as catalysts for growth and innovation in foreign contexts. A strategic emphasis on research and development, technological advancement, and continual innovation is essential for fostering firm-level innovation capacities that, in turn,

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drive superior performance. Export-oriented firms are advised to cultivate a multidimensional construct of innovation capabilities that effectively encompasses the diverse innovation activities required to succeed in heterogeneous international markets.

This study also presents relevant practical implications for top-level managers and strategic decision-makers, policy-makers and innovation support agencies, and SMEs in the transport sector.

Entrepreneurial orientation, characterised by innovativeness, proactiveness, and risk-taking, is not sufficient on its own to improve export performance. Top-level managers must also ensure the firm develops robust innovation capabilities to translate strategic intent into measurable outcomes. Innovation capabilities enable firms to adapt to market volatility, identify and seize new international opportunities, and deliver customised value to global customers. Firms should proactively invest in systems and processes that foster both exploratory and exploitative innovation. Understanding customer needs and competitive dynamics is essential for building innovation capabilities. Top-level managers should emphasise market sensing and knowledge acquisition as part of the innovation process to strengthen responsiveness in export markets.

Public institutions should design initiatives to assist SMEs in developing dynamic capabilities, particularly in innovation and internationalisation, by providing access to funding, training, and knowledge networks. As entrepreneurial orientation positively affects export performance, policy should encourage firms to adopt international entrepreneurial strategies, supported by innovation capacity development, especially in high-growth-potential sectors such as transport and logistics.

SMEs should recognise that an entrepreneurial posture alone (e.g., being proactive or taking risks) does not guarantee export success. Building innovation capabilities, such as knowledge management, R&D capacity, and adaptive learning, is essential. Both exploratory innovation (new ideas, markets, and products) and exploitative innovation (refinements of existing processes and offerings) are key to sustaining international performance. SMEs should integrate both approaches into their innovation strategies. Entrepreneurial orientation drives innovation, which in turn mediates export success. SMEs that systematically cultivate innovation capabilities are better positioned to translate entrepreneurial vision into export performance. Developing a culture that supports continuous innovation and opportunity-seeking will strengthen SMEs' competitiveness abroad. This involves encouraging creativity, tolerating failure in the pursuit of new ideas, and empowering employees to contribute to innovation initiatives.

Limitations

As with most empirical studies, this study has limitations that should be considered when interpreting the results and providing guidelines for future research. In particular, it is important to note that the sample in question was selected using a non-probability convenience sampling method because the firms included were not chosen at random but were selected based on specific sector- and location-related criteria. Therefore, the results obtained in this study are only applicable to the specific context defined and cannot be generalised to all exporting firms in Portugal. The questionnaire was distributed by email to top managers, using the addresses provided in the SABI database. However, we cannot say with absolute certainty that the firms' top managers provided the answers obtained. Therefore, some bias in the responses is admitted. Regarding the database used, several problems arose, such as inactive firms and incorrect or non-existent contact information, which made the study difficult.

Future research lines

In the future, this study must be carried out with a broader, more representative sample of the target population. Subsequent studies could even extend this research to include firms across different export-related sectors and geographical contexts. They could also explore the influence of moderating variables, including the dimensions of entrepreneurial orientation and exploratory and exploitative innovation capabilities, such as international market

heterogeneity, institutional support, and export motivations. It would also be relevant to analyse the impact of innovation strategies and other types of innovation on the relationships addressed throughout the study.

Finally, this study lays a solid foundation for future research to deepen understanding of this topic by exploring how entrepreneurial orientation and innovation capabilities influence export performance in a constantly evolving, globalised world.

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CONCEPTUAL FRAMEWORK FOR HUMAN RESOURCE MANAGEMENT (HRM) AT ENERGY ENTERPRISES DURING GREEN TRANSFORMATION*

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Abstract. The green transformation of energy enterprises has become a critical component of global sustainability transitions, requiring organizations to adapt not only technologically but also strategically, institutionally, and socially. While existing research has extensively examined technological, economic, and regulatory aspects of energy transition, the role of human resource management (HRM) remains fragmented across multiple theoretical traditions. The aim of this article is to develop an integrated conceptual framework for HRM at energy enterprises during green transformation. The study employs a conceptual research design based on a systematic review and synthesis of scientific literature in the fields of institutional theory, socio-technical transition studies, strategic management, organizational capabilities, and Sustainable and Green Human Resource Management (HRM). The analysis demonstrates that green transformation should be understood as a multidimensional and context-dependent process shaped by the interaction of external sustainability-related pressures, organizational adaptation mechanisms, and workforce-related transformation processes. The findings suggest that HRM functions not merely as an administrative support activity but as a strategic organizational capability that enables workforce transformation, organizational learning, employee engagement, sustainability-oriented leadership, and the development of green competencies. Based on the cross-paradigm synthesis, an integrated conceptual framework is proposed that explains how external institutional and socio-technical drivers influence transformation outcomes through organizational mediators and HRM mechanisms. The framework provides a theoretical foundation for future empirical research and practical analysis of HRM contributions to sustainability-oriented transformation in the energy sector.

Keywords: human resource management (HRM); energy enterprises; green transformation; HRM contributions; conceptual framework

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1. Introduction

The transition toward sustainable and low-carbon development has become one of the most significant challenges facing contemporary economies. Within this process, the energy sector occupies a particularly important position due to its central role in economic systems, substantial contribution to greenhouse gas emissions, and strategic importance for economic and societal development (United Nations Development Programme, 2025; Strielkowski et al., 2024; Thomas et al., 2024). Consequently, energy enterprises are

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increasingly required to implement green transformation initiatives that encompass technological modernization, organizational adaptation, innovation, regulatory compliance, and social sustainability. Green transformation therefore extends beyond the adoption of renewable energy technologies and involves fundamental changes in organizational structures, managerial practices, workforce competencies, and corporate strategies (Geels, 2002; Schot & Geels, 2008; Liu & Song, 2023).

While existing research has extensively examined technological, economic, and policy aspects of energy transition (Geels et al., 2016; Plotkin et al., 2023; Zhou et al., 2025), considerably less attention has been devoted to the role of human resource management (HRM) in facilitating sustainability-oriented transformation. However, the successful implementation of green transformation depends not only on technological innovations and strategic decisions but also on employees' competencies, behaviours, engagement, and capacity to adapt to changing organizational requirements. As a result, HRM increasingly emerges as a strategic organizational capability that supports workforce transformation, organizational learning, innovation, and sustainability-oriented change (Ehnert, 2009; Jabbour & Santos, 2008; Yong et al., 2020).

The growing body of research on Sustainable Human Resource Management (Sustainable HRM) and Green Human Resource Management (Green HRM) demonstrates that HRM contributes to organizational sustainability through the development of green competencies, environmental commitment, employee engagement, environmental training, and sustainability-oriented leadership (Renwick et al., 2012; Jabbour, 2013; Dumont et al., 2017; Yong et al., 2020). Nevertheless, the existing literature remains fragmented across several theoretical traditions. Institutional theory explains how organizations respond to environmental and societal pressures (Selznick, 1957; Meyer & Rowan, 1977; DiMaggio & Powell, 1983; Scott, 2014), sustainability transition studies explain how socio-technical systems evolve toward sustainability (Geels, 2002; Schot & Geels, 2008; Geels et al., 2016), while strategic management and organizational capabilities theories explain how organizations adapt, innovate, and develop capabilities required for transformation (Barney, 1991; Teece et al., 1997; Eisenhardt & Martin, 2000). Although these perspectives address important aspects of transformation, they are rarely integrated into a unified framework capable of explaining the role of HRM within the broader process of green transformation at energy enterprises.

This fragmentation creates a theoretical gap in understanding how external sustainability pressures, organizational adaptation mechanisms, and HRM practices interact during the green transformation of energy enterprises. Existing studies have predominantly examined these elements separately, resulting in limited theoretical understanding of the mechanisms through which HRM contributes to sustainability-oriented organizational transformation. Addressing this gap is important both for advancing academic knowledge and for supporting managers responsible for implementing workforce-related aspects of energy transition and sustainable development.

The aim of this article is to develop a conceptual framework for human resource management at energy enterprises during green transformation. Drawing upon institutional and socio-technical transition theory (Selznick, 1957; Scott, 2014; Geels, 2002, 2024), strategic management and organizational capabilities theory (Barney, 1991; Teece et al., 1997; Eisenhardt & Martin, 2000), and the Sustainable and Green HRM paradigm (Ehnert, 2009; Renwick et al., 2012; Yong et al., 2020), the article synthesizes existing theoretical perspectives into an integrated analytical model. The proposed framework conceptualizes HRM as a strategic organizational mechanism that mediates the relationship between external transformation drivers, organizational adaptation processes, and enterprise-level green transformation outcomes.

The article contributes to the literature in three ways. First, it systematizes the principal theoretical approaches relevant to HRM in the context of green transformation. Second, it develops an integrated conceptual framework that explains the relationships between institutional pressures, organizational adaptation mechanisms, HRM practices, and transformation outcomes. Third, it identifies the key dimensions through which the contribution of HRM to the green transformation of energy enterprises can be analysed in future empirical research and managerial practice.

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2. Green transformation of energy enterprises: defining, structuring and contextualizing

The green transformation of energy enterprises represents a specific and particularly complex case of sustainability-oriented transformation due to the systemic role of the energy sector in economic development and its central contribution to global environmental challenges. Unlike many other industries, energy enterprises operate within highly capital-intensive, infrastructure-dependent, and strongly regulated systems, where technological change is closely intertwined with institutional frameworks, market structures, geopolitical dynamics, and long-term investment cycles (Strielkowski et al., 2024; Plotkin et al., 2023). At the same time, the energy sector remains the largest contributor to global greenhouse gas emissions and therefore occupies a central position in decarbonization strategies and sustainability transitions (United Nations Development Programme, 2025). Consequently, the transformation of energy enterprises extends beyond organizational change and constitutes an essential component of broader socio-technical, economic, and institutional transformation processes (Geels, 2002; Schot & Geels, 2008).

In contrast to less system-critical industries, changes occurring within energy enterprises generate cascading effects across value chains, markets, and societal systems. The transformation of the sector therefore requires coordinated changes in technologies, business models, regulatory frameworks, and organizational practices. Furthermore, energy enterprises face the challenge of balancing environmental sustainability objectives with energy security, affordability, and economic competitiveness (European Bank for Reconstruction and Development, n.d.; Vosylius et al., 2013; Thomas et al., 2024). These characteristics distinguish the energy sector from many other industries and necessitate a multidimensional analytical perspective capable of capturing the complexity of green transformation processes.

The scientific literature demonstrates that green transformation is a multidimensional, dynamic, and context-dependent phenomenon for which no universally accepted definition currently exists. Instead, scholars conceptualize it through different theoretical lenses emphasizing technological change, sustainability transitions, organizational adaptation, innovation, and institutional transformation. Amundsen and Hermansen (2021) describe green transformation as a boundary object characterized by interpretive flexibility, allowing different stakeholders to assign diverse meanings ranging from incremental environmental improvements to fundamental socio-economic restructuring. This perspective highlights the conceptual breadth of green transformation and its dependence on contextual conditions.

From a strategic perspective, green transformation can be understood as a process through which organizations seek to maintain long-term sustainability, resilience, and competitiveness under conditions of climate change, environmental regulation, and global uncertainty (Plotkin et al., 2023). Innovation-oriented approaches emphasize the integration of environmental objectives into corporate strategies, innovation systems, and operational models, where digital technologies, green innovation, and dynamic capabilities function as key transformation mechanisms (Liu & Song, 2023). Sustainability transition research further interprets green transformation as a structural shift from fossil-fuel-based socio-technical systems toward renewable, low-carbon, and resource-efficient configurations, involving changes in technologies, institutions, markets, and social practices (Geels, 2002, 2024; Thomas et al., 2024; Strielkowski et al., 2024).

International organizations similarly conceptualize green transformation as a holistic process integrating decarbonization, technological modernization, institutional reform, economic restructuring, and social inclusion. Particular emphasis is placed on the principles of sustainable development and just transition, ensuring that the benefits and costs of transformation are distributed fairly among stakeholders (United Nations Development Programme, 2025; European Bank for Reconstruction and Development, n.d.).

Synthesizing these perspectives, the authors define the green transformation of energy enterprises as a multidimensional, systemic, and non-linear process of strategic, technological, organizational, and institutional change aimed at achieving low-carbon, resource-efficient, and sustainable development while simultaneously ensuring economic resilience, social responsibility, and long-term competitiveness.

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The literature further suggests that green transformation should be understood as a multi-level and multidimensional process composed of several interrelated dimensions. At the technological level, transformation involves the deployment of renewable energy technologies, improvements in energy efficiency, infrastructure modernization, digitalization, and the adoption of advanced technological solutions, including artificial intelligence and energy storage systems (Strielkowski et al., 2024; United Nations Development Programme, 2025). At the economic and strategic level, transformation is reflected in the integration of sustainability into corporate strategy, the development of carbon-neutral business models, and alignment with ESG principles that increasingly influence investment decisions and organizational performance evaluation (Plotkin et al., 2023; European Bank for Reconstruction and Development, n.d.; Zhou et al., 2025).

The organizational and managerial dimension encompasses changes in organizational structures, managerial practices, leadership approaches, and corporate culture aimed at increasing adaptability, innovation, and sustainability orientation (Thomas et al., 2024). The innovation and capability dimension highlights the importance of dynamic capabilities, organizational learning, and innovation capacity in enabling enterprises to convert technological and digital advancements into sustainable competitive advantages (Liu & Song, 2023; Tvaronavičienė & Černevičiūtė, 2015; Zhou et al., 2025). At the institutional and regulatory level, transformation is shaped by environmental regulations, policy frameworks, financial incentives, and governance mechanisms that create enabling conditions for sustainable development and green investment (European Bank for Reconstruction and Development, n.d.; Plotkin et al., 2023). Finally, the social dimension incorporates workforce development, reskilling, employee participation, social inclusion, and just transition principles, emphasizing the human-centered nature of sustainability-oriented transformation (United Nations Development Programme, 2025). These dimensions are closely interconnected and operate simultaneously across macro, meso, and micro levels of analysis, forming a holistic structure of green transformation as a systemic and integrated process. The resulting conceptualization provides the foundation for identifying the specific role of human resource management within the green transformation of energy enterprises. The key dimensions of green transformation identified in the literature are summarized in Table 1.

Table 1. Structure of green transformation of energy enterprises across dimensions and levels

Dimensions of green transformation	Levels of green transformation		
	Macro level (policy and institutional environment)	Meso level (industry and market structures)	Micro level (enterprises)
Technological	National energy transition policies; support for renewable energy; large-scale infrastructure programs; national digitalization strategies (Strielkowski et al., 2024; United Nations Development Programme, 2025)	Industry-level diffusion of renewable technologies; development of smart grids; sectoral standards for energy efficiency; technological collaboration networks	Adoption of renewable energy technologies; implementation of energy-efficient processes; use of digital tools (AI, big data); modernization of internal infrastructure
Economic and strategic	National decarbonisation strategies; green growth policies; development of sustainable finance systems; ESG regulatory frameworks (Plotkin et al., 2023; European Bank for Reconstruction and Development, n.d.; Zhou et al., 2025)	Industry competition and market structures; sectoral investment flows; ESG-driven market expectations; value chain restructuring toward sustainability	Integration of sustainability into corporate strategy; development of carbon-neutral business models; ESG-oriented decision-making; green investment planning
Organizational and managerial	National governance models; institutional norms influencing corporate governance; cultural patterns of management and leadership (Thomas et al., 2024)	Industry-specific organizational practices; sectoral management standards; inter-organizational coordination and partnerships	Transformation of organizational structures; development of sustainability-oriented corporate culture; adaptive leadership; changes in decision-making processes
Innovation and capability	National innovation systems; R&D policies; support for green and digital innovation ecosystems (Liu and Song, 2023; Zhou et al., 2025)	Industry innovation networks; knowledge spillovers; collaboration between firms, universities, and research institutions	Development of dynamic capabilities (absorptive, adaptive, innovative); internal R&D; ability to integrate digital and green innovations into operations
Institutional and regulatory	Environmental regulations; climate policies; legal frameworks;	Industry regulation; sector-specific standards;	Compliance with regulations; implementation of internal

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	international agreements; financial incentives for green investments (European Bank for Reconstruction and Development, n.d.; Plotkin et al., 2023)	compliance mechanisms; role of industry associations and regulatory bodies	sustainability policies; alignment with ESG standards; reporting and accountability practices
Social	National social policies; just transition frameworks; education and training systems; societal attitudes toward sustainability (United Nations Development Programme, 2025)	Labor market dynamics in the energy sector; sectoral workforce transitions; social dialogue between stakeholders; professional networks	Workforce reskilling and upskilling; employee engagement in sustainability initiatives; organizational social responsibility practices; support for inclusive transition

Source: compiled by the authors based on the scientific literature

The multidimensional structure presented in Table 1 demonstrates that the green transformation of energy enterprises is a systemic process in which technological, economic, organizational, institutional, and social dimensions are closely interconnected. Although these dimensions can be analytically distinguished, they remain mutually dependent and evolve through continuous interactions across macro, meso, and micro levels of analysis. Consequently, understanding the mechanisms of green transformation requires moving beyond purely technological explanations and examining the organizational processes through which sustainability objectives are translated into concrete managerial practices and organizational outcomes.

Among the identified dimensions, particular importance can be attributed to the organizational and managerial dimension, which serves as a critical link between external transformation pressures and enterprise-level responses. Existing research suggests that organizational adaptation is shaped not only by technological change and regulatory requirements but also by internal factors such as governance structures, organizational culture, leadership practices, and decision-making processes (DiMaggio & Powell, 1983; Scott, 2014; Greenwood et al., 2017). These factors influence how organizations interpret sustainability-related challenges and how effectively they respond to changing environmental, regulatory, and market conditions.

Furthermore, organizational transformation depends on the development of adaptive capabilities, innovation-oriented cultures, and sustainability-oriented leadership capable of supporting long-term change (Eisenhardt & Martin, 2000; Teece, 2007; Walker et al., 2010; Boons & Lüdeke-Freund, 2013). From a process perspective, organizational change should be viewed as an evolving phenomenon that unfolds over time through interactions among technological, institutional, and managerial transformations (Van de Ven & Poole, 1995; Pettigrew, 1997; Geels, 2002, 2024; Schot & Geels, 2008). Consequently, analysing green transformation at the organizational level enables a deeper understanding of the managerial actions, organizational routines, and behavioural mechanisms through which sustainability objectives are implemented in practice (Whittington, 2006; Delmas & Toffel, 2008; Schaltegger & Wagner, 2011).

This organizational perspective is particularly relevant for the study of HRM. As enterprises adopt new technologies, business models, and sustainability strategies, workforce-related factors become increasingly important for successful transformation. Employees must acquire new competencies, adapt to changing work processes, participate in sustainability initiatives, and support organizational learning and innovation. Therefore, HRM represents a key organizational mechanism through which sustainability objectives are translated into employee capabilities, organizational culture, and transformation outcomes.

At the same time, the literature demonstrates that green transformation is highly context-dependent and unfolds unevenly across countries and regions. Differences in institutional quality, economic development, technological capabilities, regulatory frameworks, and cultural values shape the trajectories and outcomes of sustainability transitions (Strielkowski et al., 2024; Thomas et al., 2024; Geels, 2024). Consequently, energy enterprises operate within distinct national environments that influence their opportunities and constraints for implementing green transformation initiatives.

To illustrate this contextual diversity, it is useful to complement the conceptual discussion with comparative empirical evidence. Cross-country indicators provide an important analytical tool for examining differences in energy transition performance and transformation readiness across national contexts. One of the most widely

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used instruments for this purpose is the Energy Transition Index (ETI), developed by the World Economic Forum, which evaluates both the current performance of national energy systems and their readiness for future transformation. By integrating environmental, economic, and institutional dimensions into a unified assessment framework, the ETI provides valuable insights into the uneven geography of global energy transitions. Table 2 therefore presents the latest ETI rankings and scores, illustrating the substantial cross-country variation in green transformation processes and reinforcing the argument that sustainability transitions are shaped by specific national and institutional contexts.

Table 2. Energy Transition Index (ETI), n = 118 countries, 2025

Rank	Country	ETI Score
TOP 20		
1	Sweden	77.5
2	Finland	71.8
3	Denmark	71.6
4	Norway	71.5
5	Switzerland	71.0
6	Austria	70.6
7	Latvia	69.4
8	Netherlands	69.2
9	Germany	68.8
10	Portugal	68.6
11	Estonia	68.0
12	China	67.5
13	Iceland	67.3
14	France	67.1
15	Brazil	67.0
16	UK	66.8
17	US	66.8
18	Spain	66.6
19	Lithuania	66.6
20	Israel	66.1
BOTTOM 20		
99	Guatemala	48.7
100	Kuwait	48.6
101	Pakistan	48.5
102	Iran (Islamic Rep.)	47.6
103	Brunei Darussalam	47.6
104	Nepal	47.5
105	Bahrain	47.2
106	Mozambique	47.1
107	Nicaragua	46.8
108	Honduras	46.5
109	Zambia	46.3
110	Senegal	46.1
111	Tanzania	46.0
112	Ethiopia	45.9
113	Zimbabwe	44.8
114	Jamaica	44.5
115	Mongolia	44.2
116	Trinidad and Tobago	44.0
117	Botswana	42.8
118	Democratic Republic of Congo	42.4

Source: World Economic Forum, 2025.

The data presented in Table 2 demonstrate substantial differences in the level of energy transition across countries, confirming that the green transformation of energy enterprises unfolds unevenly in the global context. The highest ETI scores are concentrated in Northern and Western European countries, such as Sweden, Finland, Denmark, and Norway, whose strong performance is supported by advanced institutional frameworks, high shares of renewable energy, developed infrastructure, and long-term policy commitments to sustainability. In contrast, many developing and resource-dependent economies occupy lower positions, reflecting structural constraints related to fossil-fuel dependence, limited financial resources, and less developed regulatory environments.

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These differences suggest that energy enterprises operate within highly heterogeneous external environments that shape both the opportunities and constraints of green transformation. The positions of Latvia and China provide illustrative examples of different transformation pathways. Latvia ranks among the global leaders in energy transition performance, benefiting from a relatively clean energy mix, substantial integration of renewable energy sources, and close alignment with European Union climate and energy policies. Consequently, Latvian energy enterprises operate in an environment where sustainability objectives are increasingly institutionalized through regulations, market expectations, and stakeholder demands, shifting the focus from fundamental structural transformation toward optimization, innovation, and continuous sustainability improvement (Lebedeva et al., 2021; Blumberga et al., 2014, 2024; Lagzdiņa et al., 2024). This sustainability-oriented context is further supported by recent studies of Latvia's climate-neutral energy pathway and energy-sector transformation (Kudrenickis et al., 2024; Allena-Ozoliņa, 2025).

China represents a different transformation context. Despite the continued importance of fossil fuels within its energy system, the country has achieved substantial progress through large-scale investments in renewable energy technologies, rapid infrastructure development, and strong state support for sustainability initiatives. As a result, Chinese energy enterprises operate within a dynamic environment characterized by simultaneous modernization of existing energy systems and deployment of new low-carbon technologies (Sun et al., 2016; Guan et al., 2018; Liu & Song, 2023; Zhou et al., 2022). These examples illustrate that similar sustainability objectives may be pursued through different institutional arrangements, technological pathways, and organizational strategies.

More broadly, the ETI can be interpreted as an aggregated indicator of the external environment in which energy enterprises conduct their transformation activities. Higher ETI scores generally reflect stronger institutional support, more advanced technological infrastructure, and market conditions that facilitate sustainability-oriented change. Conversely, lower scores often indicate structural and institutional barriers that require enterprises to rely more heavily on internal capabilities, innovation, and adaptive strategies. Therefore, national energy transition performance not only reflects country-level progress but also signals the opportunities and constraints faced by individual enterprises operating within different contexts (World Economic Forum, 2025).

At the same time, existing research demonstrates that transformation processes vary not only between countries but also within individual national contexts. Regional studies of Latvia, for example, reveal significant differences in renewable energy potential, infrastructure development, energy consumption patterns, and socio-economic conditions (Kacare et al., 2021; Zeibote et al., 2025). Such findings indicate that even within a common institutional framework, enterprises may encounter substantially different transformation opportunities and challenges depending on their geographical location and resource base. Consequently, the spatial dimension of green transformation extends beyond national boundaries and encompasses intra-country variations that influence organizational decision-making and transformation trajectories.

The literature further emphasizes that green transformation is shaped by broader cultural and societal factors. As argued by Amundsen and Hermansen (2021), green transformation functions as a boundary object whose interpretation varies across stakeholders and contexts. Cultural values influence how sustainability is perceived, prioritized, and implemented, thereby affecting organizational responses to environmental challenges. Empirical studies demonstrate that national cultural characteristics, including long-term orientation, individualism, and attitudes toward uncertainty, are associated with differences in environmental governance, sustainability performance, and investments in sustainable technologies (Ringov & Zollo, 2007; Gallego-Álvarez & Ortas, 2017; Almaqtari et al., 2023). Consequently, transformation pathways are not only institutionally but also culturally embedded.

The importance of cultural context becomes particularly evident when comparing different governance models of sustainability transitions. Collectivist societies often rely on stronger state coordination and large-scale policy interventions, facilitating rapid implementation of transformation initiatives, whereas more individualistic societies tend to emphasize market mechanisms, innovation ecosystems, and decentralized decision-making (Sovacool, 2016; Liu et al., 2018; Buckley, 2021). These differences influence not only policy design but also

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organizational strategies, stakeholder interactions, and the mechanisms through which transformation is implemented.

From a broader socio-technical perspective, transformation involves not only technological and institutional change but also shifts in social practices, organizational routines, and cultural meanings (Geels, 2002, 2024; Geels et al., 2016). Studies of pro-environmental behaviour similarly demonstrate that societal norms, trust, and cultural attitudes significantly influence energy consumption patterns, public acceptance of renewable technologies, and participation in sustainability initiatives (Steg & Vlek, 2009; Halkos & Tzeremes, 2013). Therefore, cultural context acts as an important mediating factor that shapes how green transformation is interpreted and enacted at both organizational and societal levels.

Overall, the reviewed literature suggests that the green transformation of energy enterprises should be understood as a geographically, institutionally, and culturally embedded process. Transformation pathways differ across countries, regions, and organizations because they are shaped by the interaction of regulatory frameworks, technological capacities, cultural values, socio-economic conditions, and organizational capabilities. Recognizing this contextual diversity is essential for developing theoretically robust and practically relevant approaches to analysing the role of HRM within sustainability-oriented transformation processes.

3. Conceptualizing HRM at energy enterprises during green transformation

While the previous section established the concept, structure, and contextual characteristics of the green transformation of energy enterprises, understanding the mechanisms through which this transformation is implemented requires a closer examination of organizational processes and managerial practices. Existing research demonstrates that sustainability-oriented transformation cannot be explained solely through technological innovation, regulatory change, or strategic adaptation. Its successful implementation ultimately depends on people, their competencies, behaviours, values, and capacity to adapt to changing organizational requirements (Ehnert, 2009; Jabbour & Santos, 2008; Renwick et al., 2012). Consequently, human resource management (HRM) occupies a central position within transformation processes because it directly influences workforce development, organizational learning, employee engagement, and the adoption of sustainability-oriented practices.

The literature further suggests that the green transformation of energy enterprises is shaped by the interaction of multiple factors operating at different analytical levels. Institutional pressures, sustainability regulations, stakeholder expectations, and socio-technical transition processes create external drivers for organizational change (Selznick, 1957; DiMaggio & Powell, 1983; Scott, 2014; Geels, 2002, 2024). At the organizational level, enterprises respond to these pressures through strategic adaptation, capability development, innovation, and organizational learning (Barney, 1991; Teece et al., 1997; Eisenhardt & Martin, 2000). At the workforce level, Sustainable and Green HRM practices contribute to the development of green competencies, environmental commitment, sustainability-oriented leadership, and employee participation in transformation initiatives (Ehnert, 2009; Jabbour, 2013; Dumont et al., 2017; Yong et al., 2020). Understanding the role of HRM during green transformation therefore requires an integrated conceptual perspective capable of linking these complementary dimensions.

To establish the theoretical foundations of such a perspective, this study synthesizes several organizational and managerial paradigms that address different aspects of sustainability-oriented transformation. Institutional and socio-technical transition theories explain the external drivers and contextual conditions shaping transformation processes; strategic management and organizational capabilities theories explain how enterprises adapt and develop the capabilities necessary for sustainability-oriented change; while Sustainable and Green HRM theories clarify the mechanisms through which workforce management contributes to organizational transformation and sustainability outcomes. The principal paradigms, their core assumptions, theoretical contributions, and representative authors are summarized in Table 3, which provides the theoretical foundation for the development of the conceptual framework proposed in this article.

Table 3. Theoretical foundations of the conceptual framework for HRM at energy enterprises during their green transformation

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Paradigm	Main theoretical focus	Key concepts	Representative authors
Institutional and socio-technical context of green transformation			
Institutional and organizational adaptation paradigm	Explains how organizations respond to external institutional pressures and seek legitimacy during sustainability-oriented change	Institutionalization, legitimacy, institutional pressures, organizational adaptation, institutional isomorphism, organizational identity, stakeholder expectations	Selznick (1957); Meyer & Rowan (1977); DiMaggio & Powell (1983); Scott (2014); Delmas & Toffel (2008); Greenwood et al. (2017)
Sustainability transition and socio-technical transition paradigm	Explains how green transformation emerges and unfolds through interactions among technologies, institutions, markets, actors, infrastructures, and societal developments	Sustainability transitions, socio-technical systems, multi-level perspective, niche innovations, regimes, landscapes, organizational learning, transition pathways	Nelson & Winter (1982); Geels (2002); Schot & Geels (2008); Geels et al. (2016); Geels (2024)
Organizational adaptation and strategic transformation			
Strategic management and organizational capabilities paradigm	Explains how organizations strategically adapt to environmental change and develop capabilities required for transformation	Stakeholder management, strategic adaptation, organizational capabilities, dynamic capabilities, governance, resource allocation, organizational learning, innovation	Freeman & McVea (2001); Hart (1995); Teece et al. (1997); Barney (1991); Eisenhardt & Martin (2000)
HRM within sustainability-oriented transformation			
Sustainable and green HRM paradigm	Explains how HRM contributes to sustainability-oriented organizational transformation and environmental performance	Green HRM, Sustainable HRM, green competencies, employee engagement, environmental training, green leadership, sustainability culture, workforce transformation	Ehnert (2009); Renwick et al. (2013); Jabbour & Santos (2008); Jabbour (2013); Dumont et al. (2017); Yong et al. (2020)

Source: developed by the authors based on the analyzed scientific literature.

3.1. Institutional and socio-technical context of green transformation

Institutional and organizational adaptation paradigm

The institutional and organizational adaptation paradigm explains how organizations respond to changing external environments, seek legitimacy, and translate societal expectations into internal structures, managerial practices, and employee behaviour. Within the context of the green transformation of energy enterprises, this perspective is particularly important because sustainability-oriented change is driven not only by technological innovation but also by environmental regulations, climate policies, ESG requirements, professional standards, investor expectations, and broader societal demands for sustainable development. Consequently, energy enterprises are embedded in institutional environments that shape both the direction and the pace of transformation.

One of the foundational contributions to this perspective was made by Selznick (1957), who conceptualized organizations as social institutions rather than merely technical instruments for achieving predefined goals. According to Selznick, organizations gradually develop distinctive values, identities, and commitments, while leadership plays a central role in institutionalizing organizational purpose and maintaining organizational integrity. Applied to green transformation, this perspective suggests that sustainability requires not only technological modernization but also the development of sustainability-oriented organizational values, leadership practices, and cultural norms. From this viewpoint, HRM serves as a mechanism through which sustainability principles become embedded in recruitment, training, performance management, leadership development, and organizational culture.

The relationship between organizations and their institutional environments was further developed by Meyer and Rowan (1977), who argued that organizations frequently adopt formal structures and managerial practices because these are perceived as legitimate within their external environments. Organizations therefore seek conformity with prevailing institutional expectations in order to secure legitimacy, stability, and access to resources. In the context of green transformation, sustainability-oriented HRM practices can be interpreted as institutional responses to environmental regulations, ESG frameworks, investor expectations, and societal

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demands for responsible business conduct. Green recruitment, sustainability training, environmental performance management, and sustainability leadership development therefore contribute not only to organizational effectiveness but also to organizational legitimacy.

Building on this perspective, DiMaggio and Powell (1983) explain why organizations operating within the same institutional environment tend to become increasingly similar over time. Their theory of institutional isomorphism identifies three mechanisms of convergence: coercive pressures arising from laws and regulations, mimetic pressures resulting from imitation under uncertainty, and normative pressures associated with professional standards and educational systems. These mechanisms are highly relevant to the energy sector, where enterprises increasingly adopt similar sustainability-oriented HRM practices, including environmental training systems, green competencies, ESG-related performance indicators, and sustainability governance structures. Consequently, institutional isomorphism helps explain the growing standardization of green HRM models across energy industries.

A more comprehensive understanding of institutional influences is provided by Scott (2014), whose framework distinguishes between regulative, normative, and cultural-cognitive pillars of institutions. The regulative pillar encompasses environmental laws and climate policies; the normative pillar reflects professional standards and socially accepted sustainability practices; while the cultural-cognitive pillar relates to shared beliefs, values, and understandings concerning sustainability. Together, these pillars explain how external sustainability expectations become translated into organizational structures, workforce practices, and organizational culture. Importantly, Scott emphasizes that organizational actors are not merely constrained by institutions but also actively participate in reproducing and transforming them, highlighting the role of managers and employees as active agents of green transformation.

While institutional theory explains why organizations respond to sustainability pressures, Delmas and Toffel (2008) demonstrate how such pressures are translated into organizational action. Their research shows that organizations exposed to similar environmental demands may nevertheless adopt different responses depending on internal governance structures, managerial influence, and stakeholder relationships. This insight is particularly relevant for HRM because sustainability objectives must be interpreted, prioritized, and operationalized through organizational systems, leadership processes, workforce practices, and communication mechanisms. HRM therefore acts as a mediating subsystem connecting external sustainability expectations with internal organizational adaptation.

Contemporary organizational institutionalism further extends this perspective by emphasizing that organizations actively interpret, negotiate, and respond to evolving societal expectations (Greenwood et al., 2017). Green transformation therefore involves not only environmental objectives but also broader concerns related to social sustainability, workforce inclusion, employee well-being, and just transition principles. Accordingly, HRM should support organizational adaptability, stakeholder engagement, sustainability-oriented leadership, institutional learning, and equitable workforce transformation. From this perspective, HRM becomes a strategic organizational capability through which energy enterprises maintain legitimacy, balance competing stakeholder demands, and achieve long-term sustainability-oriented development.

Overall, the institutional and organizational adaptation paradigm suggests that HRM functions as a strategic mechanism connecting external institutional pressures with internal organizational transformation. Through recruitment, training, leadership development, performance management, organizational culture, and employee engagement, HRM facilitates the institutionalization of sustainability and supports the long-term adaptation of energy enterprises to changing environmental, social, and regulatory conditions.

While the institutional perspective explains why organizations transform and adapt to sustainability pressures, the socio-technical transition perspective explains how transformation unfolds through the interaction of technologies, institutions, infrastructures, markets, and social practices.

Sustainability transition and socio-technical transition paradigm

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The socio-technical transition perspective was further developed through the integration of evolutionary economics, innovation studies, and sustainability transition research. Building on the evolutionary foundations established by Nelson and Winter (1982) and the multi-level perspective proposed by Geels (2002), subsequent studies increasingly emphasized that sustainability transitions are not solely technological phenomena but involve the co-evolution of technologies, institutions, organizations, markets, infrastructures, policies, and social practices. Consequently, successful green transformation requires coordinated adaptation across multiple dimensions of socio-technical systems rather than isolated technological improvements.

A significant contribution in this regard was made by Schot and Geels (2008), who developed the Strategic Niche Management (SNM) approach. According to the authors, sustainability transitions emerge through the creation of protected innovation niches where new technologies, organizational arrangements, and behavioural practices can be experimented with, refined, and gradually integrated into mainstream socio-technical regimes. The authors identify learning processes, actor networking, shared expectations, and institutional alignment as critical mechanisms facilitating successful transition pathways. For energy enterprises undergoing green transformation, this perspective highlights the importance of organizational learning, experimentation, knowledge sharing, and employee participation in innovation processes. Accordingly, HRM should facilitate continuous competence development, interdisciplinary collaboration, sustainability-oriented leadership, and organizational learning capabilities that enable employees and managers to contribute to emerging green innovation systems.

The socio-technical transition perspective has also increasingly recognized the role of organizational actors and institutional dynamics in shaping transition trajectories. Geels et al. (2016) argue that low-carbon transitions are characterized by complex interactions among incumbent firms, policymakers, technology developers, civil society organizations, and market actors. The authors distinguish several transition pathways, including transformation, reconfiguration, substitution, and de-alignment/re-alignment pathways, each associated with different organizational and institutional challenges. This perspective is highly relevant for HRM because different transition pathways require different forms of workforce adaptation, leadership approaches, organizational learning mechanisms, and change management practices. Furthermore, the authors emphasize that transition processes are inherently non-linear and frequently involve conflicts, resistance, power struggles, and competing institutional logics. Therefore, HRM systems should support employee engagement, organizational resilience, conflict management, adaptive leadership, and workforce flexibility to facilitate successful organizational adaptation under conditions of uncertainty and change.

More recently, Geels (2024) further elaborated the Multi-Level Perspective by emphasizing the multidimensional nature of sustainability transitions and the interactions between niche innovations, socio-technical regimes, and broader landscape developments. The study demonstrates that green transformation unfolds through several stages, including experimentation, stabilization, diffusion, and institutionalization, each requiring different organizational capabilities and management approaches. From an HRM perspective, these stages imply changing priorities throughout the transformation process. During the early phases, organizations require experimentation, innovation-oriented culture, employee learning, and competence development. During later phases, HRM becomes increasingly responsible for embedding sustainability-related competencies, values, and practices into organizational routines, performance management systems, leadership structures, and long-term workforce strategies.

Overall, the sustainability transition and socio-technical transition paradigm suggests that green transformation is a systemic, evolutionary, and multi-actor process requiring continuous organizational adaptation, learning, innovation, and institutional change. Within this process, HRM functions as a strategic organizational capability that supports workforce transformation, competence development, organizational learning, stakeholder coordination, and the institutionalization of sustainability-oriented practices. Consequently, HRM becomes an essential mechanism through which energy enterprises adapt to evolving technological, institutional, and societal conditions associated with the transition toward sustainable energy systems.

3.2. Organizational adaptation and strategic transformation

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Strategic management and organizational capabilities paradigm

The green transformation of energy enterprises represents a complex organizational process that extends beyond technological modernization and environmental compliance. It requires the reconfiguration of organizational resources, capabilities, structures, managerial systems, and organizational cultures in response to evolving environmental, technological, regulatory, and stakeholder pressures. Consequently, understanding green transformation requires a theoretical perspective capable of explaining how organizations adapt, learn, innovate, and transform over time. Strategic management and organizational capabilities theories provide such a perspective by emphasizing the role of resources, capabilities, managerial decision-making, organizational learning, and strategic adaptation in enabling long-term organizational development.

One of the foundational perspectives within this paradigm is the resource-based view of the firm. Penrose (1959/2009) conceptualizes organizations as collections of productive resources whose value depends on managerial capabilities, organizational learning, and the effective utilization of human resources. According to Penrose (1959/2009), organizational growth depends not merely on access to resources but on the ability to develop and deploy organizational capabilities, while the pace of transformation is constrained by managerial and organizational capacities, a phenomenon later conceptualized as the Penrose effect (Kor et al., 2016). Similarly, Barney (1991) argues that sustainable competitive advantage emerges from resources that are valuable, rare, difficult to imitate, and non-substitutable. Within the context of green transformation, sustainability-related competencies, environmental knowledge, innovation capabilities, leadership expertise, and sustainability-oriented organizational cultures may be regarded as strategic resources capable of generating long-term organizational competitiveness (Barney, 1991). Consequently, HRM assumes a strategic role in developing, maintaining, and renewing these resources through recruitment, training, knowledge management, leadership development, and employee engagement.

While resource-based theories explain the sources of organizational advantage, dynamic capabilities theory explains how organizations adapt these resources under conditions of environmental change. Teece et al. (1997) argue that sustainable organizational success depends not only on possessing valuable resources but also on the ability to integrate, build, and reconfigure internal and external competencies in response to changing environments. Teece (2007) further develops this perspective by identifying organizational capacities to sense opportunities and threats, seize opportunities, and reconfigure organizational resources as key mechanisms of strategic adaptation. Similarly, Eisenhardt and Martin (2000) conceptualize dynamic capabilities as identifiable organizational routines that enable firms to achieve new resource configurations under conditions of uncertainty and market dynamism. These perspectives are particularly relevant to green transformation because energy enterprises operate within rapidly evolving technological, institutional, and regulatory environments shaped by decarbonization pressures, digitalization, renewable-energy innovation, climate policy, and sustainability-related stakeholder expectations (Teece et al., 1997; Eisenhardt & Martin, 2000; Teece, 2007). Within this context, HRM functions as a strategic dynamic capability that supports workforce adaptation, organizational learning, competence development, innovation, and organizational resilience.

Recent studies further demonstrate that digital transformation increasingly interacts with sustainability-oriented organizational adaptation. Zhou et al. (2025) argue that digitalization and green innovation form a dual mechanism supporting sustainable transformation within energy enterprises. Similarly, Liu and Song (2023) demonstrate that digital transformation enhances green innovation through improvements in absorptive capability, innovation capability, organizational learning, and human capital development. These studies suggest that successful green transformation requires workforce reskilling, digital capability development, innovation-oriented behaviour, adaptive organizational cultures, and continuous learning systems (Liu & Song, 2023; Zhou et al., 2025). Consequently, HRM contributes to organizational transformation by facilitating the development of digital and sustainability-oriented competencies that support innovation and long-term adaptation.

The strategic management literature also emphasizes the importance of organizational adaptation as an emergent and evolutionary process. Mintzberg (1978) argues that strategy should be understood not only as a deliberate plan but also as a pattern emerging from organizational decisions and actions over time. This distinction between

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intended and realized strategies highlights the adaptive nature of organizational transformation under conditions of uncertainty. Mintzberg et al. (1998/2009) further demonstrate that strategy formation involves multiple interconnected processes, including learning, leadership, culture, environmental adaptation, organizational power relations, and transformation. Likewise, Whittington (2006) conceptualizes strategy as a social practice enacted through the activities of managers and employees, emphasizing the importance of strategy practitioners, strategic practices, and strategic praxis. Together, these perspectives suggest that green transformation cannot be fully planned in advance but instead emerges through continuous interaction between organizational intentions, environmental changes, managerial actions, and organizational learning processes (Mintzberg, 1978; Mintzberg et al., 1998/2009; Whittington, 2006). Accordingly, HRM supports strategic adaptation through leadership development, employee participation, organizational learning, and workforce flexibility.

A complementary perspective is provided by organizational change and transformation theories. Lewin's (1951) Field Theory explains organizational change through the interaction between individuals and their organizational environments, highlighting the importance of behavioural adaptation, group dynamics, and organizational culture. Van de Ven and Poole (1995) conceptualize organizational transformation as a multidimensional process involving teleological, dialectical, evolutionary, and life-cycle mechanisms of change. Pettigrew (1997) further emphasizes the processual nature of organizational transformation, arguing that change unfolds through dynamic interactions between organizational actors, structures, contexts, and temporal processes. Chandy and Tellis (1998) add that successful transformation depends on organizational willingness to abandon established routines and embrace innovation, a capability they describe through the concept of willingness to cannibalize. Walker et al. (2010) further demonstrate that organizational innovation contributes to performance only when supported by effective management systems and performance management structures. Collectively, these theories suggest that successful green transformation requires not only technological and strategic adaptation but also behavioural, cultural, managerial, and organizational change (Lewin, 1951; Van de Ven & Poole, 1995; Pettigrew, 1997). The innovation and performance-management aspects of organizational change are further emphasized by Chandy and Tellis (1998) and Walker et al. (2010). Therefore, HRM contributes to transformation by facilitating employee adaptation, managing organizational resistance, supporting organizational learning, and fostering sustainability-oriented organizational cultures.

The literature also highlights the importance of sustainable business model innovation and stakeholder-oriented organizational transformation. Freeman's stakeholder theory argues that organizational success depends on the effective management and integration of relationships among multiple stakeholders, including employees, customers, suppliers, investors, governments, and local communities (Freeman, 1984; Freeman & McVea, 2001). Similarly, Hart (1995) emphasizes the importance of governance structures, decision-making authority, and organizational adaptability under conditions of uncertainty. Boons and Lüdeke-Freund (2013) further argue that sustainable transformation requires the redesign of organizational business models, stakeholder relationships, and value-creation processes. Together, these perspectives suggest that organizational adaptation during green transformation extends beyond internal organizational changes and requires continuous interaction with external stakeholders, institutional environments, and broader sustainability ecosystems (Hart, 1995; Boons & Lüdeke-Freund, 2013). Consequently, HRM contributes to stakeholder-oriented transformation by supporting collaboration, communication, employee participation, sustainability leadership, and organizational legitimacy.

Overall, the strategic management and organizational capabilities paradigm suggests that successful green transformation depends on the organization's ability to develop, integrate, renew, and reconfigure resources and capabilities while simultaneously adapting organizational structures, cultures, managerial systems, and stakeholder relationships (Penrose, 1959/2009; Barney, 1991; Teece et al., 1997). This adaptive logic is further clarified by Teece (2007) and Eisenhardt and Martin (2000). Within this process, HRM emerges as a strategic organizational capability that supports organizational learning, workforce transformation, innovation, leadership development, stakeholder engagement, and long-term organizational adaptability. Therefore, HRM should be understood not merely as an administrative personnel function but as a central mechanism through which energy enterprises build the organizational capacities necessary for successful sustainability-oriented transformation.

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3.3. HRM within sustainability-oriented transformation

Sustainable and Green HRM paradigm

The growing importance of sustainability challenges and the accelerating green transformation of economic sectors have substantially expanded the role of HRM within contemporary organizations. Traditionally, HRM was primarily associated with workforce administration, productivity enhancement, and organizational performance. However, sustainability-oriented transformation requires organizations not only to improve economic performance but also to simultaneously address environmental and social objectives. As a result, HRM increasingly functions as a strategic organizational capability that contributes to long-term organizational sustainability, workforce adaptation, and the successful implementation of transformation processes. Within this context, the Sustainable and Green HRM paradigm has emerged as an important theoretical perspective explaining how workforce management supports sustainability-oriented organizational transformation through the development of human capital, organizational capabilities, environmental commitment, and sustainability-oriented behaviour.

The theoretical foundations of this paradigm are largely associated with the concept of Sustainable Human Resource Management proposed by Ehnert (2009). Unlike traditional HRM approaches that emphasize short-term efficiency and organizational performance, Sustainable HRM focuses on the long-term maintenance, development, and regeneration of human resources while simultaneously contributing to organizational, social, and environmental sustainability objectives (Ehnert, 2009). According to this perspective, organizations must balance multiple and often competing demands, including economic efficiency and employee well-being, organizational flexibility and workforce stability, as well as short-term performance and long-term sustainability. Rather than eliminating these tensions, Sustainable HRM seeks to manage them through organizational practices capable of addressing multiple sustainability objectives simultaneously (Ehnert, 2009). This perspective is particularly relevant to energy enterprises undergoing green transformation because sustainability-oriented restructuring requires continuous workforce adaptation, competence development, organizational learning, and employee engagement. Consequently, HRM can be understood as a strategic organizational subsystem that supports workforce sustainability, organizational resilience, and long-term adaptation under conditions of environmental, technological, and societal change.

Building upon the broader Sustainable HRM perspective, Green Human Resource Management (Green HRM) focuses specifically on integrating environmental sustainability objectives into HRM systems and practices. Green HRM reflects the growing recognition that environmental performance cannot be achieved solely through technological innovation and environmental management systems but also depends on employee competencies, attitudes, behaviours, and organizational culture. Renwick et al. (2012) conceptualize Green HRM as the integration of environmental management and HRM practices, enabling organizations to align workforce management with environmental objectives. Drawing upon the Ability–Motivation–Opportunity framework, the authors argue that environmental performance can be enhanced through HRM practices that develop environmental competencies, motivate environmentally responsible behaviour, and provide opportunities for employee participation in environmental initiatives (Renwick et al., 2012). Accordingly, Green HRM encompasses environmentally oriented recruitment and selection, sustainability-related training and development, environmental performance appraisal, green reward systems, employee involvement, and sustainability-oriented leadership development (Renwick et al., 2012). For energy enterprises undergoing green transformation, these practices provide mechanisms through which sustainability objectives can be translated into workforce capabilities and organizational behaviour.

The strategic significance of HRM within sustainability-oriented transformation is further emphasized by Jabbour and Santos (2008), who conceptualize HRM as a central organizational mechanism connecting economic, social, and environmental dimensions of sustainability. According to the authors, HRM contributes to sustainable organizational development through the promotion of innovation, diversity and inclusion, environmental management, and organizational learning (Jabbour & Santos, 2008). From this perspective, sustainability-oriented transformation depends not only on technological modernization but also on the organization's capacity to develop sustainability-related competencies, stimulate innovative behaviour, and

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cultivate sustainability-oriented organizational cultures. Consequently, HRM functions as an intermediary mechanism linking green transformation initiatives with organizational sustainability outcomes.

A particularly important element of Green HRM concerns the development of environmental competencies through environmental training and organizational learning. Jabbour (2013) identifies environmental training as a fundamental component of Green HRM and a critical mechanism supporting organizational sustainability. Environmental training enables organizations to develop the knowledge, skills, competencies, and behaviours necessary for effective environmental management and sustainability-oriented transformation (Jabbour, 2013). This function is especially important within energy enterprises, where green transformation frequently requires employees to acquire competencies related to renewable energy technologies, environmental management systems, carbon reduction strategies, resource efficiency, and environmental innovation. Furthermore, environmental training should not be treated as an isolated activity but should be integrated into broader Green HRM systems, including recruitment, performance management, reward systems, and employee involvement initiatives (Jabbour, 2013). Consequently, environmental training contributes not only to competence development but also to organizational learning, environmental commitment, and the institutionalization of sustainability-oriented behaviours throughout the organization.

While Green HRM practices establish organizational systems supporting sustainability, their effectiveness ultimately depends on employee responses and workplace behaviour. Therefore, the behavioural dimension of Green HRM has become an increasingly important area of research. Dumont et al. (2017) demonstrate that Green HRM practices influence both in-role and extra-role employee green behaviour through the development of a psychological green climate. Employees are more likely to engage in environmentally responsible behaviour when they perceive that environmental sustainability is genuinely valued, supported, and rewarded within the organization (Dumont et al., 2017). Moreover, individual green values strengthen the relationship between psychological green climate and voluntary environmental behaviour, highlighting the importance of employee attitudes and organizational culture in sustainability-oriented transformation (Dumont et al., 2017). These findings suggest that successful green transformation depends not only on formal environmental policies but also on employee commitment, participation, and behavioural adaptation. Consequently, HRM contributes to transformation by shaping organizational climate, promoting sustainability-oriented values, and encouraging environmentally responsible behaviour.

The growing maturity of Green HRM as a research field is demonstrated by the systematic literature review conducted by Yong et al. (2020). Reviewing seventy peer-reviewed studies published between 2007 and 2019, the authors identify several core dimensions of Green HRM, including green recruitment and selection, environmental training and development, green performance management, green reward systems, employee involvement, and sustainability-oriented leadership (Yong et al., 2020). The review further demonstrates that Green HRM contributes to both individual-level outcomes, such as environmental commitment, employee engagement, and green workplace behaviour, and organizational-level outcomes, including environmental performance, sustainability performance, innovation, and competitiveness (Yong et al., 2020). These findings provide substantial empirical support for the argument that Green HRM constitutes a strategic organizational capability facilitating workforce transformation and supporting sustainability-oriented organizational change.

Synthesizing the reviewed literature, the Sustainable and Green HRM paradigm suggests that human resource management plays a central role in enabling green transformation through the development of sustainability-related competencies, environmental commitment, organizational learning, and employee participation. Sustainable HRM provides the broader conceptual foundation by emphasizing long-term workforce sustainability and the integration of economic, social, and environmental objectives (Ehnert, 2009), while Green HRM operationalizes these principles through concrete workforce management practices aimed at improving environmental performance (Renwick et al., 2012; Jabbour, 2013).

At the same time, organizational sustainability outcomes emerge through behavioural and cultural mechanisms that foster employee engagement, environmental commitment, and green workplace behaviour (Dumont et al., 2017). Collectively, these perspectives demonstrate that successful sustainability-oriented transformation depends not only on technological innovation and environmental management systems but also on integrated

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HRM practices capable of developing green human capital, fostering sustainability-oriented organizational cultures, and supporting workforce adaptation under conditions of environmental and organizational change (Jabbour & Santos, 2008; Yong et al., 2020). Therefore, within the context of the green transformation of energy enterprises, HRM should be conceptualized as a strategic organizational capability that facilitates workforce transformation, organizational resilience, and the achievement of environmental, social, and economic sustainability objectives.

3.4. Synthesis and development of an integrated conceptual framework

The literature reviewed in the preceding sections demonstrates that the green transformation of energy enterprises is a multidimensional phenomenon that cannot be adequately explained through a single theoretical perspective. The institutional and socio-technical transition literature highlights the external drivers of transformation, including regulatory pressures, stakeholder expectations, sustainability requirements, and technological transitions that reshape organizational environments (Selznick, 1957; Meyer & Rowan, 1977; DiMaggio & Powell, 1983; Scott, 2014). The socio-technical dimension of transformation is additionally explained by Geels (2002) and Schot and Geels (2008).

Strategic management and organizational capabilities theories explain how organizations respond to these pressures through capability development, organizational learning, innovation, and strategic adaptation (Penrose, 1959/2009; Barney, 1991; Teece et al., 1997). The adaptive and emergent character of transformation is further supported by Eisenhardt and Martin (2000) and Mintzberg (1978). Finally, the Sustainable and Green HRM literature explains how workforce management contributes to sustainability-oriented transformation through the development of green competencies, employee engagement, environmental commitment, organizational learning, and sustainability-oriented organizational culture (Ehnert, 2009; Renwick et al., 2012; Jabbour & Santos, 2008). The operational and behavioural dimensions of Green HRM are further developed by Jabbour (2013), Dumont et al. (2017), and Yong et al. (2020).

Although these perspectives originate from different research traditions, they collectively suggest that successful green transformation emerges through the interaction of external transformation drivers, organizational adaptation processes, and HRM mechanisms. Institutional and socio-technical changes create pressures and opportunities for transformation; organizations respond through the development of strategic capabilities and adaptive organizational processes; and HRM facilitates the workforce transformation required to support sustainability-oriented organizational change. In this regard, HRM should be understood not merely as a supporting organizational function but as a strategic organizational capability that enables energy enterprises to translate sustainability objectives into organizational practices, employee competencies, and transformation outcomes.

To integrate these complementary perspectives, Table 4 synthesizes the principal theoretical paradigms and identifies their respective analytical contributions to the study of HRM at energy enterprises during green transformation. The table provides the foundation for the subsequent development of an integrated conceptual framework by highlighting the key concepts, mechanisms, and relationships emerging from the reviewed literature.

Table 4. Cross-paradigm synthesis for the conceptual framework

Paradigm	Main analytical focus	Key transformation mechanisms	HRM implications	Expected HRM outcomes
Institutional and socio-technical context of green transformation	Explains why green transformation emerges and how external institutional, technological, and societal pressures shape organizational change	Institutional pressures; legitimacy requirements; climate regulation; ESG expectations; socio-technical transitions; niche innovations; regime transformation; organizational learning	Development of green competencies; sustainability-oriented leadership; organizational learning; workforce adaptation; transition readiness	Sustainability-oriented workforce; institutional legitimacy; employee adaptability; readiness for transformation

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Strategic management and organizational capabilities paradigm	Explains how organizations adapt strategically and develop capabilities necessary for transformation	Resource development; dynamic capabilities; organizational learning; strategic adaptation; innovation; stakeholder management; capability reconfiguration	Reskilling and upskilling; talent management; leadership development; workforce flexibility; knowledge management; innovation-oriented culture	Organizational resilience; adaptive workforce; innovation capability; strategic flexibility; competitive advantage
Sustainable and Green HRM paradigm	Explains how HRM directly contributes to sustainability-oriented transformation and environmental performance	Sustainable HRM; Green HRM practices; environmental training; psychological green climate; employee engagement; green behaviour	Green recruitment; environmental training; green performance appraisal; green rewards; employee participation; sustainability leadership	Green competencies; environmental commitment; employee green behaviour; sustainability culture; environmental and organizational performance

Source: developed by the authors based on Selznick (1957), Meyer & Rowan (1977), DiMaggio & Powell (1983), Scott (2014), Geels (2002, 2024), Schot & Geels (2008), Barney (1991), Teece et al. (1997), Eisenhardt & Martin (2000), Ehnert (2009), Jabbour & Santos (2008), Renwick et al. (2012), Jabbour (2013), Dumont et al. (2017), Yong et al. (2020).

The cross-paradigm synthesis presented in Table 4 identifies the principal theoretical perspectives that explain the role of HRM in the green transformation of energy enterprises. However, synthesizing these perspectives requires not only identifying their individual contributions but also clarifying the relationships among the key constructs and mechanisms emerging from the literature.

Collectively, the reviewed studies suggest that green transformation should be understood as a multi-level process in which external institutional and socio-technical forces influence organizational adaptation processes, which subsequently shape workforce-related practices and transformation outcomes. Consequently, the analyzed paradigms should not be viewed as separate explanatory approaches but as complementary components of a broader analytical model.

The literature further indicates that institutional pressures, sustainability regulations, ESG requirements, and socio-technical transition dynamics constitute the primary external drivers of transformation. Organizational responses to these drivers are mediated through adaptation processes, including strategic management, capability development, organizational learning, and innovation-oriented change.

Within this process, HRM performs a strategic role by translating sustainability-related transformation requirements into workforce competencies, employee engagement, sustainability-oriented behaviour, and organizational learning. Thus, transformation outcomes emerge not from the influence of any single factor but from the interaction among external drivers, organizational adaptation mechanisms, and HRM practices.

Based on this synthesis, the present study conceptualizes HRM at energy enterprises during green transformation as a strategic mechanism linking external transformation pressures with workforce-related and organizational outcomes. The proposed conceptual framework integrates insights from institutional theory, socio-technical transition theory, strategic management, organizational capabilities, and Sustainable and Green HRM to explain how sustainability-oriented transformation is initiated, mediated, and implemented within organizations. Figure 1 presents the resulting conceptual framework and illustrates the relationships among external drivers, organizational mediators, HRM mechanisms, and transformation outcomes in the context of the green transformation of energy enterprises.

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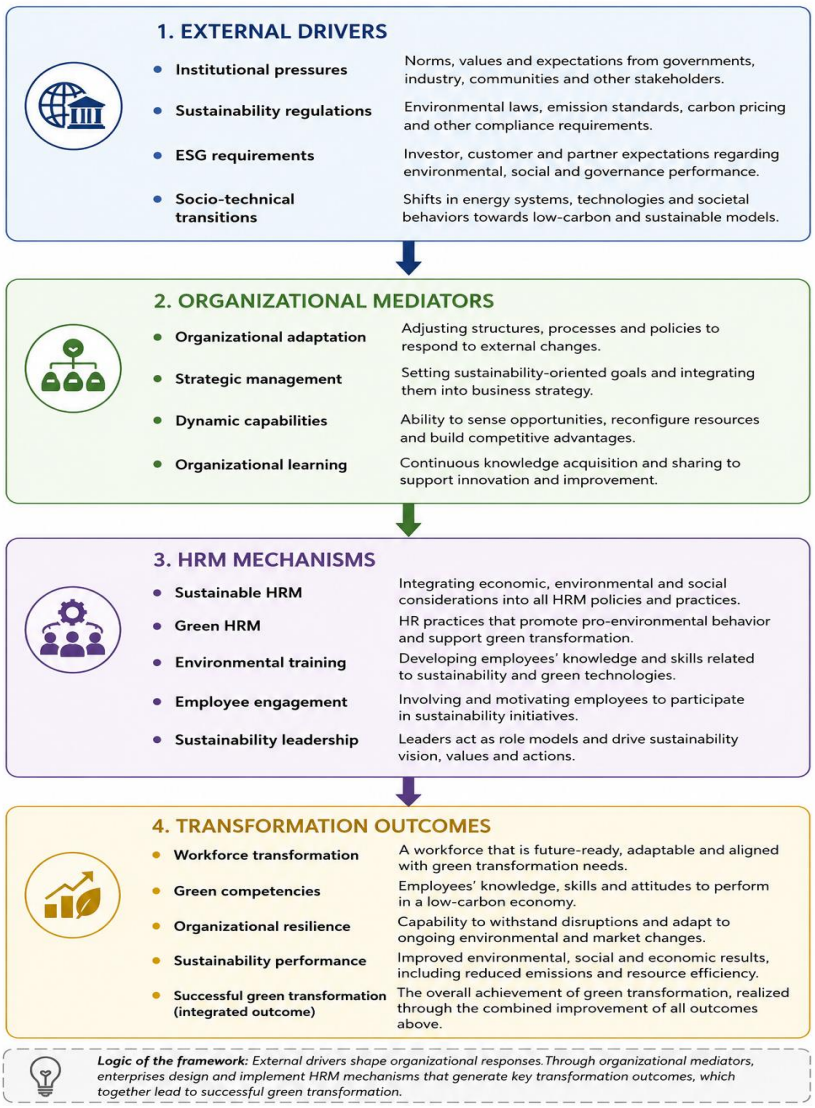


Figure 1. Integrated conceptual framework for HRM at energy enterprises during their green transformation

Note: The organizational mediators and HRM mechanisms together represent the organizational and managerial dimension of green transformation identified in Table 1. The transformation outcomes correspond to enterprise-level (micro-level) manifestations of green transformation (Table 1) and reflect the extent to which organizational adaptation processes and HRM mechanisms contribute to transformation outcomes.
Source: developed by the authors based on the analyzed scientific literature and Table 1.

The conceptual framework presented in Figure 1 synthesizes the theoretical perspectives discussed in the preceding sections and illustrates the causal logic through which HRM contributes to the green transformation of energy enterprises. The framework proposes that external sustainability-related pressures, including institutional requirements, ESG expectations, and socio-technical transition dynamics, influence organizational transformation indirectly through organizational adaptation processes and HRM mechanisms. In this way, green transformation is conceptualized as a multi-stage process in which external drivers create the conditions for change, while organizational and managerial mechanisms determine how these pressures are translated into enterprise-level outcomes.

The organizational mediators and HRM mechanisms presented in Figure 1 together represent the organizational and managerial dimension of green transformation identified in Table 1 and constitute the principal analytical

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focus of the empirical investigation of HRM at energy enterprises during green transformation. Organizational mediators, including organizational adaptation, strategic management, dynamic capabilities, and organizational learning, reflect the strategic and organizational capacities through which enterprises interpret, coordinate, and respond to sustainability-related challenges. HRM mechanisms, including Sustainable HRM, Green HRM, environmental training, employee engagement, and sustainability leadership, represent the workforce-management practices through which these organizational responses are operationalized and embedded within everyday organizational activities.

The framework therefore conceptualizes HRM as an integral component of a broader organizational transformation process rather than as an isolated managerial function. Organizational adaptation processes and HRM mechanisms operate in a complementary manner: the former establish the organizational conditions necessary for transformation, while the latter translate transformation requirements into employee competencies, behaviours, engagement, and leadership practices. Together, they explain how energy enterprises develop the organizational capacity required to respond to changing environmental, regulatory, and societal expectations.

The transformation outcomes presented in Figure 1 correspond to enterprise-level (micro-level) manifestations of green transformation identified in Table 1. Workforce transformation, green competencies, organizational resilience, and sustainability performance reflect the extent to which organizational adaptation processes and HRM mechanisms contribute to sustainability-oriented organizational change. In this regard, successful green transformation should be understood not as a separate outcome but as an integrated result emerging from the combined achievement of these interrelated outcomes.

Consequently, the framework narrows the broad and multidimensional phenomenon of green transformation to those organizational and managerial processes through which energy enterprises adapt to sustainability-related pressures and implement transformation at the enterprise level. While green transformation encompasses technological, economic, institutional, innovation-related, and social dimensions, the present study focuses specifically on the organizational and managerial dimension and its micro-level manifestations within energy enterprises. This analytical focus provides the theoretical foundation for the subsequent empirical investigation of HRM at energy enterprises during green transformation.

4. Conclusions

The conducted literature review demonstrates that the green transformation of energy enterprises is a multidimensional, systemic, and context-dependent process that extends beyond technological modernization and encompasses technological, economic, organizational, institutional, and social dimensions. The analysis confirms that transformation processes are shaped by interactions across macro, meso, and micro levels and are influenced by country-specific institutional arrangements, socio-economic conditions, technological capacities, and cultural contexts. Consequently, green transformation should be understood as a non-linear process of organizational and societal change rather than solely as the adoption of environmentally friendly technologies.

The synthesis of the reviewed literature further shows that the green transformation of energy enterprises can be explained through the interaction of three complementary theoretical perspectives. Institutional and socio-technical approaches explain the external pressures and contextual conditions that drive transformation; strategic management and organizational capabilities theories explain how organizations adapt to changing environments through capability development, organizational learning, and strategic reconfiguration; while Sustainable and Green HRM perspectives explain how workforce-related mechanisms support and sustain transformation processes.

A central conclusion of the study is that HRM should be conceptualized not merely as an administrative function but as a strategic organizational capability that enables sustainability-oriented transformation. Through recruitment, training, competence development, employee engagement, performance management, and sustainability-oriented leadership, HRM translates external sustainability requirements into concrete

organizational practices and workforce-related changes. In this sense, HRM acts as a critical mechanism linking external transformation pressures with organizational adaptation and long-term sustainability outcomes.

The principal contribution of the article is the development of an integrated conceptual framework for HRM at energy enterprises during green transformation. The framework proposes a causal logic in which external institutional and socio-technical drivers influence organizations through organizational adaptation mechanisms, while HRM serves as the primary operational channel through which transformation requirements are translated into workforce transformation, green competencies, organizational resilience, and sustainability performance. By integrating insights from institutional theory, socio-technical transition theory, strategic management, organizational capabilities, and Sustainable and Green HRM, the framework provides a coherent theoretical foundation for future empirical research on the role of HRM in sustainability-oriented transformation within the energy sector.

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AI READINESS FOR SUSTAINABLE DEVELOPMENT: EUROPE'S REGULATORY BURDEN AND THE GAPS IN INNOVATION AND CYBERSECURITY

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Abstract. Research examines the relationships among digital maturity, artificial intelligence (AI) readiness, and cybersecurity resilience in EU member states, highlighting their collective relevance to sustainable digital development. Drawing on multiple international datasets—including the Digital Economy and Society Index (DESI), the Government AI Readiness Index, the ITU Global Cybersecurity Index, and the European Repository of Cyber Incidents (EuRepoC)—we develop a novel composite indicator, the Digital Resilience Index (DRI). The aim is to test whether higher levels of digitalisation and AI readiness are associated with stronger cybersecurity capacity, and to identify imbalances in which rapid digital growth is not matched by adequate resilience, potentially undermining the long-term sustainability of digital governance systems. Methodologically, the study employs comparative quantitative analysis, correlation techniques, and robustness checks (Spearman coefficients and bootstrap confidence intervals) to ensure the stability of the results. The findings reveal that digitally advanced countries tend to report more incidents due to stronger monitoring and transparency, but these incidents are typically less severe. They confirm that the absence of attacks does not define resilience, but rather the ability to detect, contain, and mitigate them effectively—an essential condition for sustainable, trustworthy and future-proof digital ecosystems. By introducing an integrated index and empirically demonstrating its policy relevance, the study contributes to academic debates on digital governance and sustainable development, while offering actionable insights for policymakers. Specifically, it highlights the need to embed security-by-design principles into digital transformation, strengthen GovTech reforms, and adopt AI governance frameworks that support resilient, inclusive and sustainable digital societies.

Keywords: digital resilience; public administration; cybersecurity; AI readiness; sustainability

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1. Introduction

The accelerating digital transformation of public administration has become a central policy priority in the European Union, especially under the framework of the European Digital Strategy and the Digital Decade 2030. Digital maturity enables governments to deliver more efficient, user-centric, and data-driven services. However, this expansion of digital infrastructures simultaneously increases the attack surface and introduces systemic vulnerabilities that can threaten public trust and national security (Eom & Lee, 2022; Kamatchi & Uma, 2025; Hazdiuk et al., 2025; Mohammed et al., 2025). While many EU member states have achieved significant progress in e-government development, research shows that digitalisation alone does not automatically lead to greater security capacity. Instead, cybersecurity must evolve in parallel with institutional, technical, and human resources (Kuziemski & Misuraca, 2020; Haug, Dan & Mergel, 2024). Without such a balance, rapid

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digitalisation may pose governance risks, making states more vulnerable to ransomware, supply chain disruptions, and politically motivated cyberattacks (Hozouri, Mirzaei & Effatparvar, 2025). Artificial intelligence (AI) adds further complexity to this landscape. On the one hand, AI supports anomaly detection, incident response, and predictive analytics. On the other hand, adversarial AI, model poisoning, and deepfakes introduce novel forms of attacks that challenge existing defence mechanisms (Kaur, Gabrijelčič & Klobučar, 2023; Rjoub et al., 2023). The capacity of states to use AI responsibly—captured in governance, infrastructure, and skills—thus determines whether AI strengthens resilience or amplifies vulnerabilities (Gianni, Lehtinen & Nieminen, 2022). This article addresses these challenges by analysing the interplay between digital maturity, AI readiness, and cybersecurity resilience across the 27 EU member states. It draws on multiple datasets, including the Digital Economy and Society Index (DESI), the Government AI Readiness Index (Oxford Insights, 2024), the ITU Global Cybersecurity Index (2024), and incident-level data from the European Repository of Cyber Incidents (EuRepoC, 2025). The central aim is to examine whether higher levels of digital and AI readiness are associated with stronger cybersecurity performance and resilience, and to identify countries where digitalisation is not matched by proportional security capacity. By developing and applying a novel Digital Resilience Index (DRI), this study contributes to both academic and policy debates. The findings offer practical insights for EU policymakers, highlighting the need to embed security-by-design principles into digital government initiatives, strengthen GovTech reforms, and adopt integrated AI governance frameworks to ensure that digital transformation enhances both efficiency and security (ENISA, 2023). The urgency of studying the relationship among digital maturity, AI readiness, and cybersecurity resilience stems from governments' increasing dependence on digital infrastructure. Public administrations across the EU now operate as data-driven ecosystems where digital platforms mediate service delivery, decision-making, and citizen engagement. While this shift enhances efficiency and transparency, it also generates complex risks, as cyber incidents can undermine not only service continuity but also democratic trust and national security (ENISA, 2023; Safitra, Lubis & Fakhrurroja, 2023). Moreover, the integration of artificial intelligence intensifies both opportunities and vulnerabilities. AI can support more accurate threat detection and faster responses, but poorly governed AI adoption exposes public institutions to adversarial manipulation, disinformation, and ethical concerns (Kaur, Gabrijelčič & Klobučar, 2023; Taddeo, Blanchard & Thomas, 2024). Without coordinated frameworks, governments risk creating a digital–security imbalance in which rapid innovation outpaces resilience measures (Huang & Madnick, 2019). This makes resilience a central governance challenge. Understanding which EU member states manage to align digital transformation with security capacity, and which do not, provides crucial insights for policymakers. By benchmarking resilience across countries and identifying imbalances, this study provides evidence to inform the design of future EU strategies, such as Digital Europe and the AI Act, ensuring that digital innovation is implemented responsibly and sustainably (Oxford Insights, 2024; ITU, 2024; EuRepoC, 2025). Several frameworks already exist for measuring digital maturity (DESI), cybersecurity capacity (GCI), and AI readiness (Oxford Insights, 2024). However, as Jarzębowski et al. (2024) argue, these indices capture only partial aspects of resilience and often neglect the outcomes of real-world incidents. Datasets such as the European Repository of Cyber Incidents (EuRepoC, 2025) provide a corrective by documenting the actual frequency and severity of attacks. Still, they have not yet been systematically integrated into resilience benchmarking.

2. Theoretical background

The digital transformation of public administration has become one of the most significant policy priorities in the European Union under initiatives such as the Digital Decade 2030 and the European Digital Strategy. While digital maturity enables governments to provide more efficient, citizen-oriented services, it also expands the attack surface and introduces new vulnerabilities. Research shows that digitalisation by itself does not automatically lead to higher levels of security. Instead, security capacity must co-evolve with institutional, technical, and human resources to prevent unintended risks (Eom & Lee, 2022; Kuziemski & Misuraca, 2020; Ayeola, 2025).

Cyber resilience has therefore emerged as a crucial element of digital government strategies. Comparative analyses reveal that countries that rapidly digitalised without developing systematic cybersecurity frameworks became more exposed to ransomware, phishing, and supply chain attacks. The literature stresses that digital maturity alone is insufficient unless accompanied by governance and capacity-building initiatives designed to

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address security and privacy challenges (Haug, Dan & Mergel, 2024; Dritsas & Trigka, 2025; Zettl-Schabath et al., 2025).

Artificial intelligence (AI) has become a double-edged sword in this context. On the one hand, AI techniques enhance anomaly detection, threat classification, and incident response. On the other hand, adversarial AI, deepfakes, and automated exploitation introduce novel forms of attacks. Recent surveys highlight the importance of explainability, fairness, and robustness in AI-enabled cybersecurity, particularly for critical infrastructures and the public sector (Capuano et al., 2022; Rjoub et al., 2023). These findings suggest that AI readiness—including infrastructure, skills, and governance—determines whether AI functions as a defensive capability or a vulnerability amplifier (Gianni, Lehtinen & Nieminen, 2022).

Governance capacity is also a decisive factor. From a dynamic capabilities perspective, governments must continuously reconfigure their technological and institutional assets to respond to evolving cyber risks. Indicators such as the GovTech Maturity Index (GTMI) capture not only digital infrastructure but also governance mechanisms, citizen engagement, and institutional coordination, all of which are critical to embedding security by design in government platforms. Empirical studies confirm that higher GovTech maturity often coincides with stronger resilience to digital risks (Gajdzik, Grabowska & Saniuk, 2021; World Bank, 2022).

Measurement frameworks such as the Digital Economy and Society Index (DESI), the Global Cybersecurity Index (GCI), the Government AI Readiness Index, and the European Repository of Cyber Incidents (EuRepoC) provide complementary insights into the interplay between digital maturity and cyber resilience. While DESI captures the level of e-government development, GCI reflects national cybersecurity capacity, and AI Readiness highlights the ability to adopt artificial intelligence responsibly. EuRepoC, by contrast, provides evidence on the actual number and intensity of cyber incidents, offering a reality check against self-reported capacity measures (Oxford Insights, 2024; ITU, 2024; EuRepoC, 2025).

Finally, the human factor remains central to cybersecurity in the public sector. Studies demonstrate that the majority of cyber incidents originate from human error, insider misuse, or credential compromise. Advanced approaches, such as user and entity behaviour analytics (UEBA), are recommended to detect anomalies and reduce insider-related risks. European agencies emphasise that security-by-design principles, combined with AI-enabled detection systems, are essential for reducing the impact of attacks, even if the frequency of incidents remains high (ENISA, 2023). The rise of digital maturity in public administration—characterised by digitised services, data-driven decision-making, and platform interoperability—has significantly enhanced service efficiency and citizen engagement, yet simultaneously expands the cybersecurity attack surface, introducing dependencies and systemic vulnerabilities. To assess digital readiness, numerous digital government maturity models (DGMMs) have been developed, though many still inadequately address citizen-centric security dimensions—only half explicitly integrate citizen considerations into maturity frameworks (Waara, 2025).

As digitalisation accelerates, governments increasingly rely on cybersecurity maturity models to evaluate and strategically enhance their security posture, with recent systematic reviews underscoring the need for models tailored to diverse sectors and organisational sizes (Brezavšček & Baggia, 2025). The integration of artificial intelligence (AI) into cybersecurity introduces dual dynamics: it enables advanced detection, threat intelligence, and automation, while simultaneously creating novel risks such as adversarial attacks, model poisoning, and explainability deficits. Emerging studies on generative AI (GenAI) reveal its capacity to manage threat detection and response autonomously, improving efficiency. Yet, it demands robust governance, human oversight, and bias mitigation to prevent unintended consequences (Nott, 2025). The proliferation of large language models (LLMs) in cybersecurity operations enhances analytical capabilities but also raises concerns about prompt injection attacks and data exfiltration, thereby complicating traditional security controls.

From a socio-technical perspective, AI in cybersecurity must be accompanied by ethical and regulatory frameworks to ensure transparency, accountability, privacy, and human oversight, especially as AI systems permeate critical public infrastructure (Kulothungan, 2025; Taddeo, Blanchard, & Thomas, 2024). The concept of a 'risk society' highlights how AI shifts the nature of cyber threats into uncertain, reflexive domains, requiring

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adaptive governance frameworks that can keep pace with evolving technological landscapes (Vulpe, 2024). Moreover, cybersecurity maturity in the public sector must redefine cybersecurity as a core governance function—not merely an IT concern—by embedding it in public administration education, institutional culture, and leadership priorities. Policy and governance scholars suggest that cybersecurity capability not only protects e-government maturity but also mediates and fosters it: increased security capabilities can reduce digital trade restrictions by promoting trust and openness (Huang & Madnick, 2019). Think-tank perspectives emphasise that cybersecurity is now foundational to digital government trust, requiring strategies from the outset rather than as retrofitted elements (Public Sector Network, n.d.; Vatamanu & Tofan, 2025). At the meta-policy level, oversight delays in AI regulation, such as moratoria at the state level, pose national security risks by slowing adaptation to AI-driven cyber threats, especially in IoT and critical infrastructure. Internationally, institutions like the Centre for Security and Emerging Technology (CSET) advise that emerging technology policies must integrate security analysis, academic insight, and nonpartisan frameworks to inform governance (CSET, 2024).

To operationalise these insights, frameworks such as cybersecurity maturity models, DGMMs, and AI governance standards must converge to guide countries through phases of digital maturity, AI readiness, cybersecurity capability, and resilience (Brohi et al., 2025). Finally, reviews in cybersecurity maturity emphasise that organisations must adopt lightweight, customisable maturity models—especially tailored for public sector and small-to-medium entities—to build resilience efficiently (Brezavšček & Baggia, 2025). Most existing studies on digital government either analyse digital maturity and cybersecurity in isolation or rely on single indices that capture only partial aspects of resilience (Kuziemski & Misuraca, 2020; Haug, Dan & Mergel, 2024). However, as comparative research shows, resilience emerges from the interaction of institutional, technological, and human capacities rather than from any single dimension. For this reason, a more integrative methodological design was necessary.

The article contributes by combining multiple internationally recognised datasets—DESI, the Government AI Readiness Index (Oxford Insights, 2024), the ITU Global Cybersecurity Index (2024), and EuRepoC incident data—into a holistic comparative analysis across all 27 EU member states. Such triangulation allows us to move beyond self-reported capacity measures and assess resilience based on both structural indicators and real-world outcomes, addressing calls in the literature for multidimensional frameworks of digital governance (Waara, 2025; Brezavšček & Baggia, 2025; Aryanti, 2025).

The methodological approach is therefore appropriate because it (1) integrates multiple dimensions of digital governance, (2) responds to gaps identified in existing literature, and (3) produces actionable insights for policymakers. In line with prior calls for policy-relevant indicators (Jarzębowski et al., 2024), this study not only provides empirical correlations but also introduces a composite index to benchmark the digital–security balance across the EU.

3. Methods and Materials

Most existing research papers analyse digital maturity and cybersecurity in isolation. This article contributes by:
1) integrating multiple datasets (DESI, GCI, GTMI, AI readiness, EuRepoC) into a holistic analysis—something rarely done systematically across all EU countries;
2) developing a novel composite indicator (Digital Resilience Index – DRI) that measures not only maturity but also resilience outcomes (using incident intensity as a corrective factor);
3) highlighting insider threats as an underexplored vulnerability in digital public administration and proposing a behavioural detection model combining algorithmic monitoring with policy interventions;
4) offering practical insights for EU policymakers: identifying states with digital–security imbalances and recommending targeted resilience-building strategies.

All statistical analyses were conducted in SPSS, including descriptive statistics, correlation tests, and bootstrap confidence intervals. The graphical visualisations and final table formatting were subsequently prepared in Microsoft Excel. The research employs a comparative quantitative analysis using secondary data from internationally recognised indices and datasets. The methodological approach is described in detail below.

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Data Sources: four key international datasets were used: Digital Economy and Society Index (DESI) – focusing on digital public services; Government AI Readiness Index 2024 (Oxford Insights) – evaluating government, technology sector, and data & infrastructure pillars; ITU Global Cybersecurity Index 2024 (GCI) – measuring national cybersecurity capacity across legal, technical, organisational, and cooperative dimensions; European Repository of Cyber Incidents (EuRepoC) – providing data on the number and intensity of cyber incidents between 2020–2025.
Sample: the analysis covers all 27 member states of the European Union, ensuring comparability across common political and regulatory frameworks.
Variables: independent variables: digitalisation score (DESI), GovTech maturity, AI readiness (overall and by pillars); dependent variables: number of cyber incidents, intensity of incidents (severity, duration, and scope as classified by EuRepoC).
Analytical Techniques: descriptive statistics to summarise the performance of each country across indices. Correlation analysis to examine relationships between digitalisation, AI readiness, GovTech maturity, and cybersecurity outcomes. Comparative analysis to identify clusters of countries with similar patterns of maturity and security performance.
Interpretation: the results are interpreted with attention to whether higher levels of digital maturity and AI readiness are associated with improved security capacity (as measured by GCI) and operational resilience (as measured by incident intensity in EuRepoC).

Research Questions
RQ1: What is the relationship between the digital maturity of EU member states (DESI) and their cybersecurity capacity (GCI)?
RQ2: How does GovTech maturity influence the ability of states to integrate AI responsibly into public administration?
RQ3: Do higher combined scores in digitalisation and AI readiness correspond to fewer and less severe cybersecurity incidents (EuRepoC data)?
RQ4 (Novelty): Can the integration of DESI, GCI, GovTech, AI readiness, and EuRepoC datasets provide a new composite indicator that more accurately reflects the balance between digital maturity and cyber resilience?

Research Objectives
• O1: To empirically test correlations between digitalisation, AI readiness, and cybersecurity outcomes across the EU.
• O2: To map country clusters where high digital maturity is not matched by sufficient cyber resilience.
• O3: To design an elementary composite index (Digital Resilience Index – DRI) combining maturity and resilience indicators.
• O4: To propose a conceptual behavioural model for insider-threat detection in public administration, combining quantitative macro-data (indices, incident reports) with micro-level monitoring (algorithmic detection of abnormal user patterns)

ITU Global Cybersecurity Index 2024 (GCI)
For this research, the GCI 2024 serves as the principal indicator of national cybersecurity capacity. Each EU member state's GCI score is treated as a continuous variable (0–100), capturing both legal and institutional arrangements and operational capabilities. The Tier classification is incorporated descriptively to distinguish role-model states (Tier 1) from advancing or lower-performing states (Tier 2–5). ITU Global Cybersecurity Index 2024 is provided in Table 1 below.
The following methodological steps were applied:
1. Data Filtering. From the global GCI dataset, only the 27 EU member states were selected to maintain consistency with DESI and AI readiness comparisons.
2. Normalisation. GCI scores were standardised (z-scores) to align with the scales of other indices (DESI, AI readiness, GovTech maturity).
3. Integration. GCI scores were combined with DESI, AI readiness, and EuRepoC indicators to construct the Digital Resilience Index (DRI) proposed in this study.
4. Comparative Analysis. Countries in Tier 1 were compared with those in lower tiers to identify patterns of alignment or divergence between digital maturity and cybersecurity resilience.

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This methodological approach enables us to test whether higher levels of cybersecurity capacity, as measured by the GCI, mitigate the risks associated with greater digital maturity and AI adoption in public administration.

Table 1. ITU Global Cybersecurity Index 2024

ITU Global Cybersecurity Index 2024							
Country	Legal Measures	Technical Measures	Organisation Measures	Capacity Development	Cooperation Measures	Score	Tier
Austria	18,42	18,23	17,56	18,36	16,59	89,16	T2: Advancing
Belgium	20,00	18,11	19,51	19,19	20,00	96,81	T1: Role-modelling
Bulgaria	20,00	14,49	17,24	11,70	11,13	74,56	T3: Establishing
Croatia	20,00	17,39	19,34	16,74	14,28	87,75	T2: Advancing
Cyprus	20,00	19,38	20,00	18,64	20,00	98,02	T1: Role-modelling
Czechia	20,00	15,30	20,00	18,36	14,28	87,94	T2: Advancing
Denmark	20,00	20,00	20,00	20,00	20,00	100,00	T1: Role-modelling
Estonia	20,00	15,30	20,00	19,74	20,00	95,04	T1: Role-modelling
Finland	20,00	20,00	20,00	20,00	20,00	100,00	T1: Role-modelling
France	20,00	18,98	20,00	20,00	20,00	98,98	T1: Role-modelling
Germany	20,00	17,93	20,00	19,92	15,99	93,84	T1: Role-modelling
Greece	20,00	20,00	19,22	17,89	20,00	97,11	T1: Role-modelling
Hungary	20,00	19,40	18,96	12,63	17,74	88,73	T2: Advancing
Ireland	20,00	13,52	19,67	17,71	20,00	90,90	T2: Advancing
Italy	20,00	20,00	20,00	20,00	20,00	100,00	T1: Role-modelling
Latvia	20,00	14,89	19,34	14,12	14,28	82,63	T3: Establishing
Lithuania	17,79	19,25	17,05	18,79	20,00	92,88	T2: Advancing
Luxembourg	20,00	18,98	20,00	19,74	20,00	98,72	T1: Role-modelling
Malta	20,00	20,00	18,68	16,84	17,44	92,96	T2: Advancing
Netherlands	20,00	20,00	20,00	19,22	20,00	99,22	T1: Role-modelling
Poland	20,00	18,44	16,66	18,44	20,00	93,54	T2: Advancing
Portugal	20,00	20,00	20,00	19,86	20,00	99,86	T1: Role-modelling
Romania	20,00	14,89	17,30	19,43	20,00	91,62	T2: Advancing
Slovakia	20,00	20,00	20,00	18,45	15,99	94,44	T2: Advancing
Slovenia	20,00	19,22	18,16	19,10	20,00	96,48	T1: Role-modelling
Spain	20,00	20,00	20,00	19,74	20,00	99,74	T1: Role-modelling
Sweden	20,00	20,00	19,31	20,00	20,00	99,31	T1: Role-modelling

Government AI Readiness Index 2024 (Oxford Insights)

For this research, the AI Readiness Index 2024 is employed as an indicator of the institutional and technological preparedness of EU member states for AI adoption in the public sector. The index provides a multidimensional view of readiness, spanning governance, private-sector innovation, and data infrastructure.

The methodological treatment was as follows:

1. Data Selection. Scores for all 27 EU member states were extracted from the 2024 AI Readiness dataset to ensure comparability with DESI and GCI.

2. Normalisation. Each country's total AI readiness score (0–100) was standardised into z-scores to align with the scales of other indices used in this study.

3. Pillar Analysis. In addition to overall scores, the three pillars (Government, Technology Sector, Data & Infrastructure) were analysed separately to explore which domains most strongly correlate with cybersecurity outcomes and digital maturity.

4. Integration. AI readiness was incorporated as both an independent variable in statistical analyses and a moderating factor in the proposed Digital Resilience Index (DRI), capturing AI's dual role as an enabler of resilience and a potential risk amplifier.

This methodological approach allows us to test whether countries with higher levels of AI readiness exhibit greater resilience to cyber incidents and whether AI governance maturity moderates the relationship between digital maturity and cybersecurity performance. Government AI Readiness Index 2024 is provided below in Table 2.

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Table 2. Government AI Readiness Index 2024

Government AI Readiness Index 2024				
Country	Total Score	Government Pillar	Technology Sector	Data & Infrastructure
Austria	72.84	78.37	56.56	83.57
Belgium	72.69	81.26	56.23	80.57
Bulgaria	60.64	65.19	37.88	78.85
Croatia	51.62	40.86	39.72	74.28
Cyprus	61.5	68.53	36.18	79.8
Czechia	70.23	76.45	49.5	84.74
Denmark	74.71	84.07	57.17	82.89
Estonia	72.62	86.71	48.97	82.19
Finland	76.48	84.86	60.86	83.73
France	79.36	85.29	63.53	89.25
Germany	76.9	79.24	64.91	86.55
Greece	57.7	50.66	46.55	75.88
Hungary	63.63	74.09	41.81	75.0
Ireland	73.18	75.47	58.13	85.95
Italy	71.22	78.64	53.12	81.88
Latvia	61.87	74.46	35.72	75.43
Lithuania	67.8	77.63	43.02	82.75
Luxembourg	70.63	84.67	43.81	83.4
Malta	63.64	75.86	39.89	75.18
Netherlands	77.23	84.58	60.12	87.0
Poland	67.51	76.53	45.41	80.59
Portugal	70.93	79.47	52.49	80.83
Romania	58.08	69.25	40.41	64.58
Slovakia	63.69	68.76	41.4	80.91
Slovenia	65.85	77.48	43.32	76.76
Spain	69.25	74.58	50.75	82.43

Government AI Readiness Index 2024

DESI – Digital Economy and Society Index

In this research, the DESI public services indicators are applied as the primary measure of digital maturity in public administration. The methodological steps included:

1. Data Extraction. Pillar-level scores were retrieved for all 27 EU member states from the DESI 2024 report.

2. Computation of Averages. A simple arithmetic mean of the eight pillars was calculated to generate an overall public services maturity score for each state.

3. Normalisation. These averages were standardised (z-scores) for compatibility with other indices (GCI, AI Readiness, GTMI).

4. Integration. The aggregated DESI scores were used as independent variables in correlation and cluster analyses, and incorporated into the construction of the Digital Resilience Index (DRI) (see Table 3).

This approach enables a comprehensive comparison of EU states based not only on digital service availability but also on their alignment with cybersecurity capacity and AI readiness.

Table 3. DESI 2024 indicators

DESI 2024 indicators										
Country	e-Government users	Digital public services for citizens	Digital public services for businesses	Pre-filled Forms	Transparency of service delivery, design and personal data	User support	Mobile friendlines s	Access to e-health records	SUM	AVG
Austria	78,98	80,72	82,86	66,49	77,42	89,95	99,67	88,17	664,26	83,03
Belgium	85,85	82,33	91,59	75,08	64,78	91,01	99,26	100,00	689,90	86,24
Bulgaria	35,39	67,47	91,88	71,08	57,03	85,98	95,71	77,21	581,75	72,72
Croatia	88,46	67,17	66,18	49,38	59,14	88,89	97,83	85,57	602,62	75,33
Cyprus	72,37	73,96	86,07	59,38	32,89	80,16	89,39	68,14	562,35	70,29
Czechia	76,68	76,33	83,75	45,09	61,94	75,40	93,71	51,06	563,96	70,50
Denmark	98,68	84,24	88,69	91,01	80,08	84,92	99,59	97,92	725,13	90,64
Estonia	94,72	95,83	98,75	88,06	86,70	96,83	96,90	97,50	755,29	94,41
Finland	97,61	90,61	100,00	87,59	76,07	96,30	100,00	82,62	730,80	91,35
France	90,81	72,09	79,31	62,78	67,31	79,10	96,71	79,27	627,37	78,42
Germany	62,15	75,83	78,58	40,81	48,46	83,86	96,33	86,96	572,99	71,62
Greece	79,66	75,92	86,20	79,01	52,66	85,19	98,32	73,81	630,76	78,85
Hungary	82,39	73,36	74,86	71,11	61,15	76,46	87,19	85,98	612,51	76,56

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Ireland	91,53	81,21	100,00	62,85	70,46	96,56	98,24	11,37	612,22	76,53
Italy	68,53	68,28	76,27	47,91	49,48	77,78	92,44	82,69	563,38	70,42
Latvia	78,85	88,22	87,22	79,05	75,68	89,42	97,43	84,82	680,68	85,09
Lithuania	80,69	86,70	95,94	92,30	77,98	85,45	95,22	95,42	709,69	88,71
Luxembourg	89,43	94,78	96,67	69,63	89,94	100,00	96,74	76,10	713,27	89,16
Malta	88,00	100,00	100,00	93,97	98,27	100,00	98,89	88,03	767,15	95,89
Netherlands	95,48	85,87	86,67	89,01	81,24	99,21	99,68	72,47	709,63	88,70
Poland	66,44	63,73	72,88	79,95	65,09	74,07	93,14	90,03	605,35	75,67
Portugal	80,61	81,54	81,94	79,89	72,55	92,06	92,23	85,98	666,82	83,35
Romania	24,64	52,18	50,03	39,58	42,60	71,16	75,96	58,58	414,73	51,84
Slovakia	80,46	72,06	79,18	53,33	47,64	82,01	94,43	66,34	575,45	71,93
Slovenia	78,37	77,00	83,96	73,89	70,04	84,92	94,43	87,56	650,17	81,27
Spain	83,03	84,18	91,00	80,73	71,40	87,04	94,76	84,58	676,72	84,59
Sweden	96,44	93,28	95,97	83,12	70,45	80,16	100,00	77,94	697,36	87,17

GovTech Maturity Index (GTMI)

Within this research design, the GTMI serves as a complementary indicator of digital governance capacity, reflecting institutional readiness and the quality of core digital infrastructure in the public sector (see Table 4). The methodological treatment was as follows:

Data Extraction. GTMI scores for all EU member states were collected from the most recent World Bank report.

Normalisation. Raw scores (0–1.00) were standardised (z-scores) to align with other indices expressed on a 0–100 scale (DESI, GCI, AI Readiness).

Integration. GTMI values were incorporated as independent variables in correlation and cluster analyses, and used as a governance dimension within the newly constructed Digital Resilience Index (DRI).

This methodological step enables the study to capture how governance maturity and institutional capacity in the digital domain reinforce or constrain resilience against cybersecurity threats.

Table 4. World Bank Group GovTech Maturity Index

World Bank Group GovTech Maturity Index | GovTech Dataset					
Krajina	GTMI (GovTech Maturity Index)	CGSI (Core Government Systems Index)	PSDI (Public Service Delivery Index)	DCEI (Digital Citizen Engagement Index)	GTEI (GovTech Enablers Index)
Austria	0,892 (A)	0,892 (A)	0,977 (A)	0,810 (A)	0,892 (A)
Belgium	0,804 (A)	0,800 (A)	0,944 (A)	0,692 (B)	0,777 (A)
Bulgaria	0,681 (B)	0,702 (B)	0,845 (A)	0,467 (C)	0,712 (B)
Croatia	0,761 (A)	0,834 (A)	0,857 (A)	0,668 (B)	0,684 (B)
Cyprus	0,720 (B)	0,688 (A)	0,882 (A)	0,459 (C)	0,853 (A)
Czechia	0,790 (A)	0,842 (A)	0,830 (A)	0,635 (A)	0,850 (A)
Denmark	0,874 (A)	0,775 (A)	0,978 (A)	0,932 (A)	0,809 (A)
Estonia	0,956 (A)	0,910 (A)	1,000 (A)	0,998 (A)	0,916 (A)
Finland	0,811 (A)	0,716 (B)	0,988 (A)	0,802 (A)	0,737 (B)
France	0,945 (A)	0,923 (A)	0,957 (A)	0,950 (A)	0,952 (A)
Germany	0,768 (B)	0,725 (A)	0,908 (A)	0,612 (B)	0,826 (A)
Greece	0,855 (A)	0,859 (A)	0,935 (A)	0,765 (A)	0,859 (A)
Hungary	0,793 (A)	0,756 (A)	0,912 (A)	0,754 (A)	0,752 (A)
Ireland	0,523 (C)	0,467 (C)	0,664 (B)	0,314 (C)	0,649 (B)
Italy	0,796 (A)	0,874 (A)	0,946 (A)	0,484 (C)	0,880 (A)
Latvia	0,856 (B)	0,722 (B)	0,959 (A)	0,953 (A)	0,791 (A)
Lithuania	0,918 (A)	0,822 (A)	0,961 (A)	0,950 (A)	0,940 (A)
Luxembourg	0,814 (A)	0,816 (A)	0,752 (A)	0,881 (A)	0,807 (A)
Malta	0,752 (B)	0,681 (B)	0,856 (A)	0,708 (B)	0,764 (A)
Netherlands	0,759 (A)	0,825 (A)	0,775 (A)	0,583 (B)	0,851 (A)
Poland	0,680 (A)	0,792 (A)	0,908 (A)	0,291 (C)	0,730 (A)
Portugal	0,833 (A)	0,859 (A)	0,928 (A)	0,649 (B)	0,896 (A)
Romania	0,565 (B)	0,582 (B)	0,730 (B)	0,326 (C)	0,622 (B)
Slovakia	0,650 (B)	0,702 (B)	0,803 (A)	0,290 (C)	0,807 (A)
Slovenia	0,832 (A)	0,790 (A)	0,955 (A)	0,862 (A)	0,721 (B)
Spain	0,888 (A)	0,937 (A)	0,944 (A)	0,807 (A)	0,865 (A)
Sweden	0,752 (A)	0,813 (A)	0,930 (A)	0,447 (C)	0,819 (A)

European Repository of Cyber Incidents (EuRepoC)

Within this research, EuRepoC is employed as the primary outcome dataset to capture the real-world frequency and severity of cyber incidents. Its use allows us to move beyond self-reported capacity measures (such as GCI) and instead evaluate resilience on the basis of empirical incident data.

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Data Extraction. Incident-level data for all EU member states were retrieved from EuRepoC, focusing on the period rele-vant to the other indices (2020–2025).
Filtering. To ensure cross-country comparability, only the time filter was applied; no additional restrictions by type or sector were introduced.
Operationalisation. Two dependent variables were constructed: Incident frequency (number of incidents per country); Incident intensity (average severity based on the EuRepoC 1–15 scale).
I*ntegration*. These variables were used as dependent variables in correlation and regression analyses and as corrective factors in constructing the Digital Resilience Index (DRI). This methodological step enables the study to contrast capacity-based indicators (DESI, AI readiness, GTMI, GCI) with outcome-based indicators (EuRepoC), thereby providing a more comprehensive assessment of digital resilience in the EU. In this research, two derived variables are employed: Number of incidents – cumulative data for the period 2020–2025; Incident intensity – based on the number of sectors affected by a single incident, as well as the estimated scope and duration of the attack (see Table 5).

Table 5. European Repository of Cyber Incidents

European Repository of Cyber Incidents		
Country	Number of cybernetic attacks (2020-2025)	Intension (1-15)
Austria	11	2,90
Belgium	35	2,27
Bulgaria	4	2,5
Croatia	5	4
Cyprus	4	3,25
Czechia	14	1,57
Denmark	14	2,07
Estonia	14	1,58
Finland	12	1,91
France	115	2,98
Germany	136	2,62
Greece	5	3
Hungary	10	2,8
Ireland	3	3,33
Italy	66	2,65
Latvia	6	1,33
Lithuania	11	2,73
Luxembourg	6	2,25
Malta	1	1
Netherlands	36	2,88
Poland	28	2,38
Portugal	12	3,8
Romania	8	2,57
Slovakia	8	2,17
Slovenia	6	2
Spain	50	3,02
Sweden	13	2,54

4. Results

The comparative research in this article employs quantitative indicators for the 27 EU member states to compare their levels of digitalisation, readiness for the implementation of artificial intelligence, and resilience to cyber incidents. The analysis relies on data from the ITU Global Cybersecurity Index 2024 (GCI), the Government AI Readiness Index 2024 (Oxford Insights) – including its two main pillars (Government and Technology Sector) – as well as records on the number and intensity of cyber incidents from the European Repository of Cyber Incidents (EuRepoC).

The central research question was whether significant relationships exist between states' digital and technological maturity and their cybersecurity outcomes. Correlation analysis was selected as the methodological approach because it enables the identification of statistical interdependencies among variables without implying causality. The comparative analysis across 27 EU member states combined data from DESI (public services), the Government AI Readiness Index, the GovTech Maturity Index (GTMI), the ITU Global Cybersecurity Index (GCI), and incident data from the European Repository of Cyber Incidents (EuRepoC). Based on these sources, a new composite measure – the Digital Resilience Index (DRI) – was calculated to

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integrate digital maturity, AI readiness, governance capacity, cybersecurity strength, and real-world incident intensity.

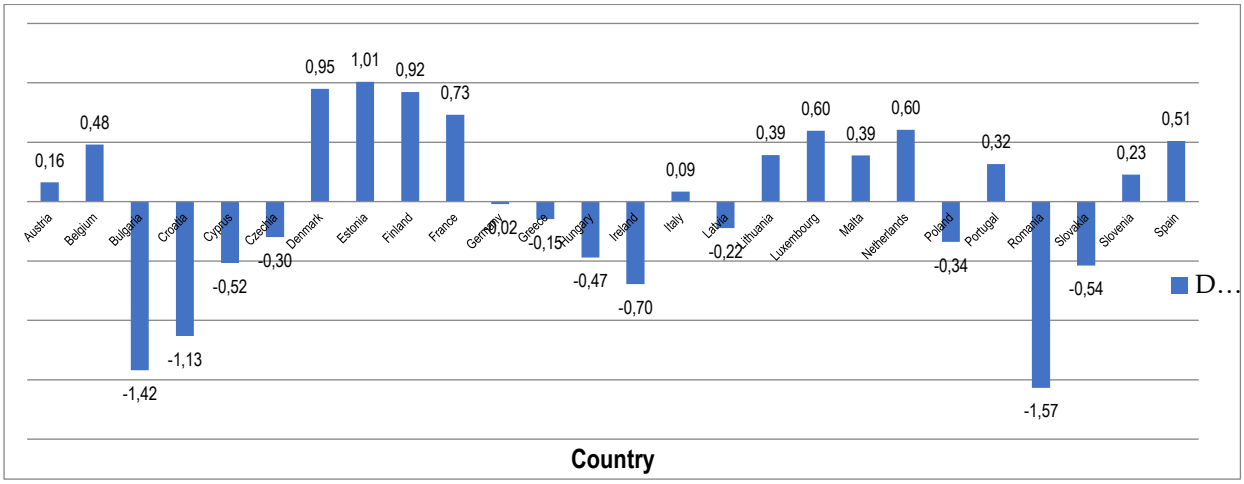


Figure 1. Digital Resilience Index (DRI) by Country in 2024

Figure 1 presents the distribution of the Digital Resilience Index (DRI) across EU member states. The chart highlights clear differences in resilience profiles: countries such as Estonia and Denmark achieve the highest DRI values, reflecting a balanced combination of digital maturity, AI readiness, GovTech capacity, and cybersecurity strength. By contrast, several Central and Eastern European states (e.g., Romania, Bulgaria) show considerably lower DRI scores, indicating gaps between digitalisation efforts and effective cyber resilience. This confirms that resilience is not simply a function of digital service provision (DESI) but depends strongly on governance and security capacity.

Figure 2 shows the correlation of DRI with other indicators. The strongest positive relationships are observed with DESI (r = 0.80), GovTech maturity (r = 0.73), and AI readiness (r = 0.72). The correlation with GCI (r = 0.67) is also substantial, reinforcing the importance of institutionalised cybersecurity frameworks. Interestingly, the number of incidents shows a weaker positive correlation with AI readiness, suggesting that digitally advanced countries may report more incidents due to greater monitoring capacity, while maintaining lower incident intensity.

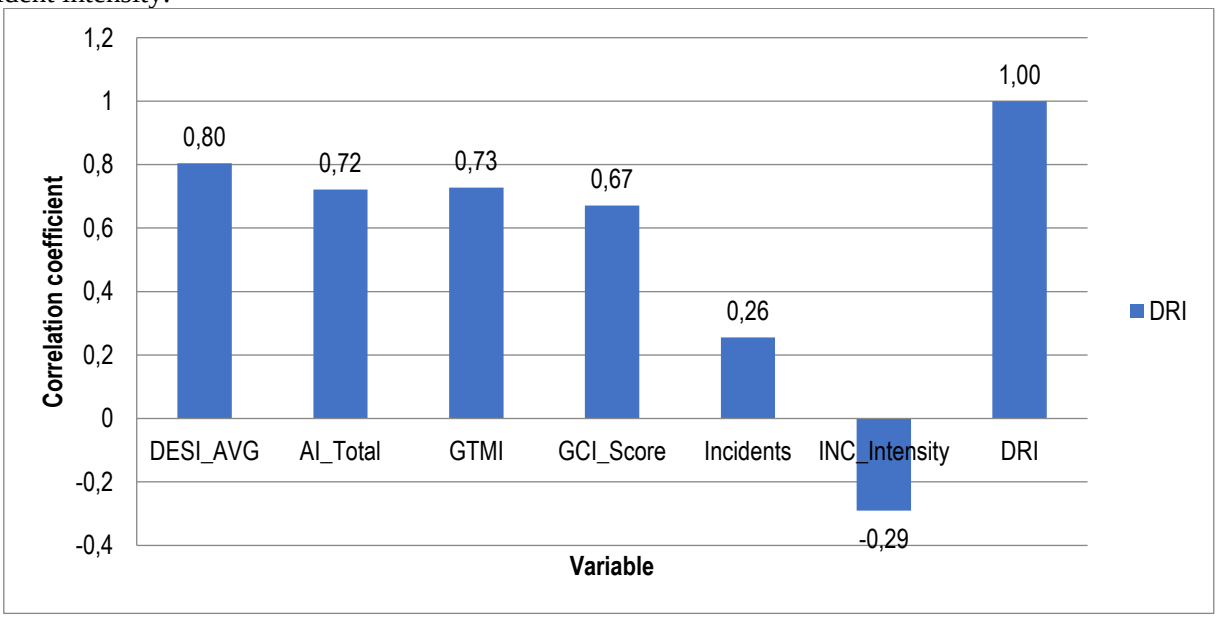


Figure 2. Correlation of DRI with other variables

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Taken together, the graphs demonstrate that the proposed Digital Resilience Index effectively captures the multidimensional character of resilience: it grows where digital maturity, governance, and AI readiness are well aligned, and declines where corresponding investments do not keep pace with rapid digitalisation in cybersecurity. Overall, the results demonstrate that the Digital Resilience Index (DRI) successfully synthesises multiple dimensions of digital maturity and cybersecurity into a single measure. Countries with high DESI, GTMI, and AI readiness scores consistently achieve high DRI values, even if incident frequency is elevated, because the impact of those incidents (intensity) remains limited.

These findings support the claim that digital resilience is not defined by the absence of incidents but by the ability to detect, report, and contain them effectively. The DRI thus provides a novel and holistic way to assess the readiness and resilience of EU member states in the face of growing cyber threats.

The correlation analysis across the 27 EU member states highlights significant relationships between digital maturity, AI readiness, cybersecurity capacity, and cyber incident data. The heatmap of the correlation matrix (Figure 1) summarises all variables. In contrast, the bar chart of incident-related correlations (Figure 3) provides a focused view on how cyber events relate to AI readiness and GCI.

The heatmap shows that the correlation between the Global Cybersecurity Index (GCI) and the AI Readiness Index (total score) is 0.49, representing a moderate positive association. This implies that states with a higher readiness to adopt AI in public administration also tend to score higher in cybersecurity capacity. However, the relationship is not strong enough to suggest causality (Table 6).

Within the AI Readiness Index, very strong correlations were observed: the AI Total score correlates with the Government pillar at r = 0.86 and with the Technology Sector pillar also at r = 0.86. This demonstrates the index's internal logic, in which these pillars are the dominant contributors. Additionally, the correlation between the Government and Technology Sector pillars is 0.53, showing a moderate link between public governance and private-sector innovation (Table 6).

Table 6. Correlation Matrix Heatmap

	AI_Total	AI_Gov	AI_Tech	AI_Data	GCI_Score	Incidents	INC_Intensity
AI_Total	1	0,86	0,86	0,83	0,49	0,54	-0,12
AI_Gov	0,86	1	0,53	0,55	0,4	0,3	-0,42
AI_Tech	0,86	0,53	1	0,72	0,48	0,63	0,16
AI_Data	0,83	0,55	0,72	1	0,33	0,49	0,07
GCI_Score	0,49	0,4	0,48	0,33	1	0,29	0,14
Incidents	0,54	0,3	0,63	0,49	0,29	1	0,14
INC_Intensity	-0,12	-0,42	0,16	0,07	0,14	0,14	1

The bar chart illustrates that the number of incidents is most strongly correlated with the Technology Sector pillar (r = 0.63), followed by Data & Infrastructure (r = 0.49). These results indicate that digitally advanced countries record more incidents, likely due to stronger monitoring and reporting systems rather than higher vulnerability (Figure 3).

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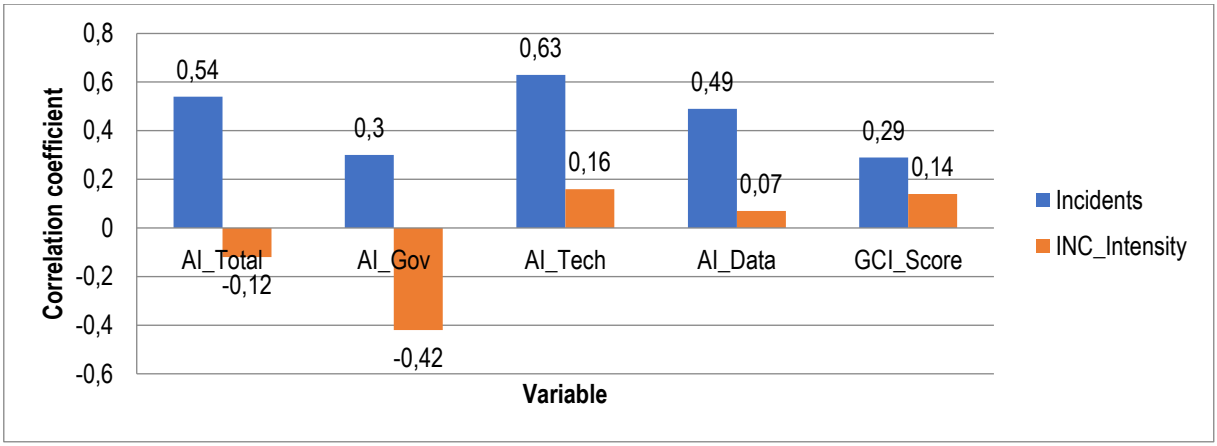


Figure 3. Correlation of Incidents and Intensity with AI Readiness and GCI

Incident intensity shows a different pattern. The correlation between Government pillar and incident intensity is –0.42, a moderate negative relationship, suggesting that stronger governance reduces the severity and duration of cyberattacks. The correlation between AI Total and incident intensity is weaker (r = –0.12), indicating a limited but still relevant effect of overall AI readiness on mitigating incident impact. In contrast, the correlation between GCI and the number of incidents is 0.29, a weak positive link. This underscores that the ITU GCI, with its focus on institutional and policy frameworks, does not directly capture the operational reality of cyberattacks.

Summary of Findings

• GCI × AI Total: r = 0.49 (moderate positive)
• AI Total × Government pillar: r = 0.86 (very strong positive)
• AI Total × Technology pillar: r = 0.86 (very strong positive)
• Government × Technology pillar: r = 0.53 (moderate positive)
• Incidents × Technology pillar: r = 0.63 (strong positive)
• Incidents × Data & Infrastructure: r = 0.49 (moderate positive)
• Government × Incident Intensity: r = –0.42 (moderate negative)
• AI Total × Incident Intensity: r = –0.12 (weak negative)
• GCI × Incidents: r = 0.29 (weak positive)

Overall, the results confirm that incident frequency is not a direct proxy for vulnerability, but may instead indicate the strength of monitoring and reporting mechanisms. Incident intensity emerges as a more meaningful resilience indicator because it reflects states' ability to detect, contain, and recover from attacks. The combination of these findings supports the use of composite measures such as the proposed Digital Resilience Index (DRI) to provide a more holistic view of resilience.

Comparative Insights

The scatterplot in Figure 4 highlights clear differences between digital frontrunners and laggard countries in the EU. Top performers such as Denmark, Finland, and Estonia combine high DESI scores (above 90) with equally high GCI scores (close to 100). These states illustrate how strategic investment in e-government services, cybersecurity frameworks, and AI governance can reinforce each other, creating a virtuous cycle of resilience. They serve as potential benchmarks for EU-wide best practices. Laggard countries, particularly Bulgaria and Romania, occupy the lower end of the scatterplot. Bulgaria demonstrates both low DESI and GCI scores, reflecting structural challenges in digital service provision and cyber capacity. Romania presents a more mixed profile, with relatively stronger GCI scores compared to its DESI values, suggesting a policy emphasis on security frameworks even in the absence of fully developed e-services. Intermediate states such as Latvia and Cyprus indicate uneven progress. While Cyprus shows relatively strong cybersecurity (high GCI) despite a lower DESI, Latvia lags in GCI despite moderate DESI performance. These discrepancies reveal that national strategies may prioritise either service provision or security frameworks, but not both simultaneously (Table 7).

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Table 7. Comparative Overview of Digital Public Services (DESI) and Cybersecurity Capacity (GCI) in EU Countries

Country	DESI_AVG	GCI_Score
Austria	83,03	89,16
Belgium	86,24	96,81
Bulgaria	72,72	74,56
Croatia	75,33	87,75
Cyprus	70,29	98,02
Czechia	70,5	87,94
Denmark	90,64	100
Estonia	94,41	95,04
Finland	91,35	100
France	78,42	98,98
Germany	71,62	93,84
Greece	78,85	97,11
Hungary	76,56	88,73
Ireland	76,53	90,9
Italy	70,42	100
Latvia	85,09	82,63
Lithuania	88,71	92,88
Luxembourg	89,16	98,72
Malta	95,89	92,96
Netherlands	88,7	99,22
Poland	75,67	93,54
Portugal	83,35	99,86
Romania	51,84	91,62
Slovakia	71,93	94,44
Slovenia	81,27	96,48
Spain	84,59	99,74

From a policy perspective, the findings underline that balanced development is critical: advancing digital public services without a proportional investment in cybersecurity can expose states to heightened risks, while focusing exclusively on security without improving service maturity may limit the benefits of digital transformation.

Table 8. Bootstrap estimates of correlation coefficients with 95% confidence intervals

Pair	Pearson_r	Pearson_95%CI	Spearman_r	Spearman_95%CI
DESI × GCI	0,291	(0.008, 0.54)	0,297	(-0.087, 0.658)
AI_Total × Incidents	0,546	(0.342, 0.722)	0,652	(0.342, 0.871)
AI_Total × Intensity	-0,098	(-0.509, 0.351)	-0,033	(-0.443, 0.39)
DESI × Incidents	-0,139	(-0.451, 0.197)	0,039	(-0.373, 0.478)
GTMI × AI_Total	0,329	(-0.041, 0.66)	0,303	(-0.099, 0.659)

Table 9. Pearson and Spearman correlation coefficients between digital maturity, AI readiness, cybersecurity capacity, and incident outcomes

	Spearman						Pearson					
	DESI	AI_Total	GCI	GTMI	Incidents	Intensity	DESI	AI_Total	GCI	GTMI	Incidents	Intensity
DESI	1,0000	0,3415	0,3041	0,5610	0,0315	-0,3443	1,0000	0,3944	0,2808	0,6043	-0,1441	-0,3299
AI_Total	0,3415	1,0000	0,5067	0,3108	0,6688	-0,0311	0,3944	1,0000	0,4856	0,3189	0,5436	-0,1226
GCI	0,3041	0,5067	1,0000	0,3124	0,4711	0,0996	0,2808	0,4856	1,0000	0,2898	0,2868	0,1355
GTMI	0,5610	0,3108	0,3124	1,0000	0,3608	-0,0407	0,6043	0,3189	0,2898	1,0000	0,2259	-0,1336
Incidents	0,0315	0,6688	0,4711	0,3608	1,0000	-0,0017	-0,1441	0,5436	0,2868	0,2259	1,0000	0,1377
Intensity	-0,3443	-0,0311	0,0996	-0,0407	-0,0017	1,0000	-0,3299	-0,1226	0,1355	-0,1336	0,1377	1,0000

Robustness Check and Correlation Analysis

To assess the stability of the findings, we complemented Pearson's correlation coefficients with Spearman's rank correlations and applied bootstrap confidence intervals (2,000 replications, 95% CI) (Table 8). The results show that most associations remain consistent across both methods, suggesting that the relationships identified are not merely linear artefacts but also hold under monotonic transformations. The strongest and most robust association was observed between AI readiness and the number of reported cyber incidents (Pearson r = 0.55, 95% CI [0.34, 0.72]; Spearman r = 0.65, 95% CI [0.34, 0.87]). This finding supports the interpretation that

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digitally and technologically advanced states tend to report more incidents, likely due to more sophisticated monitoring and reporting mechanisms.

By contrast, the relationships between DESI and GCI (Pearson r = 0.29; Spearman r = 0.30) and between AI readiness and incident intensity (Pearson r = –0.10; Spearman r = –0.03) were weak and statistically unstable, as their confidence intervals included zero. Similarly, correlations between DESI and the number of incidents showed no consistent pattern, with Pearson indicating a slight negative trend and Spearman a negligible positive trend. Finally, the link between GovTech maturity and AI readiness showed a positive trend (Pearson r = 0.33; Spearman r = 0.30), but bootstrap intervals indicated that this relationship is not robust across all resamples (Table 9).

Taken together, these robustness checks highlight two important insights. First, the association between AI readiness and incident frequency is the most reliable, reinforcing the argument that increased digital and AI maturity is linked to higher transparency and reporting rather than higher vulnerability. Second, correlations with incident intensity remain weak, indicating that resilience is not a matter of reducing the number of attacks but of mitigating their severity. This methodological triangulation strengthens the credibility of the results and provides a more nuanced understanding of how digital maturity, AI readiness, and cybersecurity resilience interact across EU member states.

5. Conclusions and Discussion

RQ1: What is the relationship between the digital maturity of EU member states (DE-SI) and their cybersecurity capacity (GCI)?
The analysis indicates a moderate positive correlation (r = 0.49) between DESI scores for digital public services and GCI cybersecurity capacity. The scatterplot (Figure 4) with a regression line demonstrates a slightly upward trend: states with higher levels of digitalisation tend to report stronger cybersecurity frameworks. However, the relationship is not deterministic. Some states, such as Romania, achieve relatively high GCI despite low DESI scores, while others, such as Latvia, show the reverse. These findings suggest that digitalisation efforts are frequently accompanied by stronger cybersecurity, but in several cases, the pace of digital service provision exceeds the development of security mechanisms.

RQ2: How does GovTech maturity influence the ability of states to integrate AI responsibly into public administration?
The results demonstrate a strong positive correlation (r > 0.70) between the GovTech Maturity Index (GTMI) and the Government AI Readiness Index. Countries with higher GovTech capacity—measured by digital infrastructure, core systems, and citizen engagement—consistently achieve higher readiness for AI adoption in public administration. This pattern suggests that GovTech maturity functions as a precondition for AI readiness, as governance structures, institutional frameworks, and digital infrastructure enable ethical and responsible AI integration. High-scoring states such as Estonia, Finland, and France exemplify how GovTech development supports AI deployment in alignment with legal, ethical, and technical safeguards.

RQ3: Do higher combined scores in digitalisation and AI readiness correspond to fewer and less severe cybersecurity incidents (EuRepoC data)?
The findings are mixed. Countries with higher DESI and AI readiness scores tend to report more incidents, as reflected in positive correlations with incident frequency (r = 0.63 for Technology Sector pillar). This counterintuitive result reflects stronger monitoring, reporting, and transparency mechanisms rather than higher vulnerability. By contrast, incident intensity shows a negative correlation with AI readiness and governance pillars (r = –0.42). This suggests that digitally advanced countries are better able to contain attacks, reduce their duration, and mitigate damage. Thus, higher scores in digitalisation and AI readiness do not reduce the number of attacks but are associated with greater resilience and lower incident severity.

RQ4: Can the integration of DESI, GCI, GovTech, AI readiness, and EuRepoC datasets provide a new composite indicator that more accurately reflects the balance between digital maturity and cyber resilience?

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Yes. The proposed Digital Resilience Index (DRI) integrates DESI, GCI, GTMI, AI readiness, and incident intensity into a composite score. Results show that DRI correlates strongly with DESI (r = 0.80), AI readiness (r = 0.72), and GovTech maturity (r = 0.73), while maintaining a substantial correlation with GCI (r = 0.67).

Importantly, DRI penalises states with high digitalisation but high incident intensity, thereby capturing not only maturity but also real-world resilience outcomes. Top performers such as Denmark and Estonia combine high digital maturity with low-intensity incidents, resulting in the highest DRI values. In contrast, Romania and Bulgaria score much lower due to weaker resilience despite progress in digitalisation. These results confirm that the DRI provides a novel and holistic measure of the balance between digital transformation and security capacity.

This research contributes to the growing body of research examining the intersection between digital maturity, AI readiness, and cybersecurity resilience in the public sector. By integrating multiple international datasets (DESI, GCI, GovTech Maturity Index, AI Readiness Index, and EuRepoC), we demonstrated that resilience cannot be equated with the absence of cyber incidents but rather reflects the ability to detect, contain, and mitigate their effects. The proposed Digital Resilience Index (DRI) offers a novel, multidimensional measure that accounts not only for institutional and technological maturity but also for operational outcomes such as incident intensity.

The findings align with prior studies that highlight the need to embed security-by-design principles in digital government initiatives (ENISA, 2023; Waara, 2025) and to recognise cybersecurity as a fundamental governance capacity rather than a purely technical concern (Thakur, 2025). Importantly, the observed strong relationship between GovTech maturity and AI readiness echoes conclusions from recent scholarship that robust institutional capacity is a prerequisite for the ethical and responsible integration of AI. At the same time, the counterintuitive positive correlation between digital maturity and incident frequency supports the argument that incident-reporting intensity often reflects stronger monitoring systems rather than greater vulnerability. This reinforces the call for more outcome-oriented resilience indicators. By proposing a behavioural detection framework, this article moves beyond descriptive benchmarking and provides a technical blueprint that operationalises resilience at the micro level.

The novelty of this study lies in three contributions:
Integrative design – By combining DESI, GCI, GovTech maturity, AI readiness, and EuRepoC data, we provide a multidimensional view of resilience that bridges capacity-based and outcome-based indicators;
Introduction of the Digital Resilience Index (DRI) – A new composite measure that corrects for incident intensity, thus capturing not only preparedness but also operational effectiveness in managing threats;
Policy relevance – the framework explicitly addresses calls from ENISA (2023) and the Public Sector Network (n.d) to embed security-by-design principles into digital government strategies, aligning innovation with resilience.

Taken together, the results and proposed framework support three key recommendations for EU policymakers: (1) integrate security-by-design into all digital transformation initiatives, (2) leverage GovTech reforms as a foundation for AI adoption, and (3) employ composite indices such as the DRI for benchmarking and targeted support.

In this way, the study builds upon existing theoretical work while filling a critical gap: moving from fragmented indicators to an integrated, policy-relevant assessment of Europe's digital resilience.

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Data Availability Statement: All data used in this study are publicly available. The Digital Economy and Society Index (DESI) can be accessed through the European Commission's digital public services portal. The Government AI Readiness Index data are available from Oxford Insights (2024). Cybersecurity capacity scores are retrieved from the ITU Global Cybersecurity Index (GCI 2024). Data on cyber incidents were obtained from the European Repository of Cyber Incidents (EuRepoC 2025). No new data were created by the authors.

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THE IMPORTANCE OF INTANGIBLE ASSETS IN TODAY'S DIGITAL ECONOMY*

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Abstract. The right perspective on intangibles can change the views of management, accounting professionals and clients alike. The changes will continue to evolve, so it is very important to understand the conditions and factors that have shaped the current economy: the internet, globalisation, and consumer preferences. The knowledge and digital economies are closely intertwined; intellectual capital is now no less important than technology. Thus, intangible assets are driven by both human resources and artificial intelligence because the digital economy was designed by people, for people, and built on knowledge. The paper approaches intangibles from different perspectives, for example, the accounting perspective looks at their classification, valuation and reporting in financial statements; the psychology perspective looks at the perception of value and the impact on behaviour in decision making; the marketing perspective looks at brands, customers, and the ethics perspective focuses on the relationship between intangibles and social life. The shift in focus from physical production to knowledge generation is a key benchmark in the evolution of intangibles within enterprises' asset structures. Creativity, through the development of patents, know-how or technological performance, is increasingly contributing to the creation of more value. Regulating the recording of intangibles is complex. Still, because intangibles are present in all areas of activity, the rules need to be as clear as possible so that companies' financial positions are presented as transparently as possible.

Keywords: intangible assets; digital economy; artificial intelligence; intellectual capital

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JEL Classifications: M41, J24, O15

1. Introduction

Since some processes rely primarily on intangibles as their main resource, their role in today's economy is growing. It has been found that, due to entities' desire to occupy a leading position in rankings generated by the competitive market, they invest more in intangible than in tangible assets, because the latter are easy to copy and implement (Ocak & Fındık, 2019). The increasing use of the concept of intangible assets is justified by the finding of differences between an organisation's market value and its net book value. Specialists in the field considered it necessary to study the causes that led entities to record different results, despite having the same financial, physical, and human resources.

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The most commonly used categorisation of intangible assets is that of intellectual capital, namely human, relational, and structural capital. Some authors argue that a clear distinction between the concepts of intellectual capital and intangible assets is necessary, with the former being divided into realised potential that leads to increased economic value added. At the same time, the latter emphasises that intangible assets are only a part of intellectual capital (Caloghirou, Piekkola & Bounfour, 2025). It must be recognised that competition for natural resources has not stagnated; countries are still fighting for the most valuable resources. In recent years, however, the fight for the most valuable employees has also intensified: football, medicine, and IT. Ownership of tangible and intangible assets can affect the balance of power, the direction and level of investment, prices, and the production of goods and services, thereby contributing to economic growth.

The intangibility of assets is a current topic of great interest to both large companies and small and medium-sized organisations. The issue of their valuation is the subject of many conferences and articles, all the more so as the emphasis on knowledge combined with the use of artificial intelligence (AI) is one way for organisations to adapt to today's economy.

The purpose of the present research is to bring together the scattered theoretical approaches to intangible assets found in accounting, marketing, ethics and healthcare literature, and to outline the path through which intangible assets are traced from the knowledge economy to the digital economy, supported by recent statistical evidence at the European Union level.

To achieve this, the paper relies on a review of recent academic literature on intangible assets and intellectual capital, complemented by statistical data published by Eurostat. The literature review is used to identify the conceptual milestones in the recognition and evolution of intangible assets. At the same time, Eurostat data illustrate the determinants driving the transition from the knowledge economy to the digital economy.

2. Intangible assets - concept and perspectives

Given the major changes in the global economy, companies are continually seeking innovative solutions that respond as quickly and effectively as possible to the needs and requirements set by regulatory bodies. Because the pace of change is fast, competitive advantage goes to those who not only adapt but also propose reliable, compelling solutions that maintain customer attention and loyalty. One of the most widely used concepts in recent years is intangible assets. The focus on intangible assets has increased, as their contribution to the company's performance is considered to be much greater, and methods are being sought to reflect them as transparently as possible in the financial statements. Intangible assets are a modern concept, though the term has been used in specialised literature for a long time, with intangible assets (IA) being used most frequently.

The explanatory dictionary of the Romanian language defines an asset, in the context of economic operations, as a concrete element of a patrimony that is an integrated part of the balance sheet, and an intangible as something that cannot be touched and must be kept intact.

The Accounting Dictionary defines an intangible asset as a non-physical asset with a life span of more than one year, without physical substance, and important to business activity, such as a franchise contract, software, customer list, trademark, or artistic goods (movies, videos). It also states that the defensive asset is that intangible acquired by a firm so that competitors will not use it; leasehold improvement is that improvement to a leased property, and amortisation is made over the shorter of the useful life or the lease term, and the initial recognition of intangibles purchased by the firm should be at fair value. The marketing dictionary emphasises that intangible assets cannot be touched in kind; they generate revenue or other financial benefits and include trademarks, patents, and customer lists.

One of the definitions of intangibles frequently encountered in the literature is the dynamic intangible investment, which comprises a predominant knowledge component that makes a characteristic contribution to the entity's value and competitiveness. Through his work, Polanyi (1958) piqued the interest of other researchers in the concept of tacit knowledge, and later Nonaka and Takeuchi (1995) wrote about the knowledge-creating entity, inspiring the subsequent formulation of intangible asset principles.

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Intangible assets are items without physical form that have a substantial input in the production of goods or provision of services and from which the firm seeks to derive future productive benefits. Intangibles are assets other than tangible assets that are identifiable by their physical form but can be acquired by the entity, including intellectual property, patents, and goodwill (Firmansyah, Umar & Musa, 2024). From the same author's perspective, the brand name is considered indefinite, while the legal agreement or contract is considered a definite intangible asset. Other scholarly sources define intangible assets as sources of an organisation's value creation, based on employee capabilities, resources, operating strategy, and shareholder relations (Gutierrez & Villavicencio, 2024; Anderson, Mendoza & Mongold, 2025).

In 2001, the International Accounting Standards Board adopted IAS 38, which defines intangible assets as resources that have arisen from past events, for which control is vested in the organisation, and from which economic benefits are expected to flow to the organisation in the next period (IAS 38, 2001). IAS 38 exemplifies identifiable, non-monetary intangible assets without physical substance, such as licenses, patents, software, intellectual property rights, and trademarks. The two categories covered under the Standard are goodwill and research and development expenditure. In support of the concept, some authors have supplemented this definition with similar qualifying conditions: intangible assets are not physical in nature, have the capacity to generate future net economic benefits, and are legally protected by a de facto right (Dong & Doukas, 2025). Intangible assets are fixed assets without a tangible form, such as legal or commercial acts that give the entity certain freedoms, namely: research and development expenditure, concessions, patents, manufacturing licenses, trademarks, goodwill, and computer software. Representative categories of intangible assets are illustrated in Figure 1.

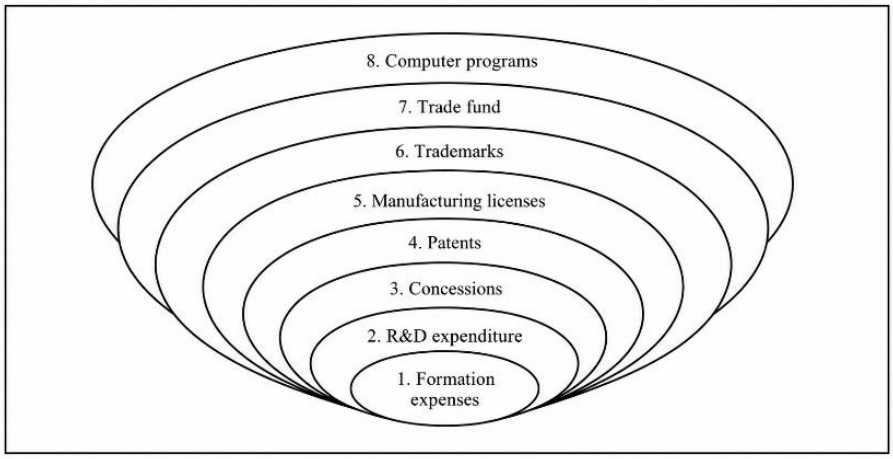


Figure 1. Representative categories of intangible assets
Source: authors' own processing

The cost of intangible assets can be reliably measured if firms report them as assets. In Romania, firms listed on the Bucharest Stock Exchange must prepare their financial statements in accordance with IASB guidelines. Thus, intangible investments made by firms are recognised as assets in their financial statements if they comply with the IASB's reporting criteria (Ionita, 2020).

The specialised literature identifies a wide range of intangible asset components, including patents, copyrights, trademarks, software, formulas, trade secrets, capitalised research and development, goodwill, databases, human capital, customer lists, customer loyalty, licenses, market share, and marketing rights (Wyatt, 2005; Penman, 2023). Brands can only attract customers and increase demand if they are coupled with innovation and change, ensuring future gains. It plays an important role in today's economy through consumer loyalty, innovation, and branding skills. To differentiate their products and services from those of other companies, to expand into new markets, and to protect their goodwill, firms use trademarks, which are considered the most valuable intangible assets generated and diversified through people's perseverance and approach (Bongaerts, Kang & van Dijk,

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2026). Loyalty, level of knowledge, quality and consumer interest are intangibles with direct implications for the company's future performance. Tangible assets differ from intangibles in their degree of utilisation. The more often fixed assets are used, and the longer the period, the lower the marginal benefit. On the other hand, the more often we use intangibles, and here we mean knowledge, the higher the return. A medical device can only be used at the same time in one place, whereas knowledge can be used over the same period of time in different locations.

Goodwill is another intangible at the centre of research studies. Its impairment affects the entity's expenses and performance, reducing the predictability of profitability (Li et al., 2011) and resulting in lower cash flow (Bostwick, Krieger & Lambert, 2016). According to accounting classifications, intangible assets rank second in size after property, plant and equipment (PP&E). They are generally divided into two categories: identifiable (trade secrets, patents, software, intellectual property) and non-identifiable (brand, reputation, goodwill). Goodwill represents the future economic benefits arising from assets that cannot be individually identified and recognised separately, indicating the difference between the cost of acquiring a business and the fair value of the identifiable assets and liabilities acquired.

Research and development expenditure addresses the issue of recognising it as an expense when it arises as an asset, with the mandatory condition requiring both a probability of future economic benefits and a reliable measurement of the cost. IAS 38 includes in the category of research expenditure activities that cannot be recognised as an asset, such as the pursuit of new knowledge, the search for and evaluation of product or process alternatives, and the formulation and design of new alternatives to existing products or processes.

In the literature, we find many terms used to describe intangible assets: intangible assets, intellectual assets, invisible assets, knowledge assets, and digital assets. Intangible assets is the term used in the accounting literature; knowledge assets is a term largely used by economists; and intellectual capital is used in the management and law literature. Knowledge in all its forms is the most valuable intangible resource (Bratianu & Bejinaru, 2019; Roth & Mitra, 2025).

The idea of non-material assets, whose trump card is long-lasting benefits (formulas, technology, special privileges). Regardless of the syntagma, the idea is the same: tangible benefits are not materially realised; they represent valuable non-physical sources, unique organisational models, or human resource practices. Referring to the group of assets with no real form, records that these are components of intellectual, even industrial property, that are provided by legislation and are found in the balance. The advantages of intangible assets for competitiveness and their impressive capacity to improve products and services offered to the market (Intara & Suwansin, 2024).

The intangibles perspective covers several fields: accounting, information technology, sociology, psychology, human resource management, education and development (Yue & Zhao, 2026). Some of the basic ideas are summarised in Figure 2 below.

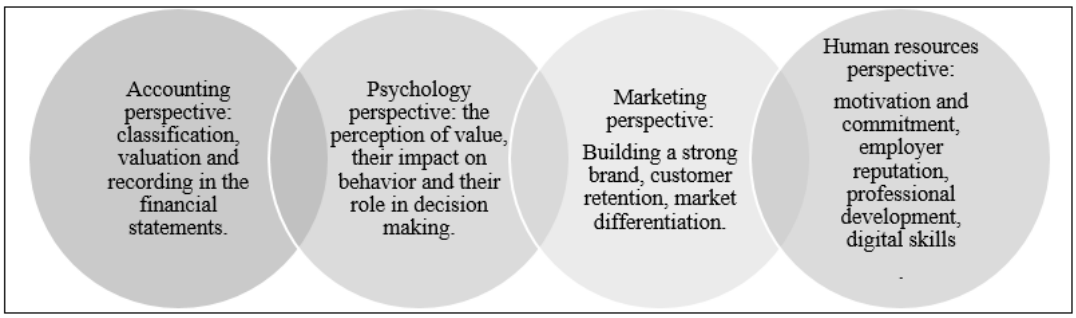


Figure 2. Different fields' perspectives on intangible assets
Source: authors' own processing

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The accounting perspective aims to refine the criteria for recognition on the balance sheet and to conduct a comprehensive analysis of the conditions that intangible assets must meet to be reliably measured at fair value. Current accounting records investments in intangible assets under current expenses, treating current income gains as a component of investments (Barker et al., 2021), and the balance sheet needs to be consistent with the income statement because it increases the investment's added value in the balance sheet. Another situation at the centre of regulators' attention is the development of precise rules for intangibles that the company produces or constructs. Quantifying the initial price that centres on the expenses directly attributable to creation, acquisition, and development; selecting an amortisation schedule that covers the period during which economic benefits are expected; and ensuring transparency in identifying intangible assets of interest to investors and management are among the concerns of experts in the field. Their subjective nature, influenced by the specific context of their use, makes it difficult to apply the same calculation to all entities. At present, the market, revenue and cost comparison methods are the most widely accepted in specialised practice (ANEVAR, 2022). The challenge is all the greater, as there is a need for a distinct valuation of intellectual capital and the assets generated by artificial intelligence, to determine the net impact of the new technology.

From a marketing perspective, intellectual capital as an intangible asset is perceived as a company's ability to understand information from both inside and outside the firm, to establish professional partnerships with business influencers, to apply market opportunities and potential faster than competing firms, to enhance its intellectual productivity and to increase its intangible assets. A company's reputation is based not only on intellectual capital but also on the image of its management team, which lends the entity prestige. It implies a set of intangible assets, both quantitative and qualitative. The organisation's future activities should include training, R&D, and marketing. Intangible assets in the marketing context refer to brands, brand names, and customer-related assets. The company's ability to adapt to strict rules while maintaining its identity provides a real competitive advantage. Similar assets may be critical in one hypothetical situation, but insignificant in another. The increased level of competition has emphasised the need for companies to develop customer knowledge and build customer loyalty. The rigorous rules of the market require generating value through innovation, design, utility, and unique experiences. Marketing strategy, by including elements of novelty and added value in products, matters as much as production facilities or material capital. At present, there are limited opportunities for managers to record these intangible assets, which diminishes the quality of the balance sheet and the information available to investors (Xiong et al., 2022).

In the literature, the relationship between intangible assets and ethics is of particular interest. From this point of view, emphasis is placed on social construction, permanent dialogue, collaboration between the institution and the actors involved, and the cultural relationship between intangibles and ethical resources. Identity, brand and reputation can generate competitive advantage. Still, the circumstances and conditions must be established in such a way that they do not contravene the moral principles of the parties. Vision, goals, mission, culture, communication systems, organisational structures, and strategies are some of the attributes of identity (Melewar, 2003). Brand can be defined as the aspirations collaborators have as a result of the other party's peremptory commitments (Song, 2025).

In corporate asset management, to maximise results, the evaluation of the firm's reputation should be conducted with ethical sensitivity (Leitter, Koonce & White, 2025). Firms that deliver products and/or services that meet their promises will gain an advantage in their reputational ranking. The credibility of the ethical management of intangibles may affect the business environment, and firms that pursue profit as their sole goal in the shortest possible time may make decisions without adhering to moral or ethical principles. Intangible capital can lead to inequality, difficulties in achieving performance, reduced employee input, and, especially, loss of trust (Uribe, 2025). It is imperative to maintain a balance among profit growth, value generation, and the execution of social commitments.

A study by Gambetti et al. (2017) presents different international rankings and indexes such as the Reputation Coefficient ranking the most reputable companies, Fortune's ranking of the most admired firms, Millward-Brown's ranking of the most highly regarded brands, Each company on these lists has among its main objectives environmental sustainability, diversity management, transparency of company behaviour, social responsibility, quality/work-life balance, talent acquisition/management, corporate citizenship. In the field of medicine,

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intangible assets are increasingly influencing the financial statements of medical institutions. Human, relational, and structural capital are representative elements of entities that provide healthcare services (Rider et al., 2019).

In all activities in this field, human capital is a driver of innovation, contributing to the distribution of technical and organisational evolution. Relational capital refers to a company's connections with the external environment. Formalities, the strategy for creating new partnerships, and associations related to brand reputation are important pillars in a medical establishment. According to Aramburu and Saenz (2011), structural capital refers to the practices of analysing data, strategising, and setting policies. Competitive advantage can be achieved by leveraging interactions and knowledge sharing through digital platforms. Constant and interconnected management of intangibles stimulates innovation and organisational restructuring (Park et al., 2024). Strategic market access visions have a significant influence on healthcare development and management, especially in the introduction of new pharmaceuticals, drugs or medical devices.

In the context of utilising relational capital, market access managers of pharmaceutical firms have expanded their knowledge and strategies in pricing and reimbursement, public affairs, and supply clauses to optimise the launch of drugs or medical devices. On the other hand, the value of a product increases with the use of integrated digital services, and digital transformation is a prerequisite for information sharing, increasing the number of end-users and removing obsolescence between providers and knowledge sharing. The transmission of real-time information and the large-scale use of information technology in health have often led to improved statistics on the number of service recipients, especially since, in this sector, the timing of intervention or action with a specific type of product is decisive in solving a problem. We are referring not only to doctor-patient and patient-drug interaction, but also to the context and speed of information transmission between specialists. Rogers (2003) emphasised the role of knowledge and innovation in the medical field by proposing 5 stages in the decision-making process: knowledge, persuasion, decision, implementation and confirmation. Research, innovation and performance are based on the best possible management of knowledge, because in medicine, all those involved, including patients, through their ability to manage information, contribute to the orientation towards effective treatment practices and schemes. An institution with an organised knowledge management system will manage much more effectively and, as a result, be more operational and productive. Even if innovation theories have often intersected with economic or political factors, this is not necessarily a negative thing, especially since no field has a perfect balance and constant profit. We point to the creation of new business models during periods of intense telemedicine use. The delivery of certain drugs or medical products during the COVID-19 period was not only a health issue but also a global political, economic, and social issue. Intellectual capital becomes an intangible asset that makes a considerable contribution to the evolution of a healthcare organisation, with complex implications for both research and innovation processes and for future economic benefits derived from establishing commercial relationships among system collaborators. All the more so, as digitisation of the healthcare system offers new opportunities to create added value and economic benefits. Patients can often suffer due to organisational management and system gaps. For this reason, regulatory processes need to be established in collaboration with all stakeholders, including international, national, and regional agencies, as well as collaborators, providers, and patients.

One of the challenges in recognising and recording intangible assets is the risk: tangible assets are considered lower-risk and easier to value. Their impact on the various sectors of the economy gives them a much greater role in financial statements than they have hitherto had. Today's definitions of these items are therefore much more complex and require updated regulations.

3. Milestones in the evolution of intangible assets in companies' balance sheet structure

It is easy to see how much our routines have changed compared with those of the same age groups 20 years ago. Even if the stages of life are almost unchanged, in our everyday life, we use different techniques, new tools, and new models of household appliances. Our professional activity adheres to fundamental principles, but we are always operating with new technology; we are constantly looking for ways to facilitate task completion, and we are much more competitive. Companies cannot ensure success or performance if they fail to meet expectations or impress. In an economy where the battle for performance is fierce, identifying and attributing the smallest element of novelty can offer substantial advantages. Tangible assets (buildings, equipment) remain

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indispensable tools of production, but attributing business success without specifying the value and quantity of tangible resources does not ensure transparency.

It is clear that we can no longer talk only about physical, tangible assets when discussing innovation, and that a society that does not progress risks falling behind in its pace of development. The globalisation of the economy, the replacement of old regulations, the adaptation of the economy to modern needs in telecommunications, transport, and financial services, the emergence of new brands, increased competition, and the growing use of information technology are some of the factors that have increased interest in intangible assets. The increasingly frequent discussions and debates linking the company's ownership structure and intangible assets are indeed challenging. The need arises from discrepancies between market and book value caused by imperfections in the categorisation and grouping of intangible assets and related items, as well as in their quantification, recording, and reporting in financial statements. It is proposed to delimit the sub-account for accounting directly with software, with a sub-account for accounting for firmware for software devices, fixing current intangible assets in a separate account, monitoring internal goodwill for the purpose of highlighting the entity's assets throughout its current activity, as well as their presentation for sale, depending on the circumstances. The same author proposes initiating analytical accounts for internal goodwill, allowing for the separation of intellectual assets by type (human, customer, organisational, environmental, social, personal internal goodwill, and intangible assets associated with contracts).

The research on this topic is useful for identifying gaps and shortcomings, and for identifying possible rules and principles that would ensure proper valuation and clear delineation of resources. Intangible assets have evolved with the changing world, and their distinct role in the enterprise capital structure is becoming increasingly evident.

One of the important milestones in this context is globalisation and intensifying competition, which have provided the prerequisites for accounting for intangible assets. The harmonisation of Accounting Standards and the adoption of the International Financial Reporting Standards (IFRS) by most countries have provided important support for the valuation of patents, trademarks, goodwill, and other intellectual property. Financial comparability enables global data analysis, technology transfer, and innovation; supports the use of intangibles by both large and small firms; and advances the idea of clear and fair reporting through access to capital markets. Accurate data and accurate reporting of asset positions boost investor confidence and make it easier to raise finance. Globalisation offers advanced methods for valuing this category, enabling firms to manage associated risks better and influence cultural and social perceptions of the importance of intangible assets. Their accounting and reporting should be done regardless of the degree of appreciation in particular regions.

Another important benchmark concerns the shift of emphasis from physical production to knowledge creation and exploitation. Innovation cannot happen without research and hypothesis testing. This is why education and intellectual capital are critical to the economy. The development of patents, know-how, and advanced technology is a response to the stimulation of creativity. Presenting and analysing collected data correctly leads to the refinement of services and products that are not necessarily physical, such as software, online platforms, and cloud-based services. The digital economy has prompted companies to focus more on leasing solutions, maintenance, and support services than on selling equipment. The labour market is seeking advanced cognitive skills, such as creative thinking and programming. The discouragement of repetitive activities in favour of innovative solutions that make it easier to perform job-related tasks is common. The use of artificial intelligence and advanced technology enables remote working for online content creators, floral stylists, film directors, journalists, tax consultants, accountants, insolvency specialists, and lawyers. The accounting recognition of intangible assets under International Accounting Standard (IAS) 38 is a key landmark in companies' capital structures. Allocating more and more resources to R&D creates the conditions for innovation and a growing portfolio of intangible assets. Employees' experience and the ability to apply skills in executing activities have become important strategic resources, and the brand can influence consumers' purchasing decisions. Knowing customers and working hard to deliver on promises can generate long-lasting future economic benefits.

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The literature highlights three variables that may be important elements in the dynamics of intangibles: organisational learning and potential that is focused on the particular firm's resources needed to build the intangibles portfolio (Penrose, 1959), technological synergies, which with the achievement of advantages can create inequalities and fair distribution influenced by heterogeneity, the possibility of large companies to invest more in R&D, patents can create barriers to entry for new competitors. The third is the signalling of the business environment and the economic sector, which emphasises the urgency of expanding methods and approaches to building intangibles to narrow the information gap between suppliers and customers, sellers and buyers.

It is worth noting that when intangible investments were first quantified at an accepted level in the US, the term "intangibles" included specific categories such as human capital, copyright, trademark, software, organisational transformation, and research and development. Despite this, a large part of these items is currently not presented as investments, is not included in gross value added (GVA), and is included in the current expenditure category. The inclusion of expenditure in GVA is justified because it is treated as an investment rather than as intermediate consumption. Companies in countries around the world have found intangible assets to be a catalyst for economic growth, but at the same time, their attribution to profit is not transparent. The study of intangible assets and the value they bring to the entity has arisen from practical situations that have challenged employers, employees, investors, and regulatory institutions. The contribution of intangibles is repressed in total factor returns and capital asset relevance.

Explaining productivity and exploring the most effective ways to boost it have been constant preoccupations in both the pre-World War and post-World War periods. Countries' economic contexts have undergone complex, dynamic developments, with some experiencing rapid, profound transformations while political, social, and technological crises and challenges have slowed others. In recent years, the struggle for the greatest competitive advantage has intensified, with countries exploring every resource to secure the best possible position in the financial consortium. Variables such as expenditures on advertising, product development, market research, and labour market training are assets created from the company's current resources and contribute directly to the subsequent increase in output. Intangibles have a substantial contribution to output and productivity growth; alas, investment in intangible assets has not been adequately captured by the statistical indicators used. However, they have a multiplier effect on output per worker, both indirectly through the diffusion of information, which increases productivity, and directly through the additional capital allocated to each employee. He suggested that the share of labour decreases as intangible assets replace it, and that investment in employee training and retraining programs, and the allocation of resources for branding and the optimisation of organisational capital processes, substitute for human effort to a greater extent. New technologies are an important factor in the development of intangibles. They expand the ways of business cooperation and management by facilitating access to new assets and the exchange of ideas, even when entities are far apart. Incremental innovation, driven by a desire to be at the forefront, has highlighted the need to build intellectual capital. The connection between organisations and the accumulation of new knowledge in the research process is increasingly recognised as a strategic resource. These network relationships enable information flow, the acquisition of new knowledge, and the sourcing of cutting-edge technologies, while mitigating risks and reducing intermediation/coordination costs.

In recent years, the technology sector has been driving interest among many of the world's companies. At the European Union level, intangible assets play a determinant role in business, serving as a catalyst for efficiency by increasing labour productivity. The European Union is increasingly opting for digitisation to boost knowledge and design a new concept of growth. Government involvement is a prerequisite for directing the necessary funds to digital skills. Investing in innovation through technology is not complete if there is no human resource possessing specific skills (Mercedes & Maudos, 2022) because, among the internal resources of the firm, one of the greatest challenges of theory as well as practice is produced by human capital, which is the foundation of the economic valorisation of intangible assets. After all, intangible assets are by no means insignificant. Their formation, development, and interpretation are guided by reason. Quality formal education before the date of employment emphasises both the employee's skills and knowledge and the intangible assets they bring to the company after the date of employment, contributing to the company's development.

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The presence of intangible assets in a company's balance sheet structure also entails risks, deadlocks, and pressures, primarily due to costs. Some employees may have impressive skills, and a research idea can often seem like a winning lottery ticket. Simulating its impact or testing it requires substantial financial resources, and if it fails, we cannot conclude that the employee has low skills or that they should be fired. On the other hand, even a simple new folder organisation can facilitate a department's work, enabling faster data access.

Another internal resource that has implications for the asset structure is the intangibles archive. Large firms have advantages in creating these assets, and there is a case for expressing the intention to show these items on the balance sheet. Corporations recruit the most talented employees because they can pay higher salaries, have access to economies of scale, invest much more in innovation, have access to technology that accelerates resource accumulation, have financial capacity that allows them to take risks, and have reputations and brands that drive a strong organisational culture. The interest of corporations in including them in financial statements is justified by the need for more accurate reflection of the value of the company and informed decision making; optimising transparency to creditors, investors and other stakeholders; financiers or banks may be more willing to lend to entities that have intangibles recorded on their balance sheet, providing a stronger guarantee; calculating profitability taking into account the value of these items can provide a clearer picture of long-term financial performance; the process of acquisitions or mergers can be simplified; and recording assets in line with the requirements of accounting standards. Small firms, although they lack a track record or long history of intangible assets, are also interested in recording them. Because they often borrow from investors or banks, quantification and recording could make it easier to obtain loans, and thus make it possible to finance large projects or to overcome crises; providing a more complex picture may be necessary when trying to attract partners or when selling the business; because small entities cannot afford to take large risks, allocating resources to specific profit-generating activities could help to move the business forward; compliance with applicable accounting standards is a condition that small firms must also comply with, and separate accounting could be a mandatory requirement in certain situations.

According to a study conducted by Statista, a global business intelligence and data platform, by 2023, there were an estimated 376.66 million companies worldwide: more than 200 million were located in Asia, in Africa, an estimated 67 million, and in Europe, the number was 34 million (Einar, 2024). The same research expert estimates that in 2000, the number was 204.42 million: over 92 million in Asia, over 40 million in Africa, and over 25 million in Europe. More companies also mean stronger competition, more patents, copyrights, etc. A large portfolio of intangibles generated at a given point in time within the entity can lead to lower costs by enabling the allocation of additional resources to concentrated, significant investments.

4. Traceability of intangible assets from the knowledge economy to the digital economy

The knowledge economy, according to the Oxford Reference economics dictionary, is an economy in which the creation and management of knowledge is a substantial component of basic production, and the digital economy is one in which business is conducted using digital technology and the internet (Hashimzade, Myles & Black, 2017). Traceability is the ability to trace the elements of a process from their perception as raw materials to the finished product. In the context of our study, the raw material is knowledge and its use. Information is the basis for the interdependence of the two concepts: the knowledge economy and the digital economy. In 2025, interest in information generated by artificial intelligence increased. Citizens from different countries are seeking answers to both their personal and professional lives. Danes, Estonians, Finns, and Maltese citizens are the biggest users of artificial intelligence, with the most requested information related to private life (25%), as shown in Figure 3.

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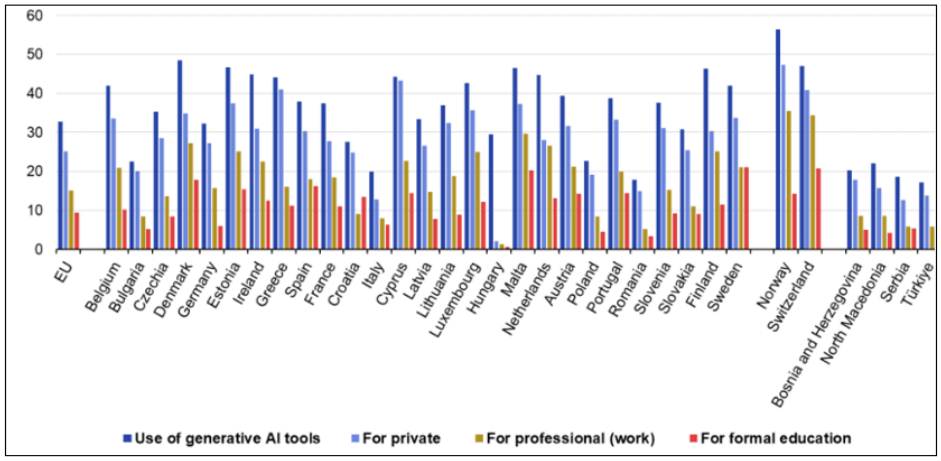


Figure 3. The purposes for which generative artificial intelligence is used, 2025
Source: Eurostat, https://ec.europa.eu/eurostat/statistics

Society has undergone a series of changes throughout history that have propelled economic restructuring and created the premises for today's digital economy. Society has undergone a series of transformations throughout history - from the industrial revolution driven by steam and electricity, to the era of electronics and nuclear energy - that have progressively created the premises for today's digital economy.

The 21st century is marked by the rise of the internet and, with it, digitisation. The world economy is strongly shaped by technology. Knowledge has enabled continuous process improvement. The development of technology has been a prerequisite for both physical and virtual meetings between suppliers and customers to review offers and select products and services. In general, the transition to the digital economy is preceded by streamlining. Businesses from the smallest to the largest are seeking to increase profits, reduce costs, and optimise operational efficiency through automation and digitalisation. Placing orders online is a method used by more and more people. In 2025, people in Ireland, the Low Countries, and Denmark purchased the most goods and services online. Their percentages are as follows: 95%, 94%, 91%. Romanians recorded a 22% increase compared to 2020, indicating that more and more people are using this method to meet their needs for goods and services (Figure 4).

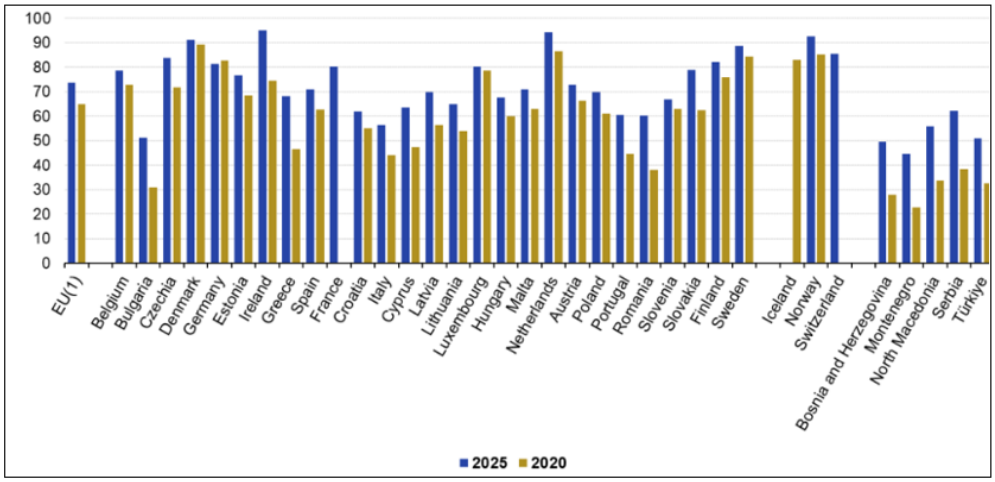


Figure 4. Percentage of internet users who ordered goods or services online in 2020, 2025
Source: Eurostat, https://ec.europa.eu/eurostat/statistics

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Among EU countries, Finland, followed by Denmark, has the highest share of citizen-public authority interactions in 2025 at 92%. They ask for information about their pension or the opening hours of the ticket offices. Romania ranks at the bottom of the EU Statistical Commission's ranking, at 24%, as shown in Figure 5.

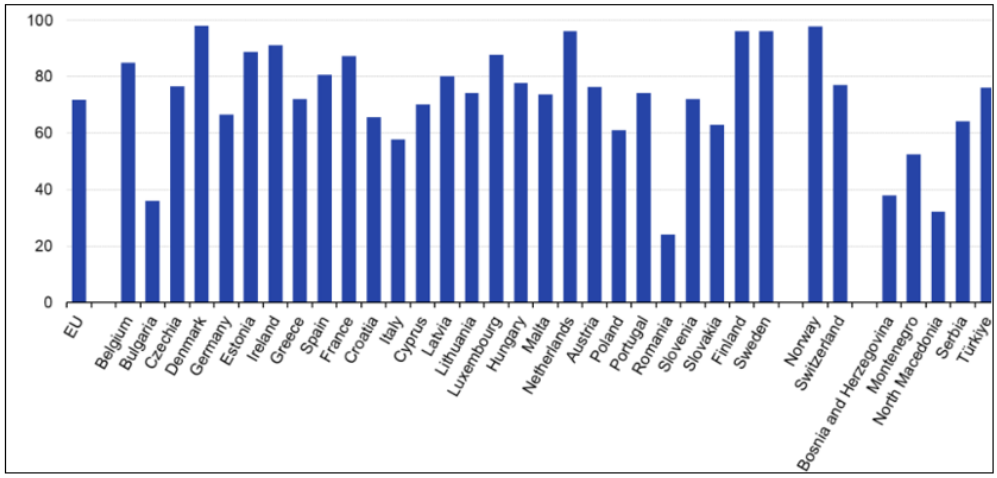


Figure 5. Internet users' interaction with public authorities, 2025
Source: Eurostat, https://ec.europa.eu/eurostat/statistics

The transition to the digital economy has been influenced by a multitude of interconnected social, economic and technological factors that have accelerated and shaped this fundamental change. Across the decades, there have been efforts at the country level through investments in infrastructure, tailored regulations, entrepreneurial policies, efforts at the private sector level through transformation to match consumer needs, formation of strategic alliances, allocation of resources for research and innovation, efforts at the civil society level through digital activism, online communities and collaboration, and initiatives through participation in information literacy programs.

Figure 6 illustrates the determinants that have stimulated the transition to the digital economic model and covers the following aspects:
- Internet usage, mobile networks, fibre optic networks, cloud computing platforms, software applications;
- Electronic trading markets and platforms. Virtual trading spaces include intangible services (advice and expertise, sports events, telephony services, transport services) and intangible products (licenses, shares, software, anti-virus software);
- Unconditional access by time and distance. Consumers can access information at any time and from any geographic region. The short time, methods and price of receiving data have conditioned firms to look for the fastest ways to deal with electronic markets;
- Globalisation, capital and labour mobility have influenced macroeconomic variables.

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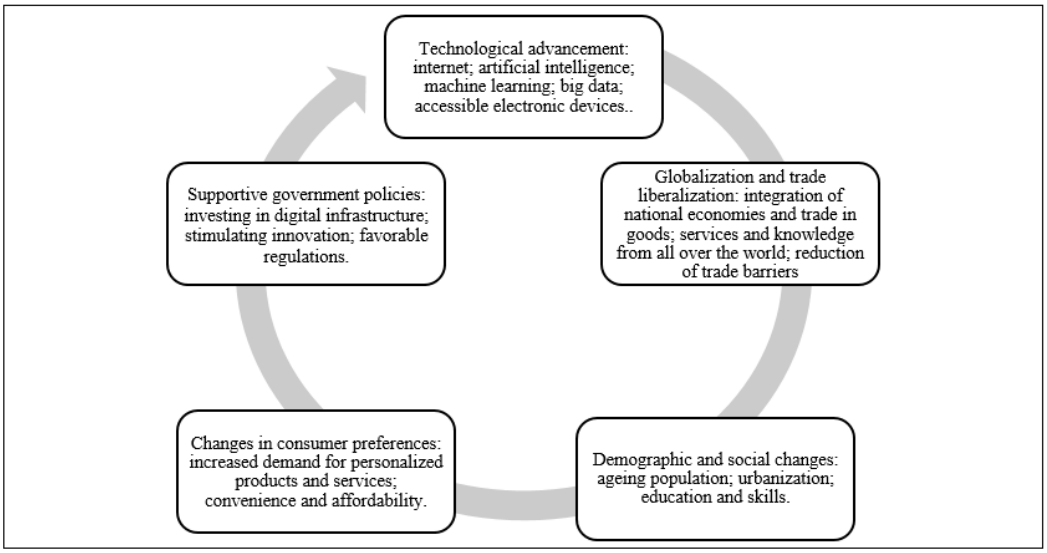


Figure 6. Key drivers of traceability from the knowledge economy to the digital economy
Source: authors' own processing

Referring to the positive arguments for digitisation, some authors argue that computers can accomplish tasks much faster than human resources and achieve a much higher level of performance. Scholars increasingly recognise a strong correlation between knowledge economics and management, viewing the optimal use of intangible resources as an essential component of organisational activity. Unlike the traditional economy, which is based on material resources, the knowledge economy emphasises the impact of intellectual capital on value creation. Entities, due to their competitive market positions, have expanded their creative horizons, striving to be as flexible as possible and to further stimulate innovation. In the evolution towards the digital economy, knowledge-based management has shifted its focus from tangible resources to innovation and intellectual potential. In the digital economy, attracting new customers is much easier thanks to expanded geographic coverage.

Customers can access and compare more information about prices, products, and services. Because they no longer feel the need to travel to different locations, the time saved is used to access more and more information. International products are much easier to purchase; for example, you can always buy English products from a Romanian shop or order items from American sites. Firms can always see competitors' products and are continually looking for ways to improve their quality and presentation to create more brand value, thereby investing in innovation and stimulating creativity. Moore (1993) states that the organisation cannot be reduced to a single industry label; rather, it is a central node in a diverse industrial ecosystem. Thanks to specific programs and technologies, companies can check their stock levels, order products online, and estimate the average daily sales for a particular product, avoiding over- or under-purchasing. Especially for goods with a short shelf life, perishability and financial losses can be avoided.

Firms can much more easily profile buyers and consumer behaviour and identify current policies to attract new potential customers. Employers, in exchange for quality, offer employees the option to work in a hybrid system. The flexibility that today's employees are looking for is a general characteristic of today's generation, and entrepreneurs use all the technical tools as they develop their businesses.

To highlight the challenges of the digital economy, some authors argue that it is driving a shift towards dynamic rather than static optimisation, prioritising new initiatives and innovative products at the expense of productivity gains. From a philosophical perspective, the concentration of technological control in the hands of a few raises concerns about the subordination of social responsibility and quality of life to personal economic gain and market dominance. Although we live in the century of speed, not all countries have the same network performance and access to technology. Africa, India, and Pakistan are among the regions with limited digital infrastructure and relatively high service costs. Low digital literacy can prevent people from benefiting from

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this economy's services. There is significant exposure to cyberattacks that can severely compromise business operations. Data privacy is a major concern in the age of technology. Protecting the privacy and security of customer data is important for building relationships with users, and failure to do so can damage the firm's reputation, erode customer trust, and cause substantial financial losses.

For firms that rely heavily on technology, there is a risk of business disruption due to technical failures or system errors. This can lead to interruptions in production processes, difficulties fulfilling orders, loss of credibility, and a negative impact on image and business relationships. Another consequence can be data loss, equipment damage and high repair costs. Long wait times to address such situations can lead to customer dissatisfaction, service or product withdrawals, and financial losses. The rapid pace of technological change also implies high costs for constantly updating software and equipment. Although the valuation of intangible assets is under-regulated, the risk of damage is high, and legal protection against unauthorised copying or use can be costly, experts are constantly seeking the best quantification methods.

Another challenge of the digital economy is information manipulation. Misinformation can influence consumers to choose the wrong products, make payments to false accounts, or provide confidential information for purposes other than those stated. This can cause market fluctuations in these regions, erode consumer confidence in the digital ecosystem, and make investors in these sectors reluctant to allocate capital.

Strong regulation is needed to protect consumers and ensure the ethical use of digital technology. Long-term internet use can affect human behaviour and how we relate to others.

Conclusions

The research set out to bring together theoretical perspectives on intangible assets and trace their evolution from the knowledge-based to the digital economy. The transition from the industrial to the knowledge-based, and then to the digital, economy has changed the relationship between labour and technology. A detailed analysis of the changes has highlighted the role of intangible assets in companies' productivity. They give companies certain freedoms and drive innovation. In a century of movement in which consumer access to products and services is much easier, firms are focusing all their efforts to gain a competitive advantage. In this context, human capital is a valuable resource because it possesses the knowledge needed for the R&D process. Moreover, it strengthens the company's connection to the external environment, brand reputation, and strategy. We can consider the IAS 38 definition as the most solid legal basis for understanding intangible assets: identifiable, non-monetary resources without physical substance that have arisen from past events, the control of which is held by the organisation and from which economic benefits are expected in the next period. The marketing, ethical, medical or accounting perspective on intangible assets highlights their strategic importance to the organisation's success. There is a common interest in developing accurate, reliable methods to measure and assess the value of intangible assets. This is essential for making informed investment decisions, reporting financial performance, and establishing a company's value.

The novelty of the paper lies in bringing together four perspectives on intangible assets — accounting, marketing, ethics and healthcare — that are rarely discussed together, and in proposing a framework, illustrated in Figure 6, that links the specific determinants of the digital economy to the broader process of traceability from the knowledge economy. Unlike previous studies, which tend to address intangible assets from a single disciplinary angle, this paper shows that accounting recognition criteria, marketing-driven brand value, ethical considerations and healthcare-specific dynamics are interconnected dimensions of the same traceability process toward the digital economy.

Globalisation, the increasing use of technology, the harmonisation of accounting standards, the shift from physical work to knowledge creation, the acceleration of digitalisation, and the contribution of innovative technologies to a company's market value are important milestones in the evolution of intangible assets within companies' asset structures. It has been found that small firms' interest in R&D projects has increased in recent years, even though they cannot afford to take large financial risks. They are banking on the fact that, unlike physical assets, which depreciate over time, investment in intangible assets can add value and long-term

competitive advantage, in inverse proportion to the degree of exploitation. Accumulating a solid portfolio of intangibles can improve valuation by investors, facilitating access to finance. Adapting to the digital economy is not a choice but a reality of today's market. The internet and communication networks have catalysed information sharing and remote collaboration. However, there is polarisation between regions with less access to digital resources and investment. The increased risk of cyber-attacks and dependence on the internet are disadvantages of the information society. Filtering information and directing the knowledge held by each citizen towards research, development and information requires time, mobility and advanced digital literacy.
The research is not without limitations. The literature review does not follow a systematic protocol, and the statistical evidence supporting the proposed framework is descriptive, drawn from a single source, without further econometric testing. Future research could test the proposed framework using firm-level or country-level data.

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INSTAGRAM COMMUNICATION STRATEGIES OF CENTRAL AND EASTERN EUROPEAN CAPITALS: ACTIVITY, ENGAGEMENT, AND CONTENT CHARACTERISTICS*

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Abstract. This paper examines how Instagram is utilised as a tool for online tourism communication through a comparative analysis of the official English-language profiles of six Central and Eastern European capitals: Bratislava, Bucharest, Budapest, Prague, Vienna, and Warsaw. The study covers a one-year period from November 2023 to October 2024. Adopting a mixed-methods approach, it combines quantitative analysis of posting activity (2,021 posts), user engagement, and caption length with qualitative keyword analysis of textual content. The results reveal substantial differences in posting behaviour, digital presentation, and communication styles across the analysed cities, reflecting distinct destination marketing strategies and underscoring the importance of content quality over posting frequency. A key empirical contribution is the identification of a positive correlation between caption length and user engagement, suggesting that more detailed and context-rich captions enhance audience interaction. At the same time, the findings indicate that strong visual identity and destination positioning may compensate for shorter captions. Furthermore, the analysis uncovers city-specific narrative patterns aligned with local tourism assets and target segments, offering deeper insight into how destinations construct their digital identities. By integrating performance indicators with content characteristics in a comparative Central and Eastern European context, the study addresses an underexplored area in existing research and advances understanding of Instagram-based city branding. The paper also offers practical implications for social media marketing and outlines directions for future research, including longitudinal, cross-platform, and behaviour-oriented analyses.

Keywords: Instagram; destination marketing; tourism communication; user engagement; content analysis; city branding; social media analytics; Central and Eastern Europe

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JEL Classifications: M31, Z32, D83

1. Introduction

Digital media represent a rapid and effective means of sharing information about current events and trends (Yujie et al., 2022; Mialkovska et al., 2023) and play a crucial role in shaping public opinion and community attitudes (Chang & Chang, 2023). In tourism, these channels are pivotal for promoting destinations and shaping their reputation and perception among potential visitors (Baber & Baber, 2022; Moscardi & Nakatani, 2022; Solanki & Thomas, 2023; Santarsiero et al., 2024). Social networks, particularly Instagram (hereinafter IG), have become central to forming the image of destinations (An et al., 2022) and strengthening their marketing

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potential (Solanki & Thomas, 2023), influencing not only the number of visitors but also tourist behaviour and emotional responses (Chen, 2023).

IG stands out as a popular platform for sharing content and social interaction (Silva & Floriano, 2024). Users can post images, captions, and hashtags that reflect personal travel experiences (Paül i Agustí, 2024), inspiring others and sparking interest in specific locations (Eman & Refaie, 2023). Destination organisations, in turn, utilise official profiles to promote events, historical and cultural attractions, and other points of interest (Mele et al., 2021; Kumar et al., 2024). Engagement metrics from these posts provide valuable feedback on audience preferences (Kajikawa et al., 2023), and systematic analysis helps reveal how digital media contribute to shaping city images and the broader landscape of tourism (Stankov & Gretzel, 2021).

2. Theoretical background

The impact of digital media on tourism has been explored from multiple perspectives, including digital literacy, technology adoption, education, and professional development (Adeyinka et al., 2020; Marx et al., 2021; Sinanan & Riter, 2024). In recent years, however, research attention has shifted towards the role of social media in tourism marketing (Armutcu et al., 2023; Kilipiri et al., 2023), city branding (Fan & Zhang, 2023; Wan & Li, 2024), and the promotion of tourist destinations or even national parks (Camilleri & Kozak, 2022; Chen, 2023; Korená & Pártlová, 2023). Social media is also frequently debated within the context of the tourism industry as a whole (Rehman et al., 2023; İlhan & Günay, 2024), with growing attention drawn to specific attributes of how destinations are perceived through official and user-generated content shared online (Ilieva & Boteva, 2023; Chen, 2024; Lazarević et al., 2024). A substantial body of research examines user engagement, satisfaction, and the influence of social media on travel intentions and decision-making processes (Damayanti & Indrawati, 2023; Ibrahim, 2023; Liu & Chong, 2023; Vieira et al., 2023; Grosso et al., 2024; Guerreiro et al., 2024; Kim & Lei, 2025; Rahayu et al., 2024; Shah et al., 2024; Viñán-Luden & de Campos, 2024).

Within IG-based research, a common distinction is made between visual and textual content. Studies dealing with visual elements analyse how images influence destination attractiveness and awareness, demonstrating that although many city-related photos on IG are not directly relevant to tourists, those with a clear tourism focus tend to generate higher engagement (Arzbaecher et al., 2022; Paradise-Vit et al., 2024). In parallel, research on the textual content of IG posts explores how captions shape user responses, applying analytical models or survey-based approaches to illustrate the effect of such content on travel decisions. These studies suggest that shorter and simpler captions about lively destinations are inclined to capture interest, encourage interaction or even build connections, whereas longer and more complex texts for less dynamic or culturally themed sites are associated with lower engagement in certain contexts (Aramendia-Muneta & Olarte-Pascual, 2022; Sharma & Arora, 2023; Tugores-Ques & Bonilla-Quijada, 2023; Yu et al., 2024). At the same time, there is increasing interest in the interaction between textual and visual elements in digital travel storytelling, with evidence that the combined use of images, hashtags, emojis, and keywords creates complex communication narratives that form user perception and engagement (Marwick, 2015; Highfield & Leaver, 2016; Qian, 2023).

Despite these significant advances, several research gaps remain. First, existing studies often examine user engagement without sufficiently linking it to concrete posting behaviour, such as activity levels or content structure. Second, while prior research highlights the importance of textual content, there is limited empirical evidence on how specific textual characteristics, particularly caption length, relate to this type of engagement in a comparative, real-world context. Third, although digital storytelling and thematic communication are widely discussed, there is a lack of systematic comparative analyses of content themes and keyword usage across multiple destinations. In addition, the existing empirical research concentrates on well-established Western destinations, while Central and Eastern European cities remain underrepresented. Moreover, quantitative indicators of posting activity and user engagement are rarely integrated with qualitative content dimensions within a single framework.

This study addresses the above gaps by providing a comparative, mixed-methods analysis of official Instagram profiles of selected Central and Eastern European capitals. The combination of quantitative metrics (posting frequency, engagement, caption length) with qualitative keyword and thematic analysis offers a more

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comprehensive perspective on how digital communication strategies contribute to destination image and audience engagement.

3. Research objective and methodology

Building on the above theoretical background, this study investigates six Central and Eastern European capitals (Bratislava, Bucharest, Budapest, Prague, Vienna, and Warsaw), characterised by a rich historical heritage, distinctive architecture, and diverse cultural offerings. Each city operates official English-language Instagram profiles that target mainly international audiences. The primary objective of the study is to analyse how these destinations communicate their tourism value over the course of one year through posting activity and textual content, with a particular focus on identifying differences in communication strategies, engagement patterns, and thematic orientation.

To achieve this objective, the study is guided by three research questions (RQ1, RQ2, RQ3):
RQ1: What differences in posting frequency and intensity can be observed among the Instagram profiles of the selected capitals?
RQ2: What is the relationship between caption length and user engagement, measured by the average number of likes?
RQ3: Which keywords appear most frequently in the posts, and which tourism-related themes and trends do they represent?

In line with these questions, the study seeks to evaluate the effectiveness of Instagram-based communication in tourism and to provide practical implications for optimising social media strategies in destination marketing.

Methodologically, the research adopts a mixed-methods approach combining quantitative and qualitative analysis of secondary Instagram data. Descriptive statistical analysis is used to assess posting activity and intensity (RQ1). Correlation analysis is applied to examine the relationship between caption length and user engagement (RQ2). Finally, qualitative content analysis, supported by keyword frequency analysis, is employed to identify dominant themes and communication patterns in the published posts (RQ3). This integrated approach enables a comprehensive assessment of both performance indicators and content characteristics.

3.1 Sampling and data collection

The research sample consists of six Central and Eastern European capitals: Bratislava, Bucharest, Budapest, Prague, Vienna, and Warsaw. Their selection was based on two criteria: 1) the existence of an official English-language Instagram profile and 2) regular posting activity, defined as at least one post per week over a one-year period. Although originally considered for the sample, Sofia (the capital of Bulgaria) was excluded as its profile did not fully meet the criteria. Table 1 lists the included profiles along with account names, creation dates, and follower counts as of October 30, 2024.

Table 1. Overview of IG profiles studied (as of October 30, 2024, in alphabetical order)

City	Profile name	Profile creation	Followers
Bratislava	visitbratislava	October 2015	36,865
Bucharest	visitbucharest_official	November 2019	11,742
Budapest	visitbudapest_official	January 2015	95,649
Prague	cityofprague	February 2015	114,931
Vienna	vienna	September 2012	496,897
Warsaw	go2warsaw	April 2014	100,953

Source: authors' own processing

Data were collected from November 1, 2023, to October 30, 2024, to capture a full year. All posts were gathered manually from public Instagram accounts. For each post, the following details were recorded: publication date, the complete caption text and its length in characters, as well as engagement metrics such as the number of likes

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and comments. Posts identified as advertisements or those lacking captions were excluded to ensure consistency and comparability of the data.

3.2 Methods

Descriptive analysis

The analysis commenced with the calculation of both the total and average monthly number of posts for each IG profile over the study period. These descriptive statistics provided a basis for answering RQ1 and are presented in the Results section.

Correlation analysis

To address RQ2, the average number of likes, comments, and the mean length of textual content (in characters) per post were computed for each profile. The Pearson correlation coefficient was subsequently applied to assess the relationship between average caption length and the number of likes per post as an indicator of user engagement according to the following formula:

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

Where:
x_i – individual values of caption length (number of characters)
$\bar{x}$ – average caption length
y_i – individual values of the number of likes
$\bar{y}$ – average number of likes
The resulting correlation values and inter-city comparisons are reported in the Results section.

Qualitative analysis

For RQ3, a qualitative content analysis was conducted using Atlas.ti software Version 25.0.0 to examine the textual components of posts. This approach enabled the identification and visualisation of frequently occurring keywords through word clouds for each city, as displayed in the Results section. The analysis focused on extracting the frequency and significance of keywords relevant to tourism promotion, particularly those reflecting cultural and social attributes. To enhance semantic clarity, common stop words (e.g. "the," "a," "an"), emojis, and other non-informative symbols were excluded. Instead, emphasis was placed on adjectives, adverbial nouns, and verbs, which provide deeper insights into the characteristics, attitudes, and actions expressed within the posts. The relative frequency of the most prevalent keywords for each city is indicated in parentheses in the Results section.

4. Results

Activity on IG profiles

To evaluate posting activity among the cities' IG profiles, both the total and average monthly number of posts were calculated for the monitored period. The analysis revealed significant variation in activity levels across the sample. An overview of these results, including follower counts for context, is provided in Table 2.

Table 2. Posting frequency and follower counts for IG profiles (as of October 30, 2024, by total number of posts)

City	Total posts	Average Posts/Month	Followers
Bratislava	587	48.9	36,865
Budapest	430	35.8	95,649
Vienna	379	31.6	496,897
Warsaw	302	25.2	100,953
Prague	166	13.8	114,931
Bucharest	157	13.1	11,742
Total	2,021	28.1 (total average)	857,037

Source: authors' own processing

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Bratislava exhibited the highest posting activity, with a total of 587 posts and an average of 48.9 posts per month, despite having a comparatively smaller follower base. Budapest ranked second, generating 430 posts and averaging 35.8 posts per month. Vienna followed with 379 posts (31.6 per month) and the highest follower count among all profiles. Warsaw produced 302 posts, averaging 25.2 per month. Prague, despite being the second-most-followed account, was less active, with 166 posts (13.8 per month). Bucharest was the least active profile, publishing 157 posts at an average of 13.1 per month.

Relationship between the length of textual content and the number of likes

A quantitative analysis was conducted to explore how the length of captions relates to user engagement on the IG profiles concerned. For each city, the total and average number of likes, comments, and average caption length (in characters including spaces) were calculated, as shown in Table 3.

Despite frequent posting, Bratislava achieved high engagement with an average of 566.7 likes and 13.5 comments per post. Vienna, however, recorded the highest overall engagement, reaching an average of 5,505.2 likes and 74.2 comments per post, even though its captions were relatively short. Prague reached a high average of 1,935.8 likes per post with less frequent posting, while Warsaw had a similar average of 1,780.6 likes and the second-highest number of comments. Budapest, despite a higher post volume and longer captions, recorded lower averages for likes and comments. Bucharest had the lowest engagement across all metrics.

Table 3. Summary statistics of likes, comments, and caption length for IG posts (by total number of posts)

City	Total number of posts	Total number of likes	Total number of comments	Total number of characters (including spaces)	Average number of likes	Average number of comments	Average number of characters (including spaces)
Bratislava	587	332,626	7,920	180,662	566.7	13.5	307.8
Budapest	430	188,998	2,261	175,249	439.5	5.3	407.6
Vienna	379	2,086,487	28,106	94,385	5,505.2	74.2	249.1
Warsaw	302	537,745	6,603	86,929	1,780.6	21.9	287.8
Prague	166	321,341	1,904	61,058	1,935.8	11.5	367.8
Bucharest	156	26,811	215	24,579	171.9	1.4	157.6

Source: authors' own processing

The analysis of caption length evidenced clear differences among the profiles, with Budapest having the longest average captions at 407.6 characters per post, followed by Prague with 367.8, and Bratislava with 307.8. Warsaw averaged 287.8 characters, whereas Vienna, despite the highest engagement, had an average of 249.1. Bucharest's captions were the shortest at 157.6 characters per post.

The findings showed no clear direct link between caption length and engagement. Vienna, with shorter average captions, led in both likes and comments, while Budapest, with longer captions, had lower engagement. This suggests that while caption length may influence engagement to some extent, other factors such as content quality, visual appeal, and the size of the established audience are likely more significant.

To further examine how caption length relates to user engagement, Pearson correlation coefficients were calculated for each profile, as presented in Table 4.

Table 4. Correlation coefficients between caption length and average number of likes (from highest to lowest)

City	Average number of likes	Average number of characters	Correlation coefficient values
Bratislava	566.7	307.8	0.62
Budapest	439.5	407.6	0.58
Prague	1,935.8	367.8	0.54
Warsaw	1,780.6	287.8	0.49
Vienna	5,505.2	249.1	0.45
Bucharest	171.9	157.6	0.33

Source: authors' own processing

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A generally positive correlation between caption length and the number of likes emerged, with the strongest relationship observed for Bratislava (0.62), followed by Budapest (0.58), Prague (0.54), and Warsaw (0.49), indicating that longer captions tend to generate higher engagement in these profiles. Vienna showed a weaker but still positive correlation (0.45), while Bucharest had the lowest value (0.33), suggesting that caption length played a smaller role in user engagement there. These results support the idea that more detailed textual content can enhance audience interaction on IG, although the impact varies across cities.

Content analysis of posts

The following section presents the results of the content analysis for each city, arranged alphabetically.

Bratislava

Bratislava (see Figure 1) stands out among the examined profiles for its strong economic context, as indicated by the most prominent words *support* (254 occurrences; 2.01%) and *financial* (253; 2.00%), surpassing the frequency of conventional tourism-related vocabulary. Other common terms include *city* (215; 1.70%) and *history* (78; 0.62%), along with positively connoted adjectives, e.g. *beautiful*, *charming*, *stunning*, *unique*, and *iconic*. This linguistic pattern highlights Bratislava's visual appeal, historical significance, and its depiction as a dynamic metropolis offering a diverse range of activities. The word cloud also features expressions such as *views*, *castle*, *streets*, *day*, *time*, *charm*, and *coronation*, further evoking the city's historical atmosphere and attractiveness. Frequently used verbs (*explore*, *experience*, *visit*, *enjoy*, *take*, and *discover*) encourage tourism and underscore the city's attractions and cultural heritage.



Figure 1. Word cloud for Bratislava
Source: authors' own processing in Atlas.ti Version 25.0.0

Bucharest

Bucharest (see Figure 2) emerges as a city with a vibrant and diverse art scene. The most frequent words are *art* and *festival* (each appearing 14 times; 0.93%), followed by *edition* (13; 0.86%), *weekend*, and *year* (each 11; 0.73%), pointing to a strong emphasis on recurring cultural events. Other commonly observed terms relate to architecture (*building*, *designers*), music (*band*, *rock*), and the urban environment (*streets*, *lake*, *park*). The presence of words such as *city*, *world*, *Romanian*, *old*, *history*, and *tradition* demonstrates a connection between Bucharest's international and local identity, as well as a bridge between past and present.

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Figure 2. Word cloud for Bucharest
Source: authors' own processing in Atlas.ti Version 25.0.0

Budapest

Budapest (see Figure 3) is portrayed as a city promoting tourism through a wide array of benefits and special offers, as reflected in these terms: *city* (185 occurrences; 1.48%), *card* (161; 1.28%), *free* (146; 1.16%), *enjoy* (124; 0.99%), and *discount* (86; 0.69%). The notable presence of the term *bio* (90; 0.72%) suggests a strategic use of digital marketing terminology. Words like *Hungarian*, *world*, *Budapest*, and *capital* emphasise the city's national identity and local distinctiveness within a global framework. Further, the posts highlight Budapest's accessible cultural and leisure facilities, with references to *thermal*, *baths*, *history*, *culture*, and *transport*, showcasing the city's renowned spa tradition. Social engagement and inclusivity are also evident, with frequent terms such as *let*, *action*, *together*, *join*, *public*, *programmes*, and *everyone* aiming to foster community involvement and social responsibility. As in other cities, positively loaded adjectives (*unique*, *perfect*, *stunning*, *best*, *iconic*) and persuasive verbs (*experience*, *get*, *visit*, *explore*, *don't miss*) are used to attract potential visitors.



Figure 3. Word cloud for Budapest
Source: authors' own processing in Atlas.ti Version 25.0.0

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Prague

The most frequent word in Prague's posts (see Figure 4) is *bio* (53 occurrences; 1.18%), reflecting the influence of IG caption formatting practices. Other prevalent expressions include *visit* (33; 0.73%), *free* (27; 0.60%), and *new* (25; 0.56%), suggesting a focus on tourism and the discovery of lesser-known or affordable attractions. The posts collectively frame Prague as a contemporary and multifaceted destination, uniting unique features (*today*, *parts*, *special*, *features*, *link*, *join*, *unit*). Efforts to provide an authentic tourist experience are supported by terms related to infrastructure (*city*, *Czech*, *original*, *walk*, *view*, *guides*, *metro*, *trams*, *line*, *public*). Historical and artistic dimensions are expressed through *years*, *style*, *baroque*, *gothic*, *legends*, and *landmarks*, confirming the city's architectural significance. Cultural and social elements are reflected in *music*, *tour*, *concert*, *museum*, and *artists*. Notably, strongly positive adjectives are less frequent, with only *best* and *magnificent* standing out, while action-oriented verbs (*enjoy*, *get*) are among the most repeated.



Figure 4. Word cloud for Prague
Source: authors' own processing in Atlas.ti Version 25.0.0

Vienna

Vienna (see Figure 5) is closely associated with art, accessibility, and the exploration of lesser-known places. The most frequent words are *city* (44 occurrences; 0.71%), *art* (42; 0.68%), *visit* (36; 0.58%), *free* (33; 0.53%), and *hidden gems* (28; 0.45%). As with Bratislava and Budapest, positively charged adjectives (*beautiful*, *stunning*, *perfect*, *vibrant*, *amazing*, *unique*) appear often. Both international and local identities are highlighted with terms such as *world's*, *Viennese*, and *Austrian*. Historical features, architectural monuments, and the city's cultural and seasonal atmosphere are depicted in *day*, *views*, *season*, *music*, *exhibition*, *locations*, *market*, *palace*, *baroque*, and *imperial*. Culinary traditions are represented by coffee, *culinary*, and *delicious*. Verbs reflecting active tourism (*enjoy*, *experience*, *live*, *explore*, *see*, *get*, *join*) are frequent, while the notable repetition of *love* connects Vienna's romantic image with similar representations of the word in Prague and Warsaw.

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Figure 5. Word cloud for Vienna
Source: authors' own processing in Atlas.ti Version 25.0.0

Warsaw

Warsaw's IG posts (see Figure 6) place a strong emphasis on visual content, as evidenced by the frequent occurrence of *photos* (72; 1.24%) and *photo* (69; 1.19%). Other common expressions include *city* (58; 1.00%), *new* (33; 0.57%), and *love* (29; 0.50%), all of which contribute to a modern and positive perception of the city. The strong focus on photography is further underlined by frequent calls to interact with images, with words such as *take*, *shots*, *share*, *find*, *tag*, *featured*, *profile*, and *comments*. Commemoration of both historical and contemporary events is represented through *know*, *today*, *history*, *years*, *celebrate*, *weekend*, and *events*. Urban culture, art, and green spaces are evident in terms like *exhibition*, *museum*, *landmarks*, *art*, *parks*, and *green*. The use of verbs related to exploration and interaction (*see*, *visit*, *explore*, *walk*, *check*, *recommend*) is high, while positive adjectives (*beautiful*, *immersive*) are less frequent compared to other profiles.

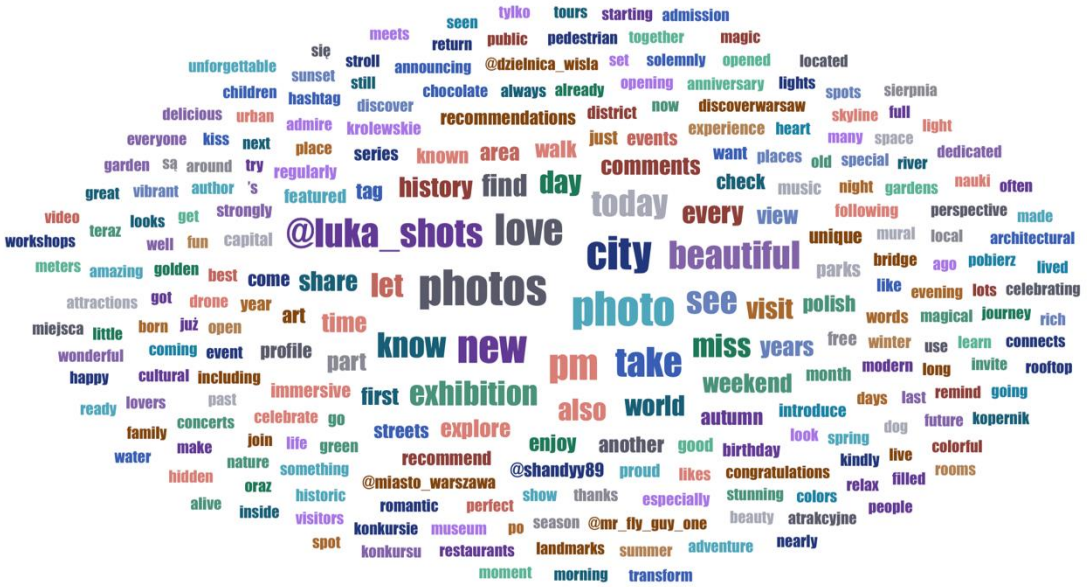


Figure 6. Word cloud for Warsaw
Source: authors' own processing in Atlas.ti Version 25.0.0

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The keyword analysis shows that each city uses a distinct strategy to engage audiences and shape an attractive destination image.

Positive emotional mood and invitations to discover
All analysed capitals aim to inspire positivity and anticipation in visitors, often using action verbs like *enjoy*, *experience*, *explore*, and *see*. The welcoming tone is adapted to the local context. For example, Bratislava combines historical and economic narratives, whereas Warsaw focuses more on visual attractions.

Tourism benefits and services
Approaches to promoting tourism benefits differ significantly. Budapest highlights discounts and tourist cards, attracting value-oriented travellers. Prague emphasises walking routes and public transport, which appeals to those seeking easy and accessible experiences. Vienna draws attention to hidden gems and gastronomy, resonating with visitors interested in authenticity and tradition. These strategies reflect varying audience preferences.

Linking the past and the present
All cities reference cultural and historical heritage, though integration varies. Bratislava connects historical motifs with economic themes. Bucharest emphasises contemporary artistic identity. Prague and Vienna combine classic architectural references with modern events and suggestions for unique attractions.

Visual and digital marketing
Visual presentation is central to all cities' digital strategies. Warsaw stands out for keywords like *photos*, *share*, and *tag*, reflecting a strong focus on visual and social engagement. Prague and Budapest make strategic use of profile features and links. Vienna and Bucharest focus more on promoting festivals and cultural events through digital content.

Target groups and positioning
Keyword choices align with diverse marketing goals and audience profiles. Bratislava targets business travellers, Budapest appeals to budget visitors, and Bucharest attracts a younger, creative demographic. Prague blends tradition with modern digital communication, widening its appeal. Vienna targets fans of classic art and food, while Warsaw appeals to visually oriented users interested in local recommendations.

In summary, each city develops a tailored communication strategy reflecting its identity and position in the market. Despite some shared features such as a positive tone and promotion of attractions, specific attributes like thermal baths, investment support, festivals, and café culture help distinguish these destinations. Thus, the keyword analysis offers valuable insight into how cities build their image and leverage social media for effective tourism communication.

5. Description of Results and Discussion

This section presents and discusses key findings derived from the analysis of the capitals' IG profiles in relation to: (1) differences in posting activity, (2) the relationship between caption length and user engagement, and (3) dominant keywords and thematic patterns. Together, these findings provide a nuanced view of how destinations construct their digital image and influence audience perception within the broader context of tourism marketing.

RQ1*:* What differences in posting frequency and intensity can be observed among the Instagram profiles of the selected capitals?
The comparative analysis reveals notable disparities in posting frequency and digital strategy across the studied capital cities. Bratislava emerges as the most active profile, with nearly 50 posts per month, indicating a strong emphasis on maintaining continuous interaction with IG audiences. This finding supports previous research highlighting the importance of sustained social media presence for destination branding (Stankov & Gretzel, 2021). In contrast, Prague and Bucharest exhibit significantly lower activity levels, averaging around 13 posts per month, which may reflect differing strategic priorities or resource limitations.

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Overall, the difference between the most and least active profiles exceeds a factor of three, pointing to considerable heterogeneity in the adoption and implementation of social media strategies. This pattern contrasts with the more consistent posting behaviour observed in Western European capitals (Tugores-Ques & Bonilla-Quijada, 2023), suggesting that Central and Eastern European capitals are at varying stages of integrating IG into their destination marketing frameworks.

Importantly, higher posting frequency does not automatically translate into stronger user engagement. The contrast between Bratislava and Vienna demonstrates that content quality may outweigh posting volume, as Vienna achieves higher engagement despite lower activity levels. This observation aligns with the conclusions of Armutcu et al. (2023), emphasising the importance of well-curated and visually appealing content. From a practical perspective, this suggests that destination management organisations should prioritise the creation of high-quality, engaging posts rather than focusing primarily on increasing posting frequency.

RQ2: What is the relationship between caption length and user engagement, measured by the average number of likes?
Engagement on the IG profiles of the analysed capitals does not increase proportionally with posting frequency, as illustrated by Bratislava, which shows the highest posting activity, yet relatively low average likes per post, compared to Vienna, which achieves the highest engagement despite lower posting intensity. This implies that content quantity alone is not a sufficient driver of user interaction and supports the concept of "content fatigue," whereby excessive posting may reduce audience responsiveness (Fan & Zhang, 2023).

Further differences across the cities reinforce this interpretation. Budapest combines high posting activity with only moderate engagement, while Prague's less frequent yet more targeted posts result in comparatively higher average likes. Vienna's strong performance likely reflects a combination of high-quality visual content, consistent branding, and a well-established follower base, confirming that content quality and strategic communication are more important than sheer volume, as pointed out by Kumar et al. (2024). In contrast, Bucharest records the lowest engagement levels, which may be linked to less effective content presentation or lower destination visibility (An et al., 2022). These disparities highlight the importance of an integrated marketing approach that, according to Pártlová et al. (2022), combines high-quality visuals, informative and engaging captions, appropriate posting timing, and active audience management.

Regarding caption length, the results indicate a generally positive correlation between longer captions and higher user engagement, particularly in Bratislava and Budapest, where audiences appear to value more detailed and context-rich information. Prague demonstrates a similar pattern, further supporting the role of comprehensive communication in enhancing engagement. However, this relationship is not universal. Vienna achieves strong engagement even with shorter captions, suggesting that visual appeal, brand strength, and audience loyalty can compensate for less extensive textual content. This finding is consistent with previous research stating that engagement is influenced not only by caption length but also by readability, complexity, and content type (Yu et al., 2024). Overall, while longer captions can enhance engagement, their effectiveness depends on contextual factors, and the optimal caption length should be adapted to the specific communication strategy and audience expectations, as suggested by Sharma & Arora (2023).

RQ3: Which keywords appear most frequently in the posts, and which tourism-related themes and trends do they represent?
The analysis of frequently used keywords and themes across the IG profiles of the capitals concerned indicates that each city employs a distinct linguistic strategy to construct its digital identity and target specific visitor segments. Action-oriented verbs such as *visit*, *explore*, and *enjoy* are consistently present across all profiles, reflecting a strong emphasis on experiential tourism and direct audience engagement. In addition, positive adjectives such as *unique*, *beautiful*, and *stunning*, particularly in posts from Bratislava, Budapest, and Vienna, contribute to an emotionally appealing and persuasive tone that enhances destination attractiveness, which is in line with Angaramo Corvalán & Pérez-Torres (2021).

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At the same time, notable thematic differences emerge in the keyword usage of individual cities. Bratislava combines references to cultural heritage with economic and business-related themes, while Budapest emphasises accessibility and value-oriented offers through terms such as *free*, *card*, and *discount*. Bucharest places a stronger focus on arts and festivals, underlining the importance of cultural programming in shaping tourism demand (Lazarević et al., 2024). Prague integrates historical and architectural references with elements of modern urban infrastructure, whereas Warsaw frequently highlights visual content and sharing practices, reflecting a more community-oriented and visually driven communication style, as shown by Qian (2023) and Highfield & Leaver (2016). Vienna, in turn, promotes art, hidden locations, and gastronomy, aligning with broader trends toward authenticity, local experience, and cultural depth in tourism (Kilipiri et al., 2023).

Overall, keyword selection and communication style are vital in shaping a destination's online image and influencing audience perception. Destinations that effectively combine cultural, historical, and contemporary elements within their digital storytelling are more likely to appeal to diverse visitor groups and foster long-term engagement. This finding is consistent with previous research emphasising the importance of well-crafted narratives and emotional tone in strengthening destination reputation and audience connection (Marwick, 2015; Fan & Zhang, 2023; Lazarević et al., 2024; Kilipiri et al., 2023; Qian, 2023). In this context, language can be understood as a strategic tool for positioning destinations within the competitive digital tourism environment.

Limitations and recommendations for future research

This study has several limitations that should be taken into account when interpreting the findings. First, the analysis focuses exclusively on textual content, while visual elements, which are central to IG communication, were not examined. Future research should therefore incorporate a systematic analysis of images and videos in order to better capture their quality, aesthetic characteristics, and narrative function within destination marketing (Aramendia-Muneta & Olarte-Pascual, 2022). Second, the use of correlation analysis limits the ability to draw causal inferences, as only associations between variables were identified. User engagement may be influenced by additional factors such as posting time, seasonality, or major events. Furthermore, the application of more advanced statistical techniques, including regression models or structural equation modelling, could provide deeper insights into these relationships and help identify underlying causal mechanisms. Another limitation lies in the absence of analysis of user-generated interactions, particularly comments and the nature of communication between account administrators and followers. Such interactions are essential for building online communities and fostering meaningful engagement (Highfield & Leaver, 2016). Thus, future studies should examine dialogic communication patterns, including comments, replies, and interaction dynamics, as well as the use of hashtags, emojis, and posting strategies. In addition, the study is limited to capital cities in Central and Eastern Europe, which restricts the generalisability of the findings. Expanding the scope to include other types of destinations, such as coastal, rural, or mountain areas, as well as different geographical regions, would enable more comprehensive comparative analyses and contribute to a broader understanding of IG communication strategies in tourism.

Despite these limitations, the study offers relevant implications for destination marketing practice. In particular, it highlights the importance of balancing posting frequency with content quality, optimising caption length, and adapting communication strategies to specific audience characteristics. More broadly, the findings provide a foundation for future research on digital tourism communication, including emerging perspectives such as neurocommunication and the behavioural dimensions of tourist engagement.

6. Conclusions

This study examined how six Central and Eastern European capitals – Bratislava, Bucharest, Budapest, Prague, Vienna, and Warsaw – use Instagram (IG) to promote their tourist destinations, focusing on posting frequency, caption length, and the thematic structure of published content. The findings show that, despite geographical and cultural proximity, these cities adopt markedly different digital communication strategies, with each building its online identity in line with its historical context, target audience, international visibility, and specific marketing priorities.

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Importantly, this study offers a novel contribution to the field of digital destination marketing by providing a systematic comparative analysis of IG communication strategies across Central and Eastern European capitals, a region that has received limited attention in previous research. In addition, it integrates quantitative indicators of posting activity and engagement with qualitative analysis of content themes, thereby offering a more comprehensive understanding of how different communication elements jointly shape audience interaction and destination branding.

The results challenge the assumption that higher posting frequency leads to greater user engagement. The contrast between Bratislava and Vienna clearly illustrates that content quality plays a more decisive role than posting volume. While longer and more detailed captions are associated with higher engagement in some cases, particularly in Bratislava and Budapest, Vienna demonstrates that strong visual content, consistent branding, and an established reputation can generate high levels of interaction even with shorter captions.

From a theoretical perspective, the study contributes to the literature on digital destination marketing by identifying five recurring patterns in city branding strategies: emotional storytelling, thematic segmentation, the integration of cultural and modern elements, the emphasis on geographic identity, and the promotion of community-oriented communication. These patterns highlight the importance of adaptive digital narratives tailored to different audience segments (McCabe, 2024). The findings further illustrate how individual cities prioritise distinct thematic dimensions. For example, Bratislava emphasises economic aspects, Budapest highlights accessibility and visitor benefits, Bucharest focuses on arts and festivals, while Prague and Vienna effectively combine historical authenticity with contemporary appeal.

Moreover, the results suggest that destination management organisations should tailor their digital strategies to the expectations of their target audiences and prioritise the creation of clear, engaging, and thematically coherent content. In this context, content quality consistently proves more important than quantity. Established destinations may benefit from focusing on visually refined and strategically curated posts, as exemplified by Vienna, whereas destinations targeting more diverse audiences may adopt a more hybrid and flexible communication approach, similar to Prague.

However, several limitations should be acknowledged. These include the absence of visual content analysis, the exclusive focus on English-language profiles, and the relatively static nature of the dataset, which may not fully capture seasonal variations or temporal dynamics. Future research should therefore integrate both textual and visual dimensions of social media content, examine engagement patterns over longer time periods, and extend the analysis to different types of destinations and geographical contexts. In addition, the application of advanced analytical methods could help establish stronger links between digital communication strategies and actual tourist behaviour, including behavioural and neurocommunication perspectives.

Overall, the study provides a robust foundation for additional research into digital tourism communication and offers practical insights for enhancing the effectiveness of Instagram-based destination marketing.

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STAFF AWARENESS OF MEDICAL WASTE MANAGEMENT AND ITS IMPACT ON ENVIRONMENTAL PERFORMANCE IN HOSPITALS IN SAUDI ARABIA

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Abstract. The research investigates the impact of staff awareness of medical waste management on environmental performance in hospitals in the Kingdom of Saudi Arabia. The study conceptualises staff awareness through four dimensions: concept and risk awareness, procedural awareness, safety and responsibility awareness, and organisational awareness. Hospital environmental performance is examined across four dimensions: internal environmental cleanliness, pollution and risk reduction, waste-handling efficiency, and environmental compliance and improvement. A quantitative cross-sectional survey design was adopted. Data were collected from 384 employees working in selected Saudi hospitals, including physicians, nurses, laboratory staff, pharmacists, technicians, housekeeping staff, environmental services workers, and administrative employees. The data were analysed using Partial Least Squares Structural Equation Modelling (PLS-SEM) through SmartPLS. The measurement model confirmed adequate reliability, convergent validity, and discriminant validity. The structural model results showed that all four dimensions of staff awareness had positive and statistically significant effects on the dimensions of hospital environmental performance. Concept and risk awareness had their strongest effect on internal environmental cleanliness. Procedural awareness was the strongest predictor of pollution and risk reduction, as well as waste handling efficiency. Safety and responsibility awareness showed consistent positive effects across all environmental performance dimensions. Organisational awareness had the strongest effect on environmental compliance and improvement. The findings confirm that staff awareness is not merely an informational factor but an important organisational capability that supports cleaner, safer, more efficient, and more compliant hospital waste-management practices. The study contributes theoretically by integrating staff awareness and hospital environmental performance into one explanatory model. Practically, it highlights the need for continuous role-based training, clear procedures, visible supervision, organisational communication, and shared responsibility among all hospital staff.

Keywords: staff awareness; medical waste management; environmental performance; hospitals; Saudi Arabia; waste handling efficiency; environmental compliance

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1. Introduction

Background

Hospitals provide critical services for safeguarding human health while creating significant environmental impacts due to their high consumption of resources to deliver services continuously, use of chemicals, release of wastewater, consumption of energy, the creation of medical waste (both hazardous and non-hazardous), and the generation of numerous categories of other types of waste. Medical waste is particularly significant because it may include infectious waste, sharps, pathological waste, pharmaceutical waste, chemical waste, and

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contaminated items that cannot be safely reused or recycled. Although most medical waste has been determined to be similar in nature to household (domestic) waste according to the World Health Organisation (WHO), the hazardous portions of the waste must be carefully separated from regular (non-hazardous) waste, and stored, transported, and treated safely to prevent harm to human health or the environment (WHO, 2014). Thus, identifying, separating, handling, and managing waste from the moment it is generated are all part of ensuring these two responsibilities can be satisfied.

Recent literature confirms that the environmental burden of healthcare waste is increasing globally across countries and health systems. In Taiwan, the amount of medical waste continued to rise steadily between 2016 and 2019, with infectious waste accounting for the largest fraction (Tsai, 2021; Kaposi et al., 2024). Consistent with our results, Khoshnevis et al. (2024) also reported a time-dependent increase in total hospital waste and hazardous healthcare waste generation in a university hospital, along with their association with intensive clinical activities, including surgical specialities, anaesthesiology, emergency care, and healthcare-associated infections. These results indicate that hospital ambient performance is not separate from clinical administration, infection-control methods, and staff behaviour.

Hospital waste systems are also susceptible to operational shocks, as accentuated during the COVID-19 pandemic. Wearables such as masks, gloves, face shields, and plastic-made testing materials are another growing sector of single-use protective items that increase pressure on waste management systems. Although most of the waste generated in hospitals is non-hazardous with proper segregation, Lee and Lee (2022) reported that healthcare institutions were not immune to environmental challenges, as healthcare workers widely use disposable products to minimise infection risk. That is important because poor segregation can turn recyclable materials and general waste into hazardous waste: treatment costs rise, and emissions and environmental risks increase. Thus, proper medical waste management is a strategic environmental issue and not just a technical housekeeping activity.

In this context, staff awareness is a key building block of hospital environmental performance. Awareness does not mean being aware of what medical waste is alone; it means understanding the levels of risk, correctly segregating procedures and colour-coding systems, knowing your responsibilities and those of your institution, and complying with institutional rules on waste management. According to a study conducted in Saudi Arabia (Thirunavukkarasu et al., 2022), there were significant differences in the knowledge, attitude and practice of biomedical waste management among the healthcare workers studied, with only 50% achieving high practice scores. This indicates that while there are both regulations and facilities in place for the management of biomedical waste, the ultimate environmental outcome will be directly related to the level of awareness among all staff regarding proper disposal methods and whether this awareness translates into their day-to-day behaviour.

The dimensions outlined in this document have been addressed to a large degree by various forms of empirical research. For example, Miamiliotis and Talias (2024) found that healthcare workers at Nicosia General Hospital had moderate familiarity with the disposal of infectious medical waste and good familiarity with the practice of segregating infectious waste. Thus, it was not surprising to find that a significant amount of infectious waste had been reported as mixed with non-hazardous waste. Their research also provided a major indication of the disconnect between knowledge and action, specifically regarding colour coding and the physical act of separating the two types of waste. Bizuneh et al. (2024) A study conducted by Bizuneh et al. (2024) found that only 20.8 per cent of respondents reported having good behaviour. Still, they had an average of 66.2 per cent of respondents reporting good knowledge and 86.9 per cent demonstrating a positive attitude toward their work. Both studies highlight the need for continuous staff education, the establishment of consistent guidelines, the implementation of staff monitoring systems, and management's follow-up with staff members to improve hospital environmental performance beyond just a positive attitude towards their work.

Staff awareness of waste management is particularly relevant for non-clinical and support staff. Millanzi et al. (2023) found that sanitary workers had not received adequate education on the proper handling of Healthcare Waste and that many believed they had no responsibility for handling the waste. These results raise an important issue because sanitary workers, cleaners, and waste handlers typically have the most direct contact with waste

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after it has been removed from a patient by the clinical staff. The absence of these groups from environmental communication and/or training may prevent hospitals from properly maintaining internal cleanliness, facilitating efficient waste transport and preventing pollution. This study will categorise staff awareness as a hospital-wide capability that encompasses clinical, non-clinical, technical, administrative, and support staff members.

Environmental performance in hospitals refers to the extent to which a hospital's operations harm the environment while still providing safe and effective medical services. When we think of environmental performance in terms of medical waste, it encompasses factors such as the cleanliness of the hospital's internal environment, efforts to reduce pollution and risk, the efficiency of waste handling, compliance with environmental regulations, and continual improvement. These measures are part of the growing trend towards "green" and sustainable healthcare, where hospitals strive to reduce their overall emissions through improved waste separation, reducing the inappropriate burning of waste, responsible management of water and energy, and compliance with environmental regulations without compromising patient safety.

Waste management has been highlighted as an element of environmental performance in several studies. The study by Thakur and Sharma (2021) evaluating existing health care solid waste management practices in hospitals in Himachal Pradesh, India, regarding environmental performance revealed weaknesses in segregation, marking of infectious waste bags, and transportation facilities; handling practices are deficient, and recycling is done without chemical disinfection or sanitisation. Their study elaborates on the direct relationship between operational practices such as collection, segregation, storage, and transportation, and stakeholder awareness, and environmental performance. Mushtaq et al. (2022) utilised a life cycle impact assessment (LCA) to demonstrate that properly segregated and recycled waste can reduce greenhouse gas emissions, thereby establishing an integrated hospital waste management scenario that is more effective than current practices. This strongly supports the notion that environmental performance is a measurable outcome variable, such as waste handling efficiency and pollution reduction.

The environmental performance perspective is not limited to waste collection alone. Yang et al. (2023) presented a dynamic framework for circularity performance in medical waste management. They proposed that traditional recycling-rate indicators may fall short of capturing the quality and circularity of recovered resources. The results indicate that hospitals and policymakers require more sophisticated performance measures to account for recycling efficiency, waste types and temporal changes. Dolcini et al. (2025) also claimed that hospitals should have environmental key performance indicators in energy, waste management, water consumption, greenhouse gas emissions (GHG), transport and traffic, and site sustainability. These contributions suggest that environmental performance is part of hospital performance management systems rather than a discrete compliance issue.

So, this study focuses on the staff awareness of medical waste management and environmental performance in hospitals. It is an answer to the call for a model that connected one side of human awareness regarding hospital waste management with the environmental performance side of operations. Employees will most likely improve environmental performance by strengthening proper segregation, reducing waste-related risks, supporting a cleaner internal environment, and doing everything possible to comply with environmental rules and regulations through continuous improvement in waste-handling practices. This position is well aligned with recent evidence that knowledge, education, and awareness play a significant role in safer practices for biomedical waste management. (Krishnamurthy et al., 2024; Thapa & Laskar, 2024), while effective waste strategies contribute to sustainability and environmental performance (Lee & Lee, 2022; Mushtaq et al., 2022; Dolcini et al., 2025).

Research Problem and Questions

The research problem arises from the extent of the existence of policies and procedures related to medical waste in health institutions, on the one hand, and the actual level of awareness among workers about these requirements, as well as their compliance with them, on the other hand. The staff vary in their professional disciplines, education pathways and histories, departments of care, exposure to waste and training experiences. The physicians, nurses, laboratory staff, pharmacists, technicians, housekeeping staff and administrative staff of the healthcare facilities cannot have awareness regarding medical waste type, colour coding segregation, etc.,

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storage and internal transport; their knowledge is poor as compared to their respective departments about personal protective equipment (PPE), emergency and responsibilities placed by the institution on employees themselves. The difference might make the hospital cleaner, reducing pollution and the risk of illness, improving waste management efficiency, and fulfilling other environmental regulations.

Earlier empirical studies found that training and knowledge are strongly correlated with safe biomedical waste management. Observational studies have suggested that not only knowledge but also attitude, training, and professional experience are associated with appropriate waste management behaviour among healthcare workers (Letho et al., 2021; Thirunavukkarasu et al., 2022; Udayanga et al., 2023). Other investigations have highlighted that environmental performance associated with hospitals requires systematic separation, storage, and transportation, monitoring, environmental assessment, and administrative commitment (Alighardashi et al., 2024; Dolcini et al., 2025; Mushtaq et al., 2022). But various studies have treated staff awareness and hospital environmental performance as two disjointed aspects. However, a relevant study is required to investigate the relationship between staff knowledge of medical waste management and hospitals' environmental performance.

Study Objectives

The main purpose of this study is to explore the effect of hospital employee awareness regarding medical waste management on environmental performance. This is significant because medical waste management is not a one-time technical process; rather, it involves a continuous organisational procedure that requires awareness, motivation, monitoring, and environmental control. Through this relationship, it will be helpful for hospital management to set up a better training programme and environmental practices, as well as improve waste-handling procedures.

Study Hypotheses

The research findings assert that awareness of medical waste management has a significant effect on environmental performance in hospitals, as indicated by the literature review, problem, and objectives. This leads to the main hypothesis and sub-hypotheses, which are worded as follows (Table 1).

Table 1. Study Hypotheses

Hypothesis Code	Hypothesis Statement
H1	Staff awareness of medical waste management has a statistically significant positive impact on hospitals' environmental performance.
H1a	Concept and risk awareness have a statistically significant positive impact on environmental performance in hospitals.
H1b	Procedural awareness has a statistically significant positive impact on environmental performance in hospitals.
H1c	Safety and responsibility awareness has a statistically significant positive impact on environmental performance in hospitals.
H1d	Organisational awareness has a statistically significant positive impact on environmental performance in hospitals.
H2	There are statistically significant differences in staff awareness of medical waste management across selected demographic and professional variables, such as job title, department, experience, and training.
H3	There are statistically significant differences in perceived hospital environmental performance across selected demographic and professional variables, such as job title, department, experience, and training.

2. The Theoretical Framework

2.1. The Independent Variable: Staff Awareness of Medical Waste Management

Conceptual and risk awareness relate to a particular worker's comprehension of what constitutes medical waste, how they differ from ordinary waste, which waste streams are considered hazardous, and how improper handling may place patients at risk; staff members must also consider the transmission of infectious diseases, potential needle-stick injuries, exposure to hazardous chemicals, the risks associated with pharmaceutical waste, the potential for contamination of soil and groundwater through mismanaged medical waste, and the potential for generating emissions through improperly treating or transporting medical waste by uncontrolled burning. WHO (2024) provides additional information about the potential release of chemical and/or biological hazards due to the unsafe management of healthcare waste; therefore, conceptual and risk awareness are viewed as the baseline

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for enabling workers to view the management of medical waste as an important safety and sustainability issue, and not just an everyday routine housekeeping issue.

Procedural awareness involves understanding the appropriate operational steps for handling medical waste. It includes knowledge of the colour-coding system, containers and bags for different waste streams, segregation at source, labelling, temporary storage, internal transportation of biomedical waste within the institution's premises, and guidelines for reporting and classification of infectious waste, including sharps waste, pharmaceutical waste, chemical hazardous waste, and non-hazardous medical waste. And procedural awareness is important because generic knowledge of risk is not very helpful if the employee does not know precisely what to do at the time of waste generation. Practical procedures are emphasised in the WHO handbook (WHO, 2014) and in the Saudi technical guidelines for safe identification, separation, containment, transport and management of healthcare waste (MWAN, 2023; WHO, 2014). Hospitals are real-Life systems where processes are performed under time pressure. This makes procedural awareness less ambiguous and more standardised behaviour in those settings. Here are a few examples: sharps must be placed immediately in puncture-resistant containers, infectious waste must be placed in the correct bags and labelled properly, pharmaceutical waste may need to be separated and treated separately when discarded, and non-hazardous recyclable materials should not be mixed with hazardous waste unnecessarily. Staff who understand these procedures are better equipped to avoid cross-contamination, minimise the volume of hazardous waste produced, and facilitate efficient waste handling.

The concept of responsibility and safety awareness is a staff member's understanding of their personal and collective responsibility for the safe management of waste. This covers understanding the use of Personal Protective Equipment, prevention of exposure incidents, and how to report them; appropriate immunisation of employees before treatment; how to handle spills; the segregation of waste at the point of generation; and responsibility for co-workers, patients, waste handlers, and the community. This dimension is significant because the management of medical waste has both environmental and occupational health impacts. Poor management can endanger employees in the hospital, as well as contractors and municipal systems, which are at risk of transferring the danger beyond the hospital vicinity to the community.

Service providers are required to continually train and orient staff on how to handle appropriate waste streams in accordance with Saudi technical guidelines (MWAN, 2023) by conducting fitness and health checks on staff. This means that responsibility awareness encompasses both personal liability and corporate duty of care. Waste safety does not start with disposal after clinical work; it starts at the generation of waste, and staff must understand this. Specifically, safe segregation of chemistries mitigates later risk posed to the workforce (in particular cleaners and waste transporters); correct labelling minimises potential danger to individuals working in treatment plants; immediate reporting of spills/injuries reduces both occupational and environmental impacts.

Organisational literacy is a staff member's understanding of the hospital policies, waste-management plan, infection-control requirements, environmental regulations, reporting lines (who must report to whom), the documentation system for these processes, the training schedule, audit principles and mechanisms, as well as accountability frameworks. This dimension assumes that staff understanding goes beyond technical knowledge to include awareness of the institutional system that facilitates or controls waste-management behaviour (Alharbi et al., 2021). The authors also argue that a holistic understanding of sustainable environmental management of healthcare waste, encompassing policy, organisational, and individual levels, is presented in Alharbi et al. (2021). This strengthens the messages regarding medical waste management as a governance process that spans not only clinical and housekeeping functions but also all areas of a hospital.

Organisational awareness is vital for the hospital to function effectively with external sources of waste, such as licensed waste transporters and treatment providers, regulatory inspectors, and environmental authorities. A staff member must know who is responsible for every step in the waste chain; how to fill out waste-related documentation; where temporary waste storage occurs; when waste pick-up occurs; how to report instances of non-compliance; and how to follow through with incident management. The technical guidelines provided by the Kingdom of Saudi Arabia mandate that every facility write a waste management plan that includes all waste generated by the facility and outlines all aspects of the waste management process, including classification,

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segregation, separation, storage, transportation, treatment, as well as health and safety (MWAN, 2023). Overall, organisational awareness ties individual actions to institutional compliance.

2.2. The Dependent Variable: Hospital Environmental Performance

The study's dependent variable is hospital environmental performance. Environmental performance is defined as the hotel or hospital's efficiency, safety, compliance and sustainability in its environmental practices. As applied to hospital environmental performance, these included internal environmental cleanliness, pollution and risk reduction, waste handling efficiency, and compliance with and improvement on environmental regulations. This conceptualisation is in line with the general literature that treats environmental performance as a multidimensional construct comprising operational outcomes (pollution prevention, resource efficiency), compliance, and continuous improvement (Seifert & Guenther, 2019; Trumpp et al., 2015).

Internal environmental cleanliness consists of ensuring that the hospital units, corridors, treatment rooms, laboratories, storage areas, and waste rooms are free from visible accumulation or cross-contamination between facilities. Due to the direct implications of cleanliness for infection prevention, staff protection, and the assurance of patient and environmental quality, it is a core marker of hospital ecological performance. Environmental cleanliness is sometimes seen as a housekeeping by-product and underpinned by behaviour factors at the point of waste creation. If this waste is improperly disposed of, not made safe, or stored in inappropriate areas, it can compromise the cleanliness of the ward's clinical spaces.

Segregation behaviour is integral to the purity of an internal environment. The correct segregation reduces leakage and odour — it is also an attractive site for pests and can lead to accidental exposure. It further facilitates the smooth transportation of waste from clinical sectors to storage and treatment facilities. WHO (2014) states that safe waste-management practices must ensure protection for healthcare workers, patients, visitors, and the public from risks posed by waste due to inadequate management. Thus, having a clean is not only an aesthetic consideration; it is in fact a safety and performance requirement. In the present study, internal cleanliness is considered one of the immediate responses expected to improve when staff cognise waste types, risks, and practices.

Pollution and risk reduction: The hospital should have a plan for managing medical waste to minimise environmental pollution and health risks. This encompasses soil and water pollution, reducing unsafe emissions, cross-contamination between dangerous and non-dangerous waste, physical exposure to the natural world, improper fire disposal, and addressing bad practices. As stated by the WHO (2024), safe and environmentally sound management of healthcare waste can prevent negative impacts on human health and the environment. Thus, pollution prevention and risk reduction are key outcomes of proper medical waste management.

Mismanagement of medical waste poses multiple environmental risks. Infectious waste can carry pathogens; sharps can injure and/or infect people; and chemical and pharmaceutical waste can contaminate ecosystems. In addition, improper incineration can lead to air pollution. Mushtaq et al. (2022) compared hospital waste-management scenarios using a life cycle assessment method and determined that a combined waste-management approach utilising segregation and recycling could provide a pathway to sustainability. Thus, your environmental risk will be determined not just by what happens at the end of the waste-management chain but also by the decisions made throughout the entire chain.

Efficiency: Waste handling refers to the hospital's ability to manage waste in a timely, organised, low-cost, and eco-friendly manner. It encompasses the segregation of hazardous waste material, reduced volume of unwanted hazardous waste disposal, internal collection with appropriate containers and a quickly filled, high-efficiency storage medical depot, efficient coordination with external contractors for their utilisation, appropriate equipment identification, and proper documentation. Therefore, it is fundamental to take effective measures in waste management; hospitals that misclassify or mix waste increase treatment costs, put pressure on storage capacity, and require greater transportation capacity while increasing environmental risk. Lee and Lee (2022) also recognised operational management issues—medical waste management, training, awareness, and environmental assessment—for effective green healthcare, with potential implications for sustainable efficiency, further illustrating the interconnectedness of operational and human factors.

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Staff awareness has a significant impact on the efficiency of waste management. Without procedures, employees may contaminate infectious-waste containers with a lot of waste, may ignore instructional streams for recyclables, may not use the correct bag, or may, by all odds, put their own trash in the incorrect items. These practices slacken operational efficiency and may need to be redone by housekeeping or waste-management teams. On the other hand, proper staff training can prevent mistakes and make assistance easier by directing how to execute correct procedures. Efficient waste handling improves environmental performance by minimising unnecessary waste treatment, lowering emissions, and creating more opportunities for resource recovery.

To create more environmentally sound and economically viable outcomes, the Saudi Arabian waste management system promotes waste reduction, separation, reuse, recycling, and proper disposal (MWAN, 2023). Efficiency should therefore be defined not only in terms of time and money but also of the environment. For instance, if a hospital disposes of its waste quickly but fails to separate hazardous from non-hazardous waste, this practice does not demonstrate environmental efficiency. As a result, an efficient waste management system should enable proper classification and the safe movement of waste while minimising environmental impact. By helping staff understand waste-handling processes, it is anticipated that they will adopt daily practices consistent with both technical and regulatory requirements.

Environmental compliance and improvement are the hospital's commitment to following national regulations and institutional policies, meeting technical audit requirements, and continuously improving medical waste management. Compliance means following the rules for classifying, segregating, storing, transporting, treating, documenting, protecting workers, and coordinating contractors. Improvements include training, monitoring, correcting identified issues, assessing performance, and gradually developing more sustainable practices. According to Alharbi et al. (2021), the performance of hospital waste management is the result of the interaction among policy, organisation, and individuals, thus making compliance a regulatory and behavioural outcome.

The compliance regime is well established through Saudi regulations and guidelines. The Uniform Law for the Management of Hazardous Substances and Medical Waste requires strict segregation between hazardous and non-hazardous medical waste, as well as specialised personnel trained to collect and transport the waste (Ministry of Health, 2019). These technical guidelines will supplement the Waste Management Law and its implementing regulations, outlining waste producers' obligations regarding the segregation, packaging, labelling, handling, storage, and treatment of waste, as well as training (MWAN, 2023). Thus, having qualified personnel who know not only what to do but also the best practices and the complete reasoning behind regulations will contribute to superior environmental performance and compliance with all applicable laws at any given moment.

Environmental performance is made up of continual improvement, too. They should be assessed through audits, incident reports, training updates, environmental indicators, and staff feedback to improve local-level medical waste management systems. Environmental management literature has highlighted that performance measurement is multi-faceted, with both outcomes and management processes needing to be incorporated (Trumpp et al., 2015). In hospitals, compliance without improvement results in doing only what is within the routine minimum performance level and improvement without compliance lacks legal discipline. Thus, compliance with and improvement in environmental issues constitute the governance aspect of hospital facility performance.

2.3 The Relationship Between the Variables Considering Different Theories

Several complementary theories may help explain the relationship between staff awareness of medical waste management and hospital environmental performance. Medical waste management is a behavioural, organisational, regulatory, ethical, and resource issue all at once, so no single theory will suffice. This framework incorporates the Knowledge–Attitude–Practice (KAP) perspective, the Theory of Planned Behaviour, Social Cognitive Theory, Institutional Theory, Stakeholder Theory, and the Natural-Resource-Based View. All these mechanisms together shed light on how awareness influences environmental performance through infotainment = awareness + capacity (knowledge, motivation & perceived control) + rituals: social

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learning by copying better workplaces to fill gaps; regulatory pressure for change in corporate behaviour; ethical responsibility; and organisational capability (Table 2).

Table 2. Critical Synthesis of Previous Studies, Research Gaps, and Implications for the Current Study

Theoretical perspective	Core idea	Implication for the study
KAP perspective	Knowledge and awareness influence attitudes and practices.	Staff awareness is expected to guide proper waste management behaviour.
Theory of Planned Behaviour	Attitude, subjective norms, and perceived control shape behavior.	Awareness strengthens the willingness and capability to follow waste procedures.
Social Cognitive Theory	People learn through observation, reinforcement, and self-efficacy.	Training, role modelling, and feedback help convert awareness into practice.
Institutional Theory	Organisations respond to regulatory and normative pressures.	Awareness helps staff internalise legal and organisational waste-management requirements.
Stakeholder Theory	Organisations should protect the interests of affected stakeholders.	Waste management is a responsibility toward patients, workers, communities, and the environment.
Natural-Resource-Based View	Pollution prevention and environmental capabilities support performance.	Staff awareness is an intangible capability that supports hospital environmental performance.

3. Previous Studies

3.1. Independent Variable: Staff Awareness of Medical Waste Management

Millanzi et al. (2023) examined the knowledge, attitudes, and perceived practices of sanitary workers concerning health care waste management in the Dodoma region of Tanzania. The researchers targeted sanitary workers as they can be directly engaged in the collection, transportation, storage and disposal (when necessary) of health care waste, but have historically received little to no training in infection control or waste management compared to those in clinical jobs; therefore, focusing on this group is relevant as they comprise a significant percentage of hospital waste management staff. Sanitation employees are not very familiar with, and do not concern themselves with, the collection, transportation, and storage of health care waste. It would benefit them to receive training in waste management tailored to the sociodemographic characteristics of sanitation employees. This research supports the current work, which holds that awareness should not be given only to physicians and nurses but also to all staff members who handle the waste, such as housekeepers and environmental services employees, who should have proper awareness and training.

Venugopal et al. (2024) identified predictive variables for nursing personnel's use of biomedical waste disposal practices at a tertiary care teaching facility in India. This study was specifically directed towards nursing staff because they are actively engaged in patient care and have a unique impact on the creation, separation, storage, and disposal of biomedical waste at the healthcare facility. The researchers stated that potential adverse effects on patients and other individuals from the unsafe disposal of biomedical waste materials could be significant, while safe disposal supports environmental protection. Researchers concluded that staff nurses should participate in periodic training programs to enhance their knowledge and strengthen their existing knowledge of biomedical waste management. Recommendations for future studies include developing creative ways to train nurses and investigating the effects of training on nurses' behaviours towards biomedical waste management across multiple centres. The original research applies to my current research because it shows a direct relationship between knowledge, training and practice and demonstrates that awareness (of environmentally responsible waste management practices) is a predictor of environmentally responsible waste management behaviour in hospitals.

Thapa and Laskar (2024) surveyed health care providers in a Primary Health Centre in Sikkim, India, to assess their understanding, attitudes, and behaviours regarding biomedical waste disposal. The research included a test to examine the relationships among knowledge, attitudes, behaviours, and demographic/professional variables. The researchers believe that biomedical waste poses a substantial risk of serious illness and that sufficient training and education are necessary for waste handlers to ensure the safe and secure handling of biological waste. The study findings revealed that 66% of participants achieved an adequate score in knowledge, 66%

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achieved a favourable score in attitude, and 60% achieved a good score in practice regarding biowaste management. However, substantial gaps exist in the knowledge of supportive health care employees due to the minimal availability of formal training. The maximum time allotted for biowaste storage was known to only 12% of respondents. Comprehension of personal protective equipment, the use of colour codes, and potential infectious risks was well understood by most respondents; however, refresher training was not conducted frequently.

Webb et al. (2024) conducted a pilot study within the United Kingdom National Health Service (NHS) to explore barriers to sustainable medical waste segregation and to understand why some medical waste is incorrectly classified as hazardous. The study is relevant to staff awareness because it focused on the practical decisions made by healthcare workers at the point of waste disposal, particularly in distinguishing between hazardous, non-hazardous, infectious, and potentially recyclable waste streams. The findings showed that staff were generally attentive to identifying hazardous waste. Still, they often classified materials that had contact with bodily fluids as hazardous even when the waste might not be infectious. The main practical barriers were limited availability of different bins, lack of space, busy schedules, and insufficient clarity about recyclable materials. The authors recommended clearer visual information, posters, bin labels, and more practical training to help staff correctly identify both hazardous and non-hazardous waste. This study supports the current thesis by emphasising that staff awareness must encompass procedural clarity, confidence in classification, and organisational support, rather than mere general knowledge of risk.

Sturm et al. (2026) examined staff attitudes toward healthcare waste separation in Germany from a triple-bottom-line perspective. The study was conducted in a developed healthcare context where hospitals and comparable facilities are expected to separate glass, paper/cardboard, residual waste and other non-hazardous materials. The study is important because it links staff interest, perceived proficiency, opinions, and awareness of waste separation to environmental, economic, and practical sustainability considerations. The results indicated that healthcare staff generally recognised the importance of sustainable waste separation; however, effective implementation depended on practical enablers such as simple instructions, accessible containers, and organisational encouragement. The study therefore reinforces the point that awareness alone is insufficient unless it translates into routine behaviour through visible procedures and supportive workplace systems. This study is highly relevant to the present thesis because it supports the procedural and organisational awareness dimensions of staff awareness of medical waste management.

3.2. Dependent Variable: Hospital Environmental Performance

Thakur and Sharma (2021) were motivated to evaluate solid waste management practices in hospitals in relation to environmental performance: Evidence from Himachal Pradesh, India. This study presents itself as necessary because of excess healthcare waste and the growing challenge of maintaining environmental quality in developing health systems. It targeted four performance areas: collection and segregation of health care solid waste; storage and transport; special precautions for handling infectious waste; and knowledge of health care solid waste management among stakeholders involved in its generation. Findings showed that most hospitals utilised separate containers and/or colour-coded bins to collect infectious healthcare solid waste, and many had on-site segregation. A few key weaknesses identified were poor demarcation of infectious waste areas and bags, inadequate storage and transport facilities, poor handling practices, and recycling without proper chemical disinfection. The study further noted that knowledge levels among stakeholder groups also differed, underscoring the need for ongoing awareness-raising and training for all workers handling waste. Lee and Lee (2022) sought to investigate the significance of medical waste management activities in promoting sustainable green healthcare. The paper contended that medical waste management is not simply a technical issue but an operational imperative for hospitals to reduce their environmental footprint, enhance resource utilisation, and support sustainable healthcare. The research context is the increased volume of medical waste produced in hospitals due to the COVID-19 pandemic and the growing urgency for sectors like health to move towards more sustainable practices. The analysis would yield five core consequences for managing medical waste toward sustainable, green healthcare. The most significant areas were medical waste management per se, operational management issues, training for the delivery of medical waste management, awareness-raising, and environmental assessment.

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To conclude, the study showed that safe storage of infectious waste, ensuring adequate policies and manuals, periodic monitoring of compliance, training staff on handling measures, and integrating waste management into day-to-day activities are key to effective waste management. It also stressed that keeping waste to a minimum is not the responsibility of one department — all members of the hospital need to be involved. Shakoor et al. (2024) conducted a quantitative/qualitative evaluation of hospital solid waste management at the Pakistan Institute of Medical Sciences Hospital in Islamabad. The present analysis described health care-related solid waste as an environmental and occupational health dilemma, particularly in developing countries, where improper disposal can increase exposure to pollutants and diseases, and expose workers involved in solid waste management. This research is significant because it examines the amount of waste and operational practices at a large-capital healthcare facility. According to this study, the hospital produces 61,030 kg of hazardous waste and 254,866.9 kg of non-hazardous waste each year. The hospital has an effective solid waste management program that segregates hazardous from non-hazardous waste at the point of generation using a colour-coded system. Non-hazardous waste is transported securely to a covered storage area in carts, whereas hazardous waste is incinerated in on-site dual-chamber incinerators. The research found that personnel responsible for managing solid waste also face significant health risks on the job, including injuries from sharp objects, exposure to diseases, stress, and anxiety.

Kaposi et al. (2024) sought to quantify the waste generated by health systems to identify the drivers of hazardous waste at a University Hospital. This research was motivated by the rapidly increasing global volume of healthcare waste and aimed to identify the clinical and operational drivers most responsible for generating hazardous waste in healthcare. The authors conceptually position health system waste as both an environmental and a patient safety issue, as detailed studies of the amount of health system waste generated, its tracking, and accountability for the origins of that waste are essential for minimising the amount of waste produced. According to the study, total healthcare waste increased by 2.11% each year, and the healthcare waste generation rate per bed ranged from 2.53 to 2.68 kg/day. Over the five years studied, hazardous healthcare waste increased by 20.19%, with an estimated hazardous healthcare waste generation rate per bed of 1.13-1.31 kg/day. Surgical specialities, anaesthesia, the Intensive Care Unit (ICU), and emergency departments produced greater-than-average amounts of hazardous waste. A positive relationship existed between hazardous waste and healthcare-associated infections, and the quantity of adult and child diapers used. Also, these predictors were validated by multiple regression analysis.

Dolcini et al. (2025) found that environmental performance dimensions and key performance indicators (KPIs) are common and important in the current scientific literature on hospitals' sustainable environmental practices. The rationale for this study was that hospitals are among the most resource-intensive healthcare institutions and have a major negative impact on the environment. Therefore, environmental sustainability must be included in hospital performance measurement systems to provide for structured assessments, comparisons between facilities or organisations, tracking over time, and the ability to continually make improvements. Six primary sustainability areas have been identified for assessing the environmental efficiency of hospitals: the management of energy resources; the management of waste products; the use of water; the production of greenhouse gases; the movement of people and goods; and the long-term sustainability of hospital sites. In addition, the review suggested a combined framework comprising 18 indicators (KPIs) to assess hospitals' environmental performance. There was significant variation in the level and detail of the information available to measure hospitals' environmental sustainability performance. This significant degree of variance demonstrates that there is currently no uniform method of measuring environmental sustainability performance in hospitals. Because there is no standard method for measuring environmental sustainability performance in hospitals, it is also impossible to effectively compare hospitals, measure progress toward sustainable practices, or incorporate environmental sustainability measures into broader hospital performance systems. Vielsack et al. (2026) conducted a nationwide benchmark study on healthcare waste in German hospitals. The study was motivated by the lack of detailed, scientifically reliable hospital-level data on waste generation in Germany, which limits hospitals' and policymakers' ability to develop evidence-based circular economy and waste-reduction initiatives. The study, therefore, directly addresses hospital environmental performance using measurable waste indicators. The results showed strong associations between waste generation and hospital structural characteristics, especially staffing levels, and revealed differences between general and university hospitals across key performance indicators. The authors proposed a differentiated extrapolation model that uses

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the number of beds as a reference to estimate waste generation. This study is relevant to the current thesis because it demonstrates how hospital environmental performance can be measured using objective indicators such as total waste mass, hazardous-waste share, infectious-waste share, benchmarking indicators, and waste-generation models, thereby supporting environmental compliance and continuous improvement.

3.3. Research Gap, and Added Value of the Current Study

Table 3 provides an overview of the most important strengths and weaknesses, as well as implications for this research based on the literature review.

Table 3. Overview of the Literature

Literature Stream	Main Strengths	Main Limitations	Implication for the Current Study
Awareness / KAP studies	Recent evidence on knowledge, attitudes, training, and practices across different hospital staff categories.	Often focus on staff scores without directly testing hospital environmental performance.	Supports measuring staff awareness as an independent variable.
Training and procedural studies	Show that training is associated with better knowledge and safer waste-management behaviour.	Training effects are often examined descriptively or cross-sectionally.	Supports testing the role of procedural awareness and safety awareness.
Support-staff studies	Highlight the importance of sanitary workers, cleaners, and waste handlers.	Often limited to a single occupational group or region.	Supports using a broader hospital-staff sample.
Environmental performance studies	Provide indicators related to waste, emissions, recycling, circularity, and compliance.	Often, they under-emphasise the human awareness factor behind performance.	Supports measuring environmental performance as a dependent variable.
Integrated waste-management studies	Show that segregation, recycling, and treatment strategies can reduce emissions and improve sustainability.	Some studies are technical and do not test staff awareness as a predictor.	Supports linking awareness to waste-handling efficiency and pollution reduction.
Green hospital/sustainability studies	Provide broad frameworks for environmental performance and continuous improvement.	Sometimes too broad for direct connection with staff waste-management awareness.	Supports focusing the current study on waste-related dimensions of environmental performance.
Saudi studies	Provide valuable local evidence on knowledge and training gaps among healthcare professionals.	Do not sufficiently connect the dimensions of awareness to hospital environmental performance outcomes.	Justifies the contextual relevance and contribution of the current study.

Accordingly, the central research gap can be articulated as follows: how the disparate impacts of different tranches of staff awareness on medical waste management and environmental performance in hospitals are explained has not been sufficiently explicated in previous studies. There is a demand for the study of concept and risk awareness, procedural awareness, safety and responsibility awareness, and organisational awareness in relation to internal environmental cleanliness, pollution and risk reduction (i.e., cleanup), waste-handling efficiency, and enhancement of environmental compliance. The present study fills the gap by proposing and testing an integrated model in which staff awareness of medical waste management positively influences hospital environmental performance. The anticipated contribution of this model is to create a bridge connecting the human, procedural, organisational, and environmental dimensions that separate medical waste management pathology. Thus, this research does not replicate earlier KAP or environmental performance studies; rather, it seeks to explain how staff awareness can be a concrete step toward cleaner, safer, more compliant hospital practice grounded in environmental responsibility.

4. Research Methodology

Population and Sample

The study population included employees working in selected hospitals within the Kingdom of Saudi Arabia whose tasks and duties were directly or indirectly related to medical waste management and environmentally responsible practices. This group comprised physicians, nurses, laboratory technicians, pharmacists, infection-control personnel, housekeeping staff, environmental services workers, and administrative employees involved

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in handling, segregating, collecting, storing, transporting, supervising, or monitoring medical waste. Since the study required participants with relevant practical experience in hospital medical waste management, a non-probability purposive sampling technique was applied. Using this criterion, 384 participants were selected from Saudi hospitals. This approach was appropriate because the research focused on staff members who had direct or indirect exposure to medical waste management practices and were therefore able to provide meaningful responses regarding awareness and environmental performance.

Data Collection Procedure

Data were collected from individuals working in selected hospitals within the Kingdom of Saudi Arabia who had direct or indirect involvement in medical waste management and related environmental practices. The field data collection process was conducted from 1 March 2026 to 15 April 2026. Before data collection, participants were informed about the study's aims, the voluntary nature of participation, and the confidentiality of their responses. They were also informed that the collected data would be used for academic research purposes only. A purposive sampling technique was adopted to target participants with relevant experience and practical involvement in medical waste handling and related environmental practices. The questionnaire was distributed to eligible hospital staff during the specified data collection period, and adequate time was provided for self-administered completion. Returned questionnaires were reviewed for completeness and suitability for analysis, and only properly completed responses were retained in the final dataset.

Respondent Profile and Sample Characteristics

The demographic profile of the respondents was reasonably diverse (Table 1), which reinforces the conclusion that the sample was representative of the heterogeneity across hospitals (and hospital functions). Regarding gender, the sample was balanced (49.7% males and 50.3% females). Age-wise, most respondents were in the 25–34 age range (37.5%), suggesting that most participants were in the early to mid-evolution stage. In terms of job titles, nurses (37.0%) were highest in proportion, followed by physicians (18.5%), and housekeeping/cleaning staff (12.8%); this demonstrates the main role that both clinical and support personnel have in respect to medical waste management practices The highest proportions in regard to departmental affiliation were in internal medicine (18.8%) and outpatient departments (16.7%), which were followed up by ICU (13.3%) and emergency units (12.2%), showing that the sample covered a wide range of hospital units with different exposure towards medical waste handling; Approximately half of the respondents were educated to degree level (53.6%), followed by diploma holders (18.5%) and postgraduate qualifications constituted a smaller but still salient cohort. Regarding work experience, the two largest groups were those with less than 5 years (27.1%) or 5–10 years of experience (29.7%), indicating that the sample was mostly composed of relatively experienced yet still active mid-level personnel. Noteworthy was the disparity between 71.4% who had received any medical waste management training and 28.6% who had not; still, within a generally acceptable level of institutional attention to the issue, with perceptions measured using socio-demographic variables. This is reinforced by the training frequency distribution: 28.6% reported having attended no training courses, while the others reported having completed one or more. On the whole, Table 4 shows that a heterogeneous and practically relevant sample was used in the study, which was enriched to examine staff awareness of medical waste management and its impacts on hospitals' environmental performance.

Table 4. Demographic Profile of Respondents

Characteristic	Categories	Frequencies	Percentages
Geographical scope	Selected hospitals within Saudi Arabia	384	100.0%
Gender	Male	191	49.7%
	Female	193	50.3%
Age	Less than 25 years	27	7.0%
	25–34 years	144	37.5%
	35–44 years	110	28.6%
	45–54 years	72	18.8%
	55 years or above	31	8.1%
Job title	Physician	71	18.5%
	Nurse	142	37.0%
	Pharmacist	20	5.2%
	Laboratory Staff	32	8.3%
	Technician	39	10.2%

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	Housekeeping / Cleaning Staff	49	12.8%
	Administrative Staff	19	4.9%
	Other	12	3.1%
Department / Unit	Emergency	47	12.2%
	Surgery	38	9.9%
	Internal Medicine	72	18.8%
	ICU	51	13.3%
	Laboratory	31	8.1%
	Pharmacy	17	4.4%
	Outpatient Department	64	16.7%
	Housekeeping	40	10.4%
	Other	24	6.2%
Educational level	Secondary school or below	49	12.8%
	Diploma	94	24.5%
	Bachelor's degree	171	44.5%
	Master's degree	47	12.2%
	Doctorate	23	6.0%
Years of experience	Less than 5 years	104	27.1%
	5–10 years	114	29.7%
	11–15 years	73	19.0%
	16–20 years	58	15.1%
	More than 20 years	35	9.1%
Received training in medical waste	Yes	274	71.4%
	No	110	28.6%
Number of training courses attended	None	110	28.6%
	1	94	24.5%
	2	70	18.2%
	3	70	18.2%
	More than 3	40	10.4%

Statistical Analysis

The data from the questionnaire were analysed using SmartPLS, employing partial least squares structural equation modelling (PLS-SEM). This approach was used because it is suitable for investigating causal relationships between latent constructs and for evaluating research models that aim to predict and explain. Statistical analyses were performed in two sequential steps. Stage 1: Measurement of the measurement model to confirm that the study measures are sufficient. Namely, this was done by exploring indicator loadings, Cronbach's alpha, composite reliability, and average variance extracted (AVE) to assess convergent validity and internal consistency. Subsequently, discriminant validity was evaluated with the Fornell–Larcker criterion and the heterotrait–monotrait ratio (HTMT). The structural model was assessed during the second stage by analysing collinearity, path coefficients, coefficient of determination (R^2), effect size (f^2), and predictive relevance (Q^2). The significance of pathways was checked through the bootstrapping procedure (5,000 subsamples). It is important to note that only the questionnaire data were included in the SmartPLS analysis, and 45 personal interviews were conducted, independently of the quantitative model analysis, to strengthen the contextual understanding of the results.

Bootstrapping was added to assess the significance and stability of the structural model estimates. In SmartPLS, the bootstrapping procedure was conducted using 5,000 resamples to generate empirical t-values, p-values, standard errors, and confidence intervals for the path coefficients. This non-parametric procedure was appropriate because it does not require the assumption of multivariate normality and allows the researcher to determine whether each hypothesised relationship is statistically significant (Hair et al., 2021).

Semi-Structured Interview Guide

The semi-structured interview guide was designed to align with the study variables and explain how the interviews supported the interpretation of the quantitative results (Table 5).

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Table 5. The Semi-Structured Interview Guide

Theme	Interview Question	Purpose
Opening	Can you briefly describe your current role in the hospital and your connection with medical waste management?	To identify participant role and level of exposure to waste-related activities.
Concept and risk awareness	How do you define medical waste, and how do you distinguish it from general hospital waste?	To assess conceptual understanding of medical waste categories.
Concept and risk awareness	What risks may result from improper handling or disposal of medical waste?	To explore perceived risks to staff, patients, visitors, community, and environment.
Procedural awareness	What are the main steps followed in your hospital for segregating, collecting, storing, and moving medical waste?	To understand procedural knowledge and workflow clarity.
Procedural awareness	How clear are the colour-coded containers, labels, and disposal instructions used in your workplace?	To assess the clarity of segregation tools and visual guidance.
Safety and responsibility awareness	What safety precautions do staff usually follow when dealing with medical waste?	To explore PPE use, exposure prevention, and incident response.
Safety and responsibility awareness	Who do you think is responsible for safe medical waste management inside the hospital?	To identify whether waste management is viewed as a shared responsibility or delegated only to support staff.
Organisational awareness	Are hospital policies and procedures related to medical waste clearly communicated to staff?	To assess awareness of institutional rules, instructions, and communication.
Organisational awareness	What type of training or supervision is provided regarding medical waste management?	To explore role-based training, monitoring, and supervision mechanisms.
Environmental performance	In your view, how does proper waste management affect internal cleanliness and hygiene in the hospital?	To connect awareness and procedures with internal environmental cleanliness.
Environmental performance	How can proper medical waste management reduce pollution, risks, and unnecessary hazardous waste?	To connect awareness and procedures with pollution and risk reduction.
Environmental performance	What improvements would you suggest to strengthen medical waste management and environmental performance?	To identify practical recommendations from participants.

Thematic Analysis Procedure

- Step 1: Familiarisation. The researcher reviewed all interview notes several times to identify recurring themes related to awareness, procedures, responsibility, organisational practices, and environmental outcomes.
- Step 2: Initial Coding. Statements were coded according to the study's main dimensions: concept and risk awareness, procedural awareness, safety and responsibility awareness, organisational awareness, internal cleanliness, pollution and risk reduction, waste-handling efficiency, and environmental compliance.
- Step 3: Theme Development. Related codes were grouped into broader qualitative themes. For example, comments about colour-coded containers, storage, and transport were grouped under procedural clarity; comments about policy, reporting, and supervision were grouped under organisational awareness.
- Step 4: Theme Review. Themes were reviewed against the quantitative findings to determine whether they helped explain the pattern of significant relationships found in the structural model.
- Step 5: Interpretation. The final themes were used as contextual support in Chapter Five. They were not used to calculate statistical relationships and were not entered into SmartPLS.

Qualitative Interview Findings as Contextual Support

The qualitative interviews provided additional contextual support for the quantitative findings. Although the interview data were not included in the SmartPLS analysis, they helped explain how different types of staff awareness were reflected in daily hospital waste-management practices. The interview findings were organised into six main themes.

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First, participants generally perceived medical waste management as a shared responsibility across clinical, technical, support, and administrative groups. This supports the quantitative finding that safety and responsibility awareness had consistent positive effects across all environmental performance dimensions. Participants indicated that errors in waste handling may occur when some staff assume that medical waste management is the responsibility of housekeeping or environmental services only. Therefore, the interviews reinforced the importance of fostering a culture of collective responsibility rather than assigning waste management to a single occupational group.

Second, the interviews showed that conceptual and risk awareness helped staff understand why medical waste should be separated from general waste and why incorrect disposal may increase infection risk, environmental contamination, and treatment burden. This contextualises the positive effect of concept and risk awareness on internal environmental cleanliness. When staff understood the risks of improper segregation, they were more likely to describe cleanliness as a direct outcome of careful disposal behaviour at the point of waste generation.

Third, procedural awareness emerged as the most practical theme in the interviews. Participants repeatedly emphasised the importance of knowing the correct container, colour code, label, temporary storage point, and internal movement procedure. This supports the quantitative result showing that procedural awareness was the strongest predictor of pollution and risk reduction, and a strong predictor of waste handling efficiency. The qualitative evidence suggests that pollution prevention begins within the hospital, when staff follow proper procedures before waste reaches final treatment or disposal.

Fourth, organisational awareness was strongly linked to compliance and improvement. Participants referred to the importance of clear policies, visible supervision, reporting channels, responsible units, training programs, and audit procedures. This explains why organisational awareness had the strongest effect on environmental compliance and improvement in the structural model. The interviews indicate that compliance is not achieved solely through individual knowledge; it also depends on whether staff understand the hospital waste-management system and know how to operate within it.

Fifth, training was repeatedly identified as a major factor in improving awareness and reducing errors. Participants emphasised that general lectures are less effective than practical, role-based training that shows staff how to segregate waste, use PPE, respond to exposure incidents, and report non-compliance. This finding is consistent with the study recommendations calling for continuous training, visual reminders, supervision, and feedback mechanisms.

Sixth, the interviews helped explain perceived barriers to stronger environmental performance. These barriers included inconsistent training, uncertainty about responsibilities in some departments, weak follow-up after training, limited visibility of reporting channels, and variation in procedural knowledge across occupational groups. These barriers suggest that hospitals should not rely only on written policies but should combine policies with practical training, continuous monitoring, and departmental accountability.

Overall, the interview findings support the conclusion that staff awareness is not merely theoretical knowledge. Rather, it operates as a practical organisational capability that helps hospitals improve internal cleanliness, reduce pollution and risk, increase waste-handling efficiency, and strengthen environmental compliance and improvement efforts. The qualitative findings, therefore, enrich the quantitative results by showing how awareness translates into daily waste-management behaviour within hospitals.

5. Results

Common Method Bias (CMB) and Data Normality

We conducted Harman's single-factor test as a preliminary diagnostic method for testing common method bias (CMB). An unrotated exploratory factor analysis was conducted on all 29 measurement items, and the initial overall variance explained by the first factor relative to the total variance was calculated to be 40.19%. The result indicates that common method bias is not a serious problem in the current study, as this value falls below the conventional cut-off point of 50%. This interpretation is consistent with the methodological literature,

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suggesting that if a single factor drives most of the variance, then common method variance poses a major threat (Podsakoff et al., 2003). But Harman's single-factor test is generally seen as a preliminary criterion rather than as determinative. Thus, researchers in PLS-SEM also suggest complementary statistical tests, particularly a full collinearity test, since variance inflation factor (VIF) values above 3.3 can indicate common method bias (Kock, 2015). So, it may be concluded that common method variance does not seem to jeopardise the external validity of a study, and as shown in current research, based on Harman's single factor result, which was discovered was 40.19%, though assessments of reports' full collinearity VIF values would be extra methodological incremental evidence.

Evaluating the Reflective Measurement Model

Before testing the reflective indicator reliability and validity, the overall fit of the conceptual measurement model was evaluated by assessing how well the proposed model structure represented the data. In SmartPLS, model fit indices provide further evidence of whether the measurement specification at both the saturated and estimated levels is acceptable. Thus, several frequently reported fit indicators were considered: standardised root mean square residual (SRMR), geodesic discrepancy (d_G), unweighted least squares discrepancy (d_ULS), chi-square, and the normed fit index (NFI). Table 6 shows the results of these indices for both saturated and estimated models.

Table 6. Model fit indices for the saturated and estimated models

Fit index	Saturated model	Estimated model
SRMR	0.040	0.042
d_ULS	0.690	0.754
d_G	0.397	0.402
Chi-square	934.243	943.077
NFI	0.875	0.874

The model-fit results presented in Table 4.1 indicate that both the saturated and estimated models had low SRMR values, reflecting a relatively small discrepancy between the observed correlations and those implied by the model. The close values of d_ULS and d_G across the two model specifications provide further evidence of model stability. In addition, the NFI values (0.875 and 0.874 for the saturated and estimated models, respectively) are sufficiently high and nearly identical, supporting the adequacy of the hypothesised model. Overall, the close-fit statistics indicate that the measurement model is stable and well-specified, providing a reliable foundation for examining reliability, convergent validity, and discriminant validity.

As shown in Table 5, the assessment of the measurement model revealed adequate levels of indicator reliability, internal consistency reliability, and convergent validity, in addition to collinearity diagnostics, for both first-order constructs. First, standardised outer loadings for all items were above the desired cut-off value of 0.70 (ranging from 0.813 to 0.924), indicating that each indicator makes a proper contribution to its representative construct. In particular, Concept and Risk Awareness items loaded strongly on their respective constructs, with Procedural Awareness, Safety and Responsibility Awareness, and Organisational Awareness indicators exceeding the minimum acceptable threshold, thereby confirming sufficient staff awareness dimensions. Similarly, the items corresponding to each of the four SD dimensions of environmental performance (e.g., Internal Environmental Cleanliness, Pollution and Risk Reduction, Waste Handling Efficiency, and Environmental Compliance and Improvement) had high loadings, providing further evidence for the appropriateness of the indicators retained. High outer loadings (greater than 0.70 in PLS-SEM) are conventionally interpreted as indicating that a significant portion of the variance in its measured variables is accounted for by the latent construct being reflected (Hair et al., 2021). Cronbach's alpha values at the construct level ranged from 0.861 to 0.907. At the same time, composite reliability ranged between 0.907 and 0.942 — neatly above the necessary cut-off of 0.70, offering evidence that all constructs demonstrate decent internal consistency reliability (Hair et al., 2021).

Furthermore, the AVE values ranged from 0.687 to 0.843, all above the minimum threshold of 0.50 (Fornell & Larcker, 1981), thereby indicating an adequate level of convergent validity, as each construct captured more than half of the variance of its indicators (Hair et al., 2021). Overall, these results indicate that the first-order dimensions used to investigate staff awareness of medical waste management in hospitals, as well as those of

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environmental performance, were both psychometrically robust and appropriate for modelling at the structural level. The measurement results indicate that Waste Handling Efficiency (α = 0.907; CR = 0.942; AVE = 0.843) performed best on reliability, whilst Procedural Awareness recorded the least strong yet acceptable AVE value (0.687), indicating that even the most conservative construct still resides well within acceptable statistical parameters (see Table 7).

Table 7. Reliability and Convergent Validity of First-Order Constructs

Construct and Items	λ	VIF	Alpha	CR	AVE
Concept and Risk Awareness			**0.863**	**0.907**	**0.709**
SMA1	0.864	2.262			
SMA2	0.825	1.913			
SMA3	0.833	1.955			
SMA4	0.846	2.103			
Procedural Awareness			**0.886**	**0.917**	**0.688**
SMA5	0.813	2.008			
SMA6	0.852	2.342			
SMA7	0.822	2.070			
SMA8	0.839	2.207			
SMA9	0.819	2.050			
Safety and Responsibility Awareness			**0.882**	**0.919**	**0.738**
SMA10	0.850	2.165			
SMA11	0.861	2.262			
SMA12	0.877	2.464			
SMA13	0.849	2.163			
Organisational Awareness			**0.878**	**0.917**	**0.733**
SMA14	0.856	2.272			
SMA15	0.870	2.354			
SMA16	0.871	2.384			
SMA17	0.828	1.983			
Internal Environmental Cleanliness			**0.861**	**0.915**	**0.782**
EPH1	0.884	2.181			
EPH2	0.881	2.137			
EPH3	0.888	2.231			
Pollution and Risk Reduction			**0.891**	**0.932**	**0.821**
EPH4	0.902	2.548			
EPH5	0.902	2.554			
EPH6	0.913	2.769			
Waste Handling Efficiency			**0.907**	**0.942**	**0.843**
EPH7	0.924	3.150			
EPH8	0.917	2.947			
EPH9	0.913	2.849			
Environmental Compliance and Improvement			**0.870**	**0.920**	**0.794**
EPH10	0.880	2.154			
EPH11	0.892	2.334			
EPH12	0.901	2.451			

Note: All standardised loadings exceeded 0.70, Cronbach's alpha and composite reliability values exceeded 0.70, and all AVE values were above 0.50, supporting internal consistency reliability and convergent validity. In addition, all VIF values were below 3.30, indicating the absence of critical multicollinearity concerns.

In addition, all variance inflation factor (VIF) values for the indicators fell within a reasonable range from 1.913 to 3.150. This indicates that collinearity among indicators was not serious and did not threaten the stability of

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the estimation results. Although VIF values below 5.00 are commonly considered acceptable in PLS-SEM (Hair et al., 2021), the more conservative threshold of 3.30 provides stronger evidence that common collinearity and potential common method bias are not problematic (Kock, 2015). Overall, the evidence confirms that the first-order constructs show strong psychometric properties and are suitable for testing the relationships between staff awareness of medical waste management and hospital environmental performance. The reflective measurement model is presented in Figure 1 below.

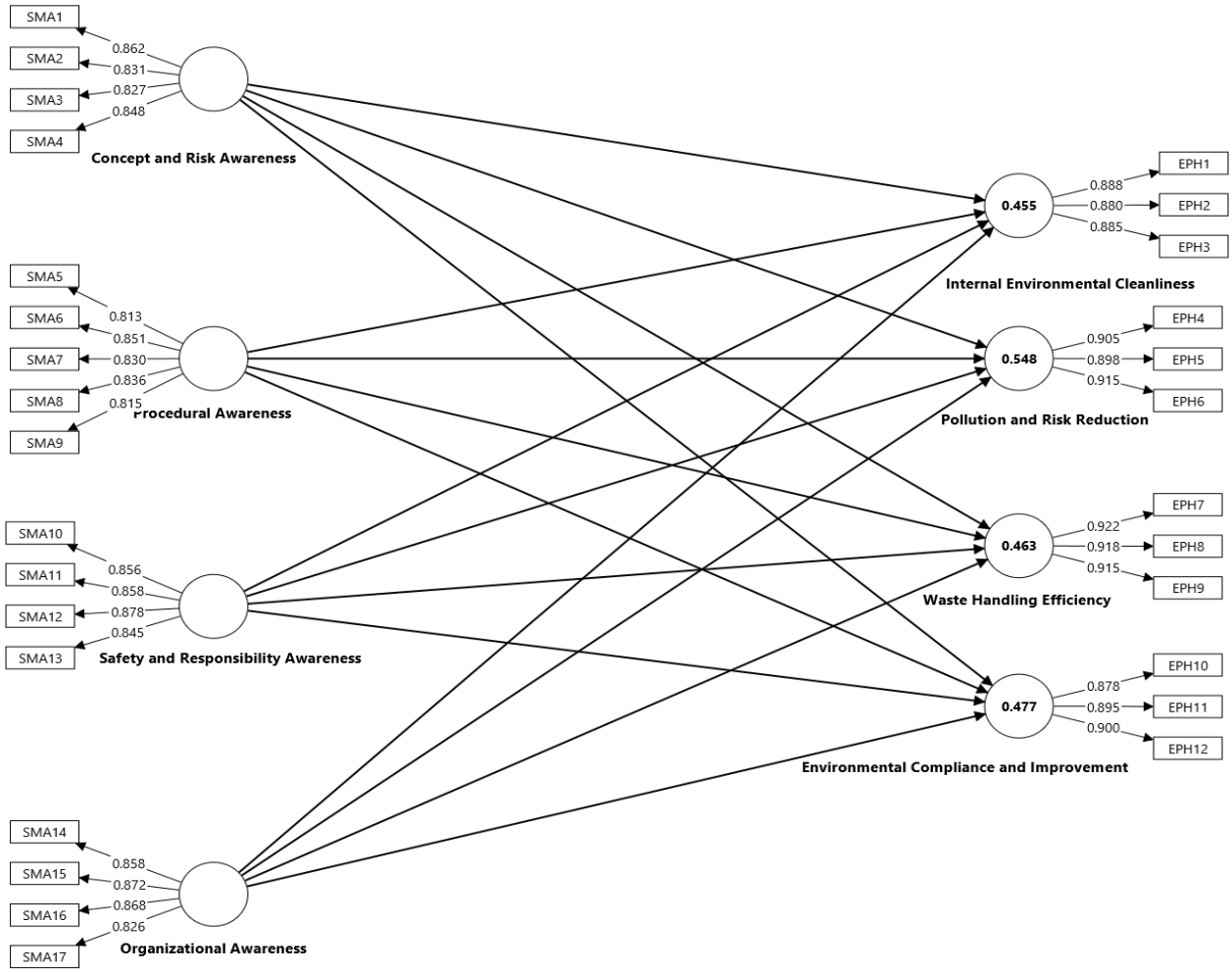


Figure 1. The reflective measurement model

Table 8. Descriptive statistics and correlations between constructs (Fornell-Larcker method)

Construct	1	2	3	4	5	6	7	8	Mean	SD
Concept and Risk Awareness	0.842								3.393	1.000
Procedural Awareness	0.339	0.829							3.419	0.979
Safety and Responsibility Awareness	0.335	0.328	0.859						3.395	1.006
Organisational Awareness	0.480	0.355	0.351	0.856					3.406	1.002
Internal Environmental Cleanliness	0.516	0.475	0.473	0.482	0.884				3.417	1.057
Pollution and Risk Reduction	0.471	0.603	0.521	0.495	0.520	0.906			3.394	1.051
Waste Handling Efficiency	0.436	0.514	0.507	0.483	0.471	0.545	0.918		3.435	1.108
Environmental Compliance and Improvement	0.483	0.378	0.514	0.572	0.491	0.534	0.492	0.891	3.402	1.070

Table 8 presents the descriptive properties of the study constructs and the discriminant validity results using the Fornell-Larcker criterion. The model measures eight first-order constructs: four dimensions of staff awareness of medical waste management, namely Concept and Risk Awareness, Procedural Awareness, Safety and Responsibility Awareness, and Organizational Awareness; and four dimensions of hospital environmental

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performance, namely Internal Environmental Cleanliness, Pollution and Risk Reduction, Waste Handling Efficiency, and Environmental Compliance and Improvement. The construct means ranged from 3.393 to 3.435, indicating generally moderate-to-positive perceptions across all dimensions. Standard deviations ranged from 0.979 to 1.108, suggesting sufficient variation in respondents' views for further structural analysis.

The correlation matrix also showed that all inter-construct correlations were positive and moderate, ranging from 0.328 to 0.603. The strongest correlation was between Procedural Awareness and Pollution and Risk Reduction (r = 0.603), which is theoretically reasonable because staff who understand segregation, storage, transport, and disposal procedures are more likely to perceive stronger pollution-control and risk-reduction outcomes. Organisational awareness was also moderately correlated with Environmental Compliance and Improvement (r = 0.572), while Safety and Responsibility Awareness was moderately correlated with Environmental Compliance and Improvement (r = 0.514). These correlations confirm that the constructs are related but still conceptually distinct.

For discriminant validity, Table 6 shows that the square root of AVE for each construct on the diagonal exceeded all corresponding inter-construct correlations. The diagonal values ranged from 0.829 to 0.918, while the largest off-diagonal correlation was 0.603. This fulfils the Fornell-Larcker criterion, indicating that each construct explains more variance in its own indicators than it shares with other constructs (Fornell & Larcker, 1981). Although recent PLS-SEM literature recommends using HTMT as an additional and more sensitive test (Hair et al., 2021; Henseler et al., 2015), the Fornell-Larcker results are clearly within acceptable limits.

The findings are summarised in Table 9 are broadly consistent with two key conclusions: First, the overview of descriptive statistics shows that respondents assessed the dimensions of staff awareness and environmental performance at moderate-to-high levels in general. Second, the discriminant validity evidence shows that the eight constructs are empirically distinguishable dimensions, supporting their retention as separate variables in subsequent structural model analysis. This is relevant, as the conceptual model of the present study hypothesises that different facets of staff awareness may have differential effects on various dimensions of environmental performance in hospitals and do not represent a simple, undifferentiated factor.

Table 9. Heterotrait-monotrait (HTMT) Criterion Values

Construct	1	2	3	4	5	6	7
Concept and Risk Awareness	—						
Procedural Awareness	0.388	—					
Safety and Responsibility Awareness	0.384	0.372	—				
Internal Environmental Cleanliness	0.598	0.545	0.543	—			
Organisational Awareness	0.551	0.403	0.398	0.555	—		
Pollution and Risk Reduction	0.537	0.679	0.588	0.594	0.560	—	
Waste Handling Efficiency	0.492	0.574	0.567	0.533	0.541	0.606	—
Environmental Compliance and Improvement	0.557	0.430	0.587	0.568	0.654	0.606	0.553

As shown in Table 7, the HTMT results provide additional evidence for discriminant validity in the PLS-SEM model. Discriminant validity is important because it confirms that each latent variable captures a distinct conceptual domain and is not merely measuring the same concept as another construct. Since HTMT is more sensitive than conventional methods such as the Fornell-Larcker criterion or cross-loadings, it has become one of the most frequently recommended criteria for assessing discriminant validity (Henseler et al., 2015).

All HTMT values were below the recommended threshold of 0.90, supporting acceptable discriminant validity across the eight first-order constructs. The HTMT values ranged from 0.372 to 0.679. The highest value was observed between Procedural Awareness and Pollution and Risk Reduction (HTMT = 0.679), indicating that these two constructs are related yet empirically distinct. This result is theoretically reasonable because procedural awareness of segregation, storage, transport, and disposal is closely associated with perceived pollution prevention and risk reduction in hospitals.

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In summary, the HTMT results provide strong evidence that all constructs included in this study have sufficient discriminant validity and should be retained as separate dimensions in the measurement model. This strengthens the credibility of the subsequent structural model analysis because the relationships among constructs can be interpreted as associations among conceptually distinct variables rather than artefacts of measurement overlap.

Evaluating the Structural Model

Subsequently, after validating the measurement model, the structural model was assessed to test the hypothesised relationships among the study constructs. It was dedicated to testing the predictive associations between staff awareness of medical waste management dimensions and hospital environmental performance components. Similar to the pathwise logic of PLS-SEM, the evaluation of the structural model provides support for whether paths are positive or negative and the strength of those relationships, indicating whether the theoretical assumptions of this research are supported empirically. The model also shed light on the extent to which the different awareness dimensions help explain the variance in environmental performance outcomes in the hospital context. The results of the structural model are shown in Figure 2, which highlights the relationships between the constructs included in this study.

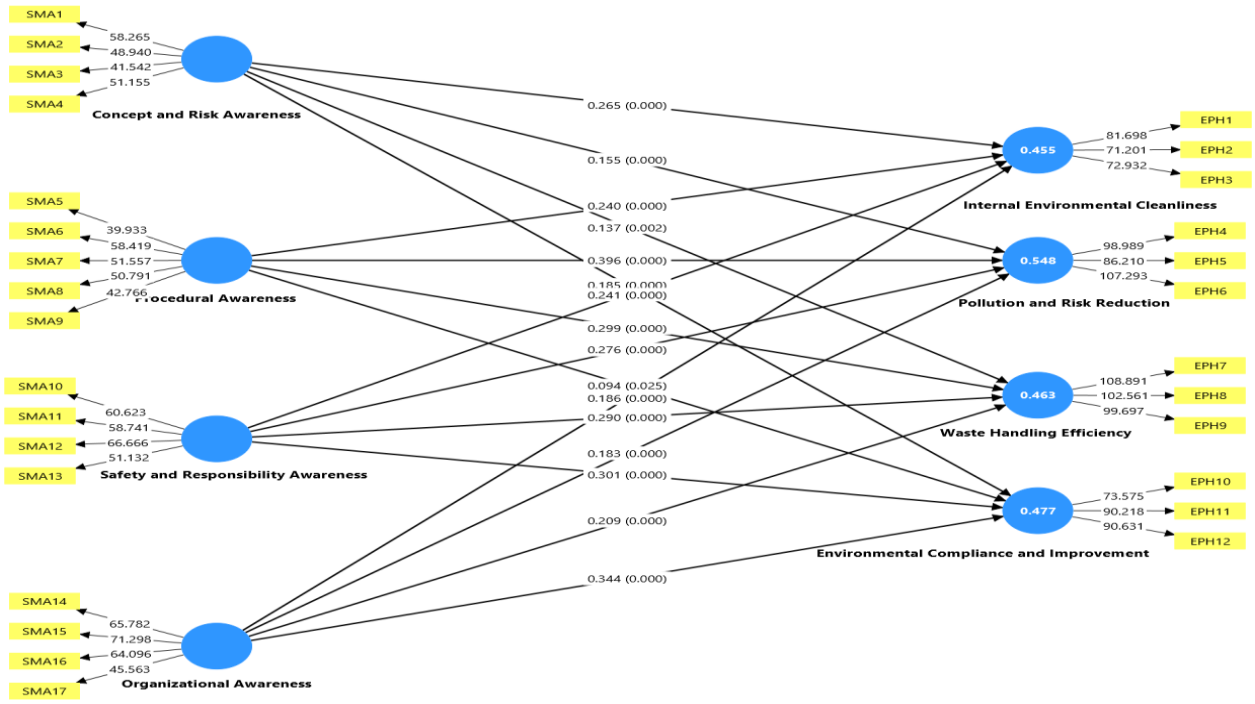


Figure 2. The Structural Model

Table 10. Results of Hypotheses Testing

Hypothesis	Path	Beta (β)	t-value	p-value	Decision
H1a	CRA → IEC	0.265	5.828	< 0.001	Supported
H1b	CRA → PRR	0.155	3.678	< 0.001	Supported
H1c	CRA → WHE	0.137	3.124	0.002	Supported
H1d	CRA → ECI	0.185	3.839	< 0.001	Supported
H2a	PA → IEC	0.240	5.330	< 0.001	Supported
H2b	PA → PRR	0.396	10.879	< 0.001	Supported
H2c	PA → WHE	0.299	7.742	< 0.001	Supported
H2d	PA → ECI	0.094	2.244	0.025	Supported
H3a	SRA → IEC	0.241	5.895	< 0.001	Supported
H3b	SRA → PRR	0.276	7.047	< 0.001	Supported
H3c	SRA → WHE	0.290	7.427	< 0.001	Supported
H3d	SRA → ECI	0.301	7.411	< 0.001	Supported
H4a	OA → IEC	0.186	3.989	< 0.001	Supported

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Hypothesis	Path	Beta (β)	t-value	p-value	Decision
H4b	OA → PRR	0.183	4.048	< 0.001	Supported
H4c	OA → WHE	0.209	4.529	< 0.001	Supported
H4d	OA → ECI	0.344	8.029	< 0.001	Supported

Abbreviations: CRA = Concept and Risk Awareness; PA = Procedural Awareness; SRA = Safety and Responsibility Awareness; OA = Organisational Awareness; IEC = Internal Environmental Cleanliness; PRR = Pollution and Risk Reduction; WHE = Waste Handling Efficiency; ECI = Environmental Compliance and Improvement.
Note: All hypothesised paths were positive and statistically significant at the 5% level, indicating support for all proposed relationships in the structural model.

The analysis of results for the hypothesis testing (Table 10) suggests that all the proposed direct relationships in the structural model were positive and significant at the 5% level, thus fully supporting our study hypotheses. In general, the results indicated that various aspects of staff knowledge on medical waste disposal and management significantly contributed toward predicting environmentally sustainable performance outcomes in hospitals. Concept and Risk Awareness, Procedural Awareness, Safety and Responsibility Awareness, and Organisational Awareness were found to have significant positive effects on the four dimensions of environmental performance: Internal Environmental Cleanliness, Pollution and Risk Reduction, Waste Handling Efficiency, and Environmental Compliance and Improvement. The results validate that staff awareness is not a general perception but rather a multidimensional capability that influences environmental performance through many distinct yet complementary pathways. The analytical approach used in the research study was implemented using SmartPLS with bootstrapping to measure the structural relationships among the mediating effects.

A closer look at the path coefficients shows meaningful differences in the relative strength of each predictor. Table 4.5 summarises the results of hypothesis testing. For internal environmental cleanliness, Concept and Risk Awareness was the strongest predictor ($\beta = 0.265$, $t = 5.828$, $p < 0.001$). Safety and Responsibility Awareness ($\beta = 0.241$, $t = 5.895$, $p < 0.001$) and Procedural Awareness ($\beta = 0.240$, $t = 5.330$, $p < 0.001$) also contributed strongly, while Organisational Awareness showed a smaller but still positive effect ($\beta = 0.186$, $t = 3.989$, $p < 0.001$). This pattern suggests that a cleaner internal hospital environment depends not only on formal organisational guidance but also on staff understanding of medical waste risks and their responsibility for safety.

For Pollution and Risk Reduction, Procedural Awareness was the most important predictor by a wide margin ($\beta = 0.396$, $t = 10.879$, $p < 0.001$). Safety and Responsibility Awareness was next ($\beta = 0.276$, $t = 7.047$, $p < 0.001$). Concept and Risk Awareness ($\beta = 0.155$, $t = 3.678$, $p < 0.001$) and Organisational Awareness ($\beta = 0.183$, $t = 4.048$, $p < 0.001$) remained important but to a lesser extent. This finding is theoretically and practically sound, as pollution prevention and risk mitigation in hospitals are significantly contingent upon the proper implementation of daily waste segregation, storage, transportation, and disposal protocols. So, procedural knowledge seems to be the most important kind of awareness when the goal is to reduce pollution and the health risks that come with it.

A similar trend was noted for Waste Handling Efficiency, with Procedural Awareness exhibiting the most significant positive impact ($\beta = 0.299$, $t = 7.742$, $p < 0.001$), closely succeeded by Safety and Responsibility Awareness ($\beta = 0.290$, $t = 7.427$, $p < 0.001$). Organisational awareness ($\beta = 0.209$, $t = 4.529$, $p < 0.001$) and Concept and Risk Awareness ($\beta = 0.137$, $t = 3.124$, $p = 0.002$) were also important factors. These results suggest that effective waste management is primarily determined by employees' practical and safety-related awareness, which is logical considering that efficiency in this context relies on proper operational conduct, consistent adherence, and responsible management throughout the waste management process. To put it another way, knowing how to do things and understanding your safety responsibilities seem to be more important for operational efficiency than just having general knowledge.

For Environmental Compliance and Improvement, the strongest effect was seen in Organizational Awareness ($\beta = 0.344$, $t = 8.029$, $p < 0.001$), followed by Safety and Responsibility Awareness ($\beta = 0.301$, $t = 7.411$, $p < 0.001$), Concept and Risk Awareness ($\beta = 0.185$, $t = 3.839$, $p < 0.001$), and Procedural Awareness ($\beta = 0.094$, $t = 2.244$, $p = 0.025$). This part of the model is very important because institutional rules, supervision,

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accountability structures, and clear hospital protocols are often linked to environmental compliance and improvement. This indicates that enhancing environmental practices in hospitals may be more contingent on staff's understanding of the institutional framework, reporting obligations, and managerial expectations regarding medical waste management. Even though procedural awareness was still important, its smaller coefficient indicates that improving the environment at the institutional level goes beyond simply knowing how to do things and depends more on how well the organisation works together and is governed.

The structural model results, when read together, tell a consistent story: all four awareness dimensions matter, but their effects vary by the type of environmental performance outcome (delivery) being addressed. Organisational awareness is the most important facilitator of environmental compliance and improvement, while Procedural Awareness is decisive for operational processes, namely, pollution control and waste-handling efficiency. Meanwhile, Safety and Responsibility Awareness were consistently strong and significant across all dependent constructs, suggesting that it is a stable, multidimensional predictor of environmental performance. Thus, the results imply that a uniform training focus would not apply to hospital managers. A more promising embodiment, however, should involve the construction of integrated awareness programs targeting significant enhancement of conceptual comprehension and procedural proficiency, as well as personal safety responsibility (SSR) and organisational role clarification regarding medical waste management.

6. Discussion

The significance decisions reported in Table 11 were based on bootstrapping results generated in SmartPLS using 5,000 resamples. Paths were considered statistically significant when the bootstrapped t-value exceeded the accepted threshold, and the p-value was below 0.05.

Table 11. Summary of the Supported Structural Hypotheses

Hypothesis	Path	Beta	t-value	p-value	Decision
H1a	CRA -> IEC	0.265	5.828	< 0.001	Supported
H1b	CRA -> PRR	0.155	3.678	< 0.001	Supported
H1c	CRA -> WHE	0.137	3.124	0.002	Supported
H1d	CRA -> ECI	0.185	3.839	< 0.001	Supported
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H3b	SRA -> PRR	0.276	7.047	< 0.001	Supported
H3c	SRA -> WHE	0.290	7.427	< 0.001	Supported
H3d	SRA -> ECI	0.301	7.411	< 0.001	Supported
H4a	OA -> IEC	0.186	3.989	< 0.001	Supported
H4b	OA -> PRR	0.183	4.048	< 0.001	Supported
H4c	OA -> WHE	0.209	4.529	< 0.001	Supported
H4d	OA -> ECI	0.344	8.029	< 0.001	Supported

Abbreviations: CRA = Concept and Risk Awareness; PA = Procedural Awareness; SRA = Safety and Responsibility Awareness; OA = Organisational Awareness; IEC = Internal Environmental Cleanliness; PRR = Pollution and Risk Reduction; WHE = Waste Handling Efficiency; ECI = Environmental Compliance and Improvement.

The results support H1a, in which concepts and awareness of risk positively impact environmental cleanliness in the internal environment ($\beta = 0.265$, $t = 5.828$, $p < 0.001$). This provides insight into how employees who understood the meaning of medical waste were able to discriminate between hazardous and non-hazardous hospital waste, were aware of the risks involved in improper handling, and supported a clean internal area within the hospital environment. Of the four dimensions of awareness, the effect was the best predictor of internal environmental cleanliness. This implies that cleanliness depends not only on housekeeping activities but also on the extent to which both clinical and non-clinical staff are aware of the environmental and infection-related consequences of their daily disposal decisions. This finding aligns with the Knowledge-Attitude-Practice perspective, which assumes that knowledge is the basis that may stimulate safer and more regular practices.

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H1b also received support with concept and risk awareness, positively influencing pollution and reducing the risk ($\beta = 0.155$, $t = 3.678$, $p < 0.001$). While the coefficient was weaker than those for procedural awareness and safety and responsibility awareness, it is still a significant relationship, as a lack of risk awareness is the motivational basis for pollution prevention. Employees who have some understanding of the potential environmental hazards associated with the combination of hazardous and non-hazardous wastes will be less likely to engage in activities that increase the risk of contamination, exposure, and treatment obligations. This effect is only moderate because when you tell people about risks without having very clear and responsible behaviour, the pollution remains quite the same. Thus, the findings emphasise that conceptual knowledge needs to be operationalised into action through training, monitoring, and waste-handling routines.

H1c was supported, as concept and risk awareness had a significant positive effect on waste handling efficiency ($\beta = 0.137$, $t = 3.124$, $p = 0.002$). The result suggests that staff members who recognise medical waste categories and related hazards can contribute to better segregation, lower unnecessary contamination of general waste, and smoother waste movement within the hospital. However, this was the weakest effect among the predictors of waste handling efficiency. This pattern is theoretically reasonable because efficiency depends heavily on knowing exactly how to act, not only on understanding why waste is dangerous. In practical terms, general awareness helps employees respect waste-management rules, but efficient handling requires specific procedural knowledge, adequate containers, clear labelling, and coordination between departments and support staff.

Support for H1d showed that concept and risk awareness significantly influenced environmental compliance and improvement ($\beta = 0.185$, $t = 3.839$, $p < 0.001$). The implication is that real benefits can be gained if those who manage the files understand the risks of medical waste, rather than treating environmental rules and improvement efforts as mere administrative boxes to check. By increasing staff awareness that institutional policies, environmental guidelines and reporting requirements exist to protect both people and the natural environment, risk awareness can reinforce compliance. However, we note that this effect was smaller than that for organisational awareness and for safety and responsibility awareness. This suggests that risk knowledge needs to be combined with observable hospital policies, accountability structures, and ongoing training to deliver better compliance and improvement outcomes.

Hypothesis 2a: Procedural awareness has a positive effect on internal environmental cleanliness. The above analyses supported H2a, as indicated by the significant use of procedural awareness in improving internal environmental cleanliness ($\beta = 0.240$, $t = 5.330$, $p < 0.001$). The authors show that improved staff knowledge of segregation, the use of containers, and proper storage, transportation, and disposal methods contributes directly to cleaner hospital units. Awareness of procedures also helps prevent improper disposal, overfilling waste containers, leakage, and odour escaping from biohazard waste bags, as well as ensuring that clinical and general waste locations do not contain cross-contaminated materials. The outcome mirrors the reality of hospital cleanliness, especially since thousands of small tasks determine hygiene performed countless times in every department and on every shift. The research also shows that training should not be just general information about medical waste risks; it needs to provide actionable, practical advice that employees can apply at the point of waste generation right away.

H2b found support and produced the most substantial path coefficient in the structural model ($\beta = 0.396$, $t = 10.879$, $p < 0.001$). It shows that procedural awareness is the strongest predictor of pollution and risk reduction. It's an obviously reasonable conclusion, since preventing pollution relies on proper segregation, labelling, storage, and transport methods. When employees know which waste streams they have and the proper bags/containers to use, this can help prevent the unnecessary mixing of hazardous waste with non-hazardous waste. This reduces the generation of hazardous materials, the exposure of waste, and thus lessens their release to the environment. This is a strong indication that pollution reduction does not rely solely on treatment technologies or external waste contractors but begins with staff procedures within the hospital, he argues.

H2c was supported, with a strong positive all-size effect of procedural awareness on efficiency in terms of waste handling ($\beta = 0.299$; $t = 7.742$; $p < 0.001$). The acknowledgement of this result is mainly contingent on employees' knowledge of the true steps required to practice safe waste management. When processes are understood, waste will flow through the hospital system in a more orderly and timely manner, resulting in fewer

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errors that need to be corrected by housekeeping, environmental services, or infection-control teams. This finding also suggests that knowledge of the procedure can prevent unnecessary costs in treatment and storage, as well as delays in waste pick-up. So efficiency is more than mere logistics: it is the result of staff ability and results from continually following standardised procedures.

H2d was verified, with the effect of procedural awareness on environmental compliance and improvement being significant ($\beta = 0.094$, $t= 2.244$, $p = 0.025$). To be sure, this was the lowest important coefficient in the model. It indicates that knowing the procedures is indeed partially responsible for compliance, but this alone does not drive broader environmental improvement. Even though you know how to segregate and transport waste, it is equally important to understand hospital policies, regulatory expectations, and environmental compliance, i.e., documentation, audit systems, and managerial accountability. Hence, the lower coefficient is significant: it indicates that processes are needed to comply, but there is a need for greater institutional awareness and accountability/ownership around safety and culture at the organisational level. This result stresses the importance of combining procedural training with the communication of governance and policy.

H3a was supported, given that safety and responsibility awareness had a significant impact on internal environmental cleanliness ($\beta=0.241$, $t = 5.895$, $p < 0.001$). This result shows that cleanliness is better when waste management is perceived as a professional responsibility of staff rather than a task delegated to housekeeping staff. Communicating well about exposure risks, personal protective measures, incident reporting, and responsibility to patients/colleagues is more likely to uphold safe disposal behaviour. This result is particularly important, as multiple occupational groups are involved in a hospital, including physicians (our main focus here), nurses and assistants, technicians (imaging and laboratory), cleaners, and administrative staff; see Box 1. Cleaner even gets diluted when one set of the group decides that the onus of dealing with waste safety is someone else's responsibility. Thus, the finding lends support to shared responsibility as a component of internal environmental purity.

Hypothesis H3b was supported, as awareness of safety and responsibility had a significant positive influence on pollution and risk reduction ($\beta = 0.276$, $t = 7.047$, $p < 0.001$). The outcome indicates that awareness of personal and collective responsibility contributes to reducing environmental and health impacts. Workers trained to recognise the repercussions of poor handling, sharps injuries, chemical exposure and spills, and infectious waste contamination are more likely to take steps to prevent unsafe practices and respond appropriately in the event of an accident. This coefficient was stronger than those for concept and risk awareness, and for organisational awareness, for this outcome; stress pollution prevention requires feeling responsible for controlling risks, not merely knowing what they are. The finding is consistent with stakeholder-oriented thinking as safe waste management safeguards patients, staff, waste handlers, surrounding communities and the environment.

H3c: The existence of safety and responsibility awareness positively influenced the efficiency of waste handling with strong support ($\beta = 0.290$, $t = 7.427$, $p < 0.001$). This product is a validation: Employees with knowledge of their responsibilities and a heavy-handed approach to handling Medical Waste take more precautionary measures and follow correct protocols to minimise or eliminate operational errors. Knowing who is responsible can eliminate delays due to incorrect sorting, incorrect transport containers, inadequate reports in neonates, and careless internal transport. It facilitates coordination between clinical staff and support staff, because everyone acknowledges their place in the waste-management line. The conclusion indicated that efficiency is beyond a technical problem, it is a behavioural and ethical effect driven by staff responsibility.

H3d was also supported by substantial historical incidence development in the contribution of safety and responsibility awareness to environmental compliance and improvement ($\beta = 0.301$, $t = 7.411$, $p < 0.001$). This was the second biggest influence on compliance and improvement behaviour (after their levels of organisational awareness). The study also shows that hospital compliance efforts garner more support from staff when they consider waste management as part of their job responsibilities, and they are more willing to comply with environmental criteria, report issues, and become involved in improvement practices. Obedience is bolstered by the belief among employees that handling waste responsibly directly affects their careers and moral obligations. The effect aligns with the belief that environmental amelioration needs norms of responsibility, in addition to

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legal constraints. It also demonstrates that personal accountability in safety training can be harnessed to support environmental governance.

Thus, H4a was supported; organisational awareness significantly promoted internal environmental cleanliness ($\beta = 0.186$, $t = 3.989$, $p < 0.001$). Your knowledge of hospital policies, reporting channels, responsible units, training systems, and supervision mechanisms contributes to cleanliness in hospital interiors. While the impact of awareness of practices was smaller than that of both conceptual and risk awareness, and procedural awareness, safety and responsibility awareness remains a key contributor to alignment within departments regarding waste behaviour. Meetings are shorter when employees know who does the actual collection, where waste should go, and how to complain about non-compliance. Therefore, organisational awareness is the institutional basis that sustains everyday practices for cleaning and disposal.

H4b Supported: Organisational awareness had a strong positive impact on pollution and risk reduction ($\beta = 0.183$), $t = 4.048$) $p < 0.001$). The study concludes that both hospital policy and effective communication across departments can mitigate environmental risk. Staff who understand institutional waste-management plans, supervision systems, and reporting mechanisms will take better precautions against unsafe practices, spills, storage issues, and deviations from environmental standards. The effect was low compared to the very strong effect of procedural awareness, indicating that organisational awareness alone can never replace field operational know-how. Nonetheless, it remains important because procedures are likely to be adhered to only when there is a clear institutional system of responsibility, leadership, and monitoring.

The results thus supported H4c, showing that organisational awareness had a significant positive influence on waste handling efficiency ($\beta = 0.209$, $t = 4.529$, $p < 0.001$). This finding suggests that successful waste management is a function not only of procedural knowledge among individual staff members but also of the staff's understanding of the larger system at play in hospitals. Management of waste involves interaction among clinical departments, housekeeping and infection-control staff, the environmental services team, and outside contractors. When staff are familiar with the institutional hierarchy, delays, duplication, confusion and inconsistent practices can all be avoided. The finding also highlights the critical necessity for clearly defined internal policies, communication channels and responsibility matrices. If a hospital has solid technical procedures but those procedures are unknown to staff regarding the organisational architecture system, then efficiency will always be limited.

H4d is supported and has the most powerful effect on environmental compliance and improvement ($\beta = 0.344$, $t = 8.029$, $p < 0.001$). This finding is one of the study's major discoveries. It lends credence to the idea that institutional compliance and ongoing improvement are closely tied to staff's understanding of hospital regulation, oversight systems, reporting requirements, training programs, and accountability relationships. Organisational clarity is a requirement of governance, and compliance is an outcome of good governance. Although staff may know how to throw away waste, sustainability can be achieved only when they understand the hospital's environmental expectations, audit processes, and accountability plans. According to institutional theory, this finding holds that rules and regulations must be internalised by organisational members so that daily behaviour and performance change as a result.

The general pattern of results supports the conclusion that all four awareness dimensions are relevant, but they impact environmental performance through different processes. For internal environmental cleanliness, concept and risk awareness were particularly relevant, as a base understanding of hazards helps staff consider waste disposal as a matter of safety and cleanliness. The most decisive predictor of pollution/risk reduction and waste-handling efficiency was procedural awareness, thus confirming the operational importance of knowing how to classify, segregate, store, and transport medical waste. The awareness of safety and responsibility was consistently high across the four dependent variables, implying that personal accountability is a stable predictor of environmental performance. For environmental compliance and improvement, domain-specific organisational awareness was key, suggesting the need for formal rules and institutional systems for continued governance.

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These discoveries cast a significant shadow over the literature on managing medical waste. These show that staff awareness should not be viewed as a single, overarching variable. Different forms of awareness lead to different environmental outcomes. Hence, hospitals should not implement a single large, generic awareness campaign but rather adopt targeted interventions. If the objective is to improve pollution control, training should emphasise procedural mastery. Persuasion regarding organisational policies, reporting structures, audits, and accountability is needed to strengthen compliance and continuous improvement. To improve internal cleanliness, hospitals should start making dual use of risk awareness, responsibility, and procedural clarity. The study's value comes in part from this differentiated interpretation.

7. Conclusions

Staff awareness of medical waste management is the strongest determinant of hospitals' environmental performance, according to this study's conclusion. The results validate the observation that awareness is not just an informational variable; it is, in fact, a practical organisational capability which aids hospitals to avoid conterminous and hazardous conditions internally, do well with sorting and segregating waste more efficiently as part of pollution prevention, while contributing towards enhanced environmental compliance aligned with improving overall environmental performance. The results across all paths we tested were both good and statistically significant, indicating that hospital environmental performance is determined by staff knowledge, interpretations of roles and responsibilities, and clarity about rules and regulations.

The first major conclusion is that the human side of medical waste management plays a key role in hospital environmental performance. Hospitals may have containers, contracts, protocols and treatment systems, but these systems are based on staff behaviour at the source of waste generation and handling. Formally established systems can be counterproductive if incorrect segregation, insecure storage, poor reporting, or confused roles undermine their impact. Thus, it is not infrastructure alone that drives environmental performance, but the combination of infrastructure with employee awareness and organisational control.

The second conclusion is that awareness is not one-dimensional. Concept and risk awareness have laid down the basic reasons for how medical waste management should be conducted. Procedural awareness details what staff should actually do. The implications of safety and responsible conduct naturally galvanise personnel to own safe waste behaviour. Organisational awareness links individual action to hospital policy, supervision, and compliance obligations. The study reveals that these dimensions must be measured and managed separately, as they exert different magnitudes of influence on specific environmental effects.

The third conclusion is that the effect of procedural awareness is particularly important for pollution and risk reduction, as well as for waste-handling efficiency. Thus, hospitals looking for immediate operational improvements should focus on training related to waste categories, colour coding and container selection, labelling of containers, segregation at source and during temporary storage, and internal transport, in addition to final disposal sites. Well-documented procedural knowledge keeps mistakes from propagating up the waste-management chain.

The fourth is that, this timely study concludes, the key dimension for environmental compliance and improvement is organisational awareness. This finding demonstrates that putting bins and bags to good use is insufficient for compliance. To implement this, staff awareness of hospital policies and responsible departments is needed, along with monitoring systems for reporting channels to be employed, and training and documentation of environmental objectives. Hospital management should thus view medical waste management as a component of institutional environmental governance.

Fifth, awareness of safety and responsibility is a consistently significant predictor of dimensional environmental performance. This implies that Hospitals should not only teach their staff about medical waste and its management but also explain why every individual affiliated with the hospital is responsible for safeguarding patients, co-employees, waste handlers, and the environment. Establishing a culture of shared responsibility for waste management can turn what is usually a bureaucratic task into a professional and ethical practice.

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7.1 Theoretical Contributions

Theoretical contributions of the study to medical waste management, sustainable healthcare and hospital environmental performance literature. The first contribution is to integrate staff awareness and environmental performance into a single empirical model. Previous studies have typically investigated attitudes, knowledge, and practices in parts of practice concerning healthcare workers or the environmental performance indicators of hospitals. This study connects those two streams by demonstrating that staff awareness can account for differences in environmental performance among hospitals. In doing so, it addresses the need for a socio-technical perspective on medical waste management: a view where human awareness and organisational factors are considered important determinants of environmental impact.

The second theoretical contribution is its multidimensional conceptualisation of staff awareness. Instead, the study differentiates among concept and risk awareness, procedural awareness, awareness of safety and responsibility, and organisational awareness, rather than relying on general constructs to measure awareness. To clarify these concepts, the distinction between awareness and doctor wisdom is clarified through its practice-relative application in the medical waste (MW) context. It also aids in clarifying the variance of effects amongst measures of awareness across outcomes. The results confirm, as expected, that procedural awareness is most strongly related to operational outcomes, and organisational awareness is most strongly related to compliance and improvement.

Third, this paper examines hospital environmental performance from a multidimensional perspective. This study does not reduce environmental performance to a single unified attitude. Attached to that, it differentiates the construct into internal environment cleanliness, pollution and risk reduction, waste disposal efficiency and environmental management. This method enables researchers to pinpoint the specific factors of environmental performance that are most effectively influenced by each type of staff awareness. It also makes it a more valuable resource for future research that will connect specific human or organisational drivers to specific environmental outcomes in the health care sector.

The fourth contribution concerns the empirical validation of several theoretical positions. So, given the positive influence of knowledge on environmental performance, they are in line with the traditional perspective called the Knowledge-Attitude-Practice because awareness is placed upon Practice. Procedural and organisational awareness also support the Theory of Planned Behaviour, as these dimensions primarily strengthen perceived behavioural control and subjective norms regarding proper waste behaviour. Because training, role modelling and awareness of responsibility can translate knowledge into more habitual practices, Social Cognitive Theory is also an important aspect. Institutional Theory corroborates the strong impact of organisational awareness on compliance and improvement. Stakeholder Theory shows that, through awareness of safety and responsibility, there is a sense of obligation toward staff, patients, waste handlers, communities, and the environment.

The fifth contribution is contextual. The study provides information on the Saudi healthcare context, which is characterised by concerns regarding waste management institutions, environmental performance, and regulatory compliance, by focusing on hospitals in the Al-Qassim Region. These results further extend medical waste management research beyond descriptive and technical approaches by showing how staff awareness can inform a practical organisational capability in hospital environmental management systems.

Last but not least, the paper adds to research on PLS-SEM applications in the healthcare environment. The analysis revealed adequate psychometric properties, with reliable indicators, acceptable convergent validity, discriminant validity using the Fornell-Larcker and HTMT calculators, and relevant structural relationships. This is an advantageous methodological example for approaching a multidimensional awareness-performance model in hospital settings for future researchers.

7.2 Practical Contributions

The study has practical implications, and the findings are relevant for hospital managers, quality departments, infection-control units, environmental services, and training departments, as well as for health policymakers.

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The first practical contribution is the identification of staff awareness as an organisation-controllable driver of hospital environmental performance. Awareness can be trained, oriented, supervised, communicated, and reinforced through reminders (e.g., post-it notes or signboards), audits, and feedback systems, and made part of accountability. So, some aspects of environmental performance can be strengthened without waiting for large-scale changes in infrastructure; hospitals can begin by strengthening daily waste-handling behaviour and staff awareness.

The second main contribution is that the study demonstrates which dimensions of awareness need to be targeted for specific environmental objectives. If the second goal is to increase internal cleanliness, concept and risk awareness, procedural awareness, and responsibility awareness should be reinforced in hospitals. Finally, if the aim is to reduce pollution and risk, practical procedural training should be favoured because it has a greater impact on these outcomes. For instance, if the aim is to enhance efficiency in waste management, then hospitals must ensure procedural awareness and assume safety accountability. However, if the goal is to improve environmental compliance and continuous improvement, hospitals need to raise organisational awareness by discussing policies, reporting lines, audit procedures & accountability structures.

The third, it contributes in practical terms by highlighting collective responsibility. The findings revealed that an awareness of safety and responsibility has a large positive impact on all aspects of environmental performance. Hence, medical waste management should not be regarded as just an obligation of housekeeping staff. Waste-management chain: physicians, nurses, pharmacists, laboratory workers, technicians and administrative staff, cleaning team with environmental services. This result allows for hospitals to structure inter-departmental awareness programs that minimise responsibility shifting amongst groups.

The fourth practical contribution is the role-based training support. Various forms of waste are encountered, and each staff group has its own responsibilities. Nurses and doctors are on the front lines of healthcare waste and needles. It is all the more special because laboratory staff handle specimens, chemicals, and contaminated objects. The pharmacist may handle expired or end-of-life drugs. Housekeeping and cleaning personnel also collect, transport, and, in some cases, store waste. Administrative staff will need to be included if they are involved in documentation, supervision or policy implementation. A single general training session, therefore, is unlikely to be enough. Discipline should be customised according to job categories, departments, exposure levels, and responsibilities performed.

The fifth practical contribution is the prominent role of organisational awareness in compliance with environmental regulations and the amelioration of the environment, suggesting that leaders within hospitals should be visible and clear about waste-management policies. Employees need to know who makes decisions about waste, where to report incidents, how non-compliance is handled, and how waste performance is defined. This can help transform environmental compliance from a piece of paper into an operational reality.

The sixth practical contribution is that the study creates a basis for strong performance monitoring by hospital managers. Awareness indicators could be incorporated within internal audits and quality improvement systems. Hospitals can assess their staff's knowledge of: waste categories, procedural steps to follow when encountering a hazardous waste incident, reporting an incident, awareness of the hospital policy, and perceived environmental performance. Comparing across time by department helps hospital managers pinpoint weaknesses and tailor fixes. This is a great contribution because medical waste management is not a one-off activity, and you need to stay up to date with practices until October 2023, as that is the data I am looking at.

7.3 Limitations and Future Directions

This is a cross-sectional study, meaning that while it can show significant associations between staff awareness and environmental performance, it cannot confirm causal relationships over time. Variations in staff awareness, practices within the delivery of care, and environmental performance can change over time as regulations give rise to new practices, training programs, or infection outbreaks, managerial changes occur, or waste-management systems are updated. A second limitation was that questionnaire data were self-reported. Although staff perceptions are meaningful, as employees are directly involved in medical waste practices, self-report data may be vulnerable to social desirability and recall biases, as well as to differences in the interpretation of

questionnaire items across groups. Statistical checks for common method bias were performed, and the study ruled it out. However, such evidence may be further strengthened in future studies that combine surveys with direct observation, audit records, or objective waste data. The third limitation is geographic. The study was conducted within hospitals in Al–Qassim Region. The findings have utility within this area but should be extrapolated with caution to other areas or countries, as these factors (hospital size and resources, regulatory enforcement mode, training systems, waste infrastructure, etc.) can differ across regions.

Future work should utilise longitudinal designs to determine whether changes in staff awareness over time are linked to objectively measured environmental performance. A longitudinal design would be well-suited to assessing the impacts of training programs, new hospital policies, or environmental improvement activities. Future research may focus on integrating both self-reported questionnaire data and objective performance measurements. These include the true weights of waste, proportions of hazardous and non-hazardous waste, tipping-point error rates, incident reports, audit scores, average treatment costs, and emissions to the environment. It would also allow for a broader evaluation of hospitals' environmental performance.

While quantitative frameworks and Key Performance Indicators (KPIs) exist to measure hospital environmental performance—such as energy use intensity, regulated medical waste ratios, and greenhouse gas footprint protocols—this study faces limitations regarding data accessibility, heterogeneity, and reporting fragmentation. First, environmental reporting in healthcare remains largely voluntary in many jurisdictions, resulting in disparate datasets and a reliance on self-reported institutional surveys. Second, significant variations exist in data normalisation methodologies; for instance, differences in how "Adjusted Patient Days" (APD) are calculated or in accounting for outpatient surgical volume complicate direct cross-institutional benchmarking. Finally, while hospitals generally track direct operational metrics such as Scope 1 and Scope 2 energy emissions, comprehensive data on Scope 3 supply chain lifecycle impacts and anaesthetic gas carbon intensities remain highly fragmented or completely opaque in administrative records. Consequently, these data tracking gaps limit the generalizability and seamless comparative analysis of environmental sustainability metrics across diverse healthcare systems.

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IMPACT OF SELECTED VARIABLES ON VALUE ADDED OF INTELLECTUAL CAPITAL: THE BOOK PUBLISHING SECTOR IN SLOVAKIA*

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Abstract. This article examines how selected micro- and macro-level factors affect the Value Added Intellectual Capital (VAIC™) indicator for a set of enterprises in the book publishing sector in the Slovak Republic, using a regression model. Alternatively, authors examine the Intellectual Capital Efficiency (ICE) indicator for the same set of enterprises. They employ a regression analysis with cross-sectional panel data, considering fixed effects (FE) and random effects (RE) models. The research sample was rigorously selected, comprising 350 observations from 2018 to 2024. In the case of the fixed effects model, none of the explanatory variables turned out to be a significant determinant of the dependent variable VAIC™. In the random effects model, the authors found that the most significant factors affecting VAIC™ are profitability (positive) and company age (negative), while inflation has an additional (marginal) impact. In the case of the dependent variable ICE, the authors using a fixed-effects model found that profitability measured by the EBIT/Sales ratio positively affects the dependent variable ICE, while a higher EBITDA/Assets ratio has a slightly negative impact. The results of the random-effects model for the ICE variable show that profitability (EBIT/Sales) increases, and older companies (Age) have lower ICE. The key finding is that company size, measured by sales or asset value, is not a determining factor in intellectual capital efficiency. The results of the work indicate the need to reassess the ratio between investments in physical assets and investments in human, organisational or innovation capital. The contribution of this article is the findings of the impact of selected factors on the added value of intellectual capital and the efficiency of intellectual capital in a specific creative industry sector.

Keywords: Value Added Intellectual Capital (VAIC™); Intellectual Capital Efficiency (ICE); intangible assets; creative industries; regression model; book publishing sector; Slovak Republic

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JEL Classifications: G32, O34, L82, M41

1. Introduction

The significance of the presented research lies in its focus on the book publishing industry. This industry is a bearer of cultural identity and requires creativity and intellectual skills. It is also a bearer of digital transformation. The object of our research was a sample of Slovak book publishers. An important factor and driving force in the creation of book products and their success is human resources. The objective of this article is to examine the impact of selected microeconomic and macroeconomic indicators on the Value Added Intellectual Capital (VAIC™) indicator and the Intellectual Capital Efficiency (ICE) indicator.

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The book publishing industry has undergone significant changes in recent years, affecting its business models, product development processes and overall efficiency. In this dynamic situation, traditional performance measurement methods such as profit, margin or sales are not always sufficient to evaluate the potential performance of publishing houses. An equally important factor is the effective use of intellectual capital, i.e. the capabilities of personnel, their knowledge, skills, creativity and innovative potential that contribute to the creation of a book as a product and drive the publishing process (Abeysekera, 2021). Intellectual capital, which includes human, structural and relational dimensions, has become a key determinant of firm performance, innovative capacity and adaptability in rapidly changing environments (Passavanti et al., 2025). Book publishing is part of the cultural and creative industries, where value creation is based primarily on intangible resources such as employee expertise, editorial processes, copyright, brand and relationships with authors and distributors. For this reason, the use of traditional financial indicators is insufficient to capture the true sources of performance. Employees in the publishing industry are not just operational contributors; they are key players in creativity and innovation. Their ability to generate ideas, manage content, and adapt to changing market conditions directly impacts the competitiveness of the business, which is increasingly knowledge-based (Bontis, 1998). Book publishing is driven by knowledge, creativity, innovation, and high added value, drawing on individual and collective talent. It drives economic growth and strengthens society's identity and cohesion. Human skills, intellectual capital, talent and creativity play a key role. Behind all of this are specific creative employees with the aforementioned qualities and abilities. Book publishing, as an industry that organises the publishing process and finances the publication and distribution of books—from manuscript preparation to their final sale—has two key dimensions: economic and cultural. Like any other business activity, publishing pursues profit as its primary economic objective. However, what distinguishes book publishing is that it is not only a production activity but also a social and cultural practice that shapes a country's cultural identity and, consequently, its citizens (Tomašević & Lebeda, 2014).

In this context, given the specifics of book publishing as a knowledge- and creativity-based industry, where value creation is primarily driven by intellectual capital, the Value Added Intellectual Capital (VAIC™) indicator was chosen. VAIC™ enables assessment of the efficiency of the use of human and structural capital using publicly available accounting data and is a suitable complement to traditional financial performance indicators. Value Added Intellectual Capital (VAIC™) is a model developed by Professor Pulić to measure and evaluate the effectiveness of intellectual capital in creating enterprise value (Pulić, 2004). The author emphasises that a central principle of this concept is the assumption that all employees are regarded as equal contributors to corporate success, and they highlight the importance of information on the effectiveness of intellectual capital at both the firm and economy-wide levels.

Pulić (1998) developed an original model and tested it using a sample of 200 Austrian companies across 14 industry sectors, and 400 Croatian companies with the highest revenue. He concluded that the efficiency of intellectual capital can be measured and managed, and that there is a strong dependency between borderline intellectual potential and added value. All of the following elements of the VAIC™ indicator were designed by Professor Pulić so that they could be easily obtained from companies' accounting records. He considers these data to be publicly available and legislatively prescribed under the accounting, reporting, and financial control systems of business entities, in accordance with applicable national laws.

Value Added Intellectual Capital (VAIC™) is a model that focuses on three key components, expressed in the form of efficiency coefficients:

- Human Capital Efficiency (HCE);
- Structural Capital Efficiency (SCE);
- Capital Employed Efficiency (CEE);
- Efficiency of Intellectual Capital (ICE), ICE = HCE + SCE.

Human Capital Efficiency (HCE) measures how efficiently an enterprise utilises its human resources and indicates how much value added is generated by one monetary unit invested in employees (Pulić, 2000). In the context of book publishing, human capital includes the jobs of editors, designers, marketers, and other professionals who contribute to the production, marketing, and distribution of books. Human capital consists of

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intangible collective resources possessed by individuals and groups within a given population. These resources include knowledge, skills, abilities, experience, intelligence, talent, education, judgment, and wisdom, whether possessed individually or collectively. The cumulative value of these attributes represents a form of wealth that nations and organisations can draw upon to achieve their objectives (Huff, 2025). Human capital serves as a resource for creating material and non-material wealth in the national economy and in private enterprises. In public organisations, it is utilised to deliver public goods. As a result, the way human capital is developed and managed is one of the most important determinants of a company's economic and organisational performance.

Structural Capital Efficiency (SCE) reflects the effectiveness of an organisation's internal systems, processes, and organisational culture. In the publishing industry, this encompasses the quality of supply chains, technological infrastructure, distribution networks, and intellectual property management. Structural Capital (SC), also referred to as organisational capital, enables the creation of value by transforming human capital into organisational output (Pulić & Kolaković, 2005). Structural capital refers to the intangible assets embedded within an organisation, such as its organisational structure, management systems, collections, patents, and copyrights, which contribute to overall effectiveness and value creation. Structural capital originates from human capital and comprises knowledge and intangible assets derived from organisational processes. It encompasses efficiency, procedural innovation, and access to information, which enable knowledge codification (Gogan, Duran & Draghici, 2015). According to Pulić, the Intellectual Capital Efficiency (ICE) indicator is calculated as the sum of the Human Capital Efficiency (HCE) and Structural Capital Efficiency (SCE) coefficients (Pulić & Kolaković, 2005; Komnenić & Pulić, 2021; Pulić, Kolaković & Jelčić, 2009).

Capital Employed Efficiency (CEE) measures the efficiency with which a company utilises its physical and financial capital. In publishing houses, this includes investments in physical infrastructure, such as editorial systems and printing equipment, as well as financial capital that supports operations and long-term growth. Capital Employed (CE) refers to the total capital invested by a company to generate profit and reflects the efficiency with which this capital is utilised. It compares the value of a company's assets with its current liabilities, representing short-term obligations that must be settled within one year. The VAIC™ model assigns efficiency measures to each of these components, thereby providing a quantitative assessment of how effectively a publishing house utilises both its intellectual and tangible assets. Bontis (2001) conducted a review of the literature on the assessment of knowledge assets, considered the core of sustainable competitive advantage. He examines various measurement models, outlining their respective strengths and limitations. With regard to Professor Pulić's VAIC™ model, Bontis (2001, p. 58) highlights empirical evidence demonstrating the generalizability of results across numerous Eastern European countries.

2. Theoretical background

Enterprises that manage their intellectual capital effectively are better equipped to respond to changes in market conditions. Intellectual capital also enhances a company's attractiveness to investors and shareholders. Enterprises with strong intellectual capital demonstrate greater potential for long-term growth and improved financial sustainability (Akmalia & Muharam, 2024). Companies are more innovative in developing new products and services, improving operational efficiency, and achieving sustainable competitive advantages. Strong intellectual capital enables publishers to develop innovative products and services while adapting to evolving reader preferences and changing market demands. Empirical research further indicates that enterprises driven by intellectual capital are better able to respond to external environmental changes and generally achieve better results compared to companies with a lower intellectual capital profile. (Piyathilake & Siromi, 2024).

Intellectual capital significantly influences knowledge management and innovation, both of which positively impact company performance (Suparwadi, Riza & Hutahayan, 2024). While intellectual capital enhances knowledge management and overall performance, effective knowledge management fosters innovation, further reinforcing performance improvements. Moreover, the effective management of intellectual capital facilitates the sharing of knowledge and best practices within an enterprise, contributing to the development of a more adaptive and responsive workforce.

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By leveraging intellectual capital, publishers are better positioned to respond swiftly to emerging market trends, technological advancements, and changing consumer behaviour, thereby maintaining relevance and competitiveness. Enterprises that effectively manage their intellectual capital can achieve a lasting competitive advantage by innovating more efficiently and adapting to market changes more successfully than their competitors (Bontis, Keow & Richardson, 2000). Intellectual capital contributes to improved business performance by enhancing knowledge management, innovation, and decision-making processes, leading to greater adaptability and resilience.

In a study of 300 companies in the United Kingdom, divided into high-tech, traditional, and service sectors, Zéghal and Maaloul (2010) identified a significant positive relationship between the Value Added Intellectual Capital coefficient and corporate economic performance. Their findings suggest that intellectual capital plays a significant role in reducing production costs and is positively associated with both financial performance and stock market performance.

An analysis of IT companies listed on the Warsaw Stock Exchange over five years was conducted by Polcyn and Vovk (2023). Focusing on the IT sector—previously identified as exhibiting strong correlations between VAIC™ and market value—the authors found a high correlation between VAIC™, Human Capital Efficiency, and company market value. Their results align with broader research emphasising the role of human capital in economic growth, although data availability remained a notable limitation.

Bellucci et al. (2021) conducted a bibliometric and systematic analysis of 187 academic studies on intellectual capital published in the Journal of Intellectual Capital between 2014 and 2018. The authors identified several dominant research streams during this period, including intellectual capital reporting and disclosure; intellectual capital research in universities, education, and the public sector; knowledge management; and the relationship between intellectual capital, financial performance, and market value.

Santosa et al. (2023) conducted a bibliometric analysis of 130 research publications indexed in the Scopus database that focused thematically on the VAIC™ indicator during the period 2016–2020. The originality of their study lies in applying bibliometric analysis to VAIC™ as the central research theme. Their findings indicate that most studies examine the impact of intellectual capital on business performance, primarily measured by profitability and productivity, with Return on Assets (ROA) and Return on Equity (ROE) as the most frequently used indicators. The authors confirm that research on VAIC™ remains relevant, particularly with respect to modifying, reshaping, or extending the model to enhance its robustness. They further recommend that future research incorporate additional variables, such as innovation and relational capital, which may represent hidden sources of VAIC™ inconsistency. The effect of modified VAIC™ models on both financial and non-financial performance also represents a promising research direction.

Mrázková, Peržeľová, and Glova (2016) analysed a sample of 95 software companies from European Union countries over the period 2013–2015. Their results indicate that the components of the VAIC™ model significantly explain company profitability measured by ROE and ROA, as well as employee productivity. However, neither the aggregate VAIC™ indicator nor its individual components satisfactorily explained the market-to-book value ratio. The authors further demonstrated that the structure of intellectual capital efficiency — particularly Human Capital Efficiency and Structural Capital Efficiency — exhibits a statistically significant positive impact on both profitability and employee productivity. A notable advantage of the VAIC™ methodology, as highlighted by the authors, is the relative accessibility of the required data, which can be obtained from standard financial statements.

Rong et al. (2025) examined the influence of intellectual capital on the value creation process in commercial banks within the European Union. Using data from 2015 to 2022 for a sample of 599 banks, comprising 4,792 observations, they identified a significant positive relationship between both financial capital and human capital and banks' value-added performance. Their findings support the conclusion that financial and human resources represent the primary determinants of value creation in the banking sector. The study further revealed that during periods of financial crisis, human capital becomes less effective than financial capital in enhancing value added.

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In times of economic or organisational crisis, employee turnover and sudden declines in human capital exert a substantial negative impact on bank performance.

Tarnóczi and Kulcsár (2021) conducted a comparative analysis of the VAIC™ indicator among enterprises located in the border regions of Romania and Hungary. Their study encompassed enterprises from the agriculture, construction, manufacturing, wholesale trade, retail trade, and transportation sectors over the period 2014–2018. In total, the authors examined 687 Romanian and 653 Hungarian enterprises. Their results indicate that intellectual capital significantly contributes to enterprise performance in Romania, particularly within agriculture, wholesale trade, and transportation sectors. In Hungary, intellectual capital plays a key role in value creation within construction and wholesale trade. Overall, the findings confirm a direct relationship between the VAIC™ and enterprise performance.

An empirical study focusing on the four largest media companies in Poland, which together accounted for 94.31% of the market during 2007–2011, was conducted by Fijałkowska (2014). The study involved a practical calculation of the VAIC™ indicator and an interpretation of its development over time. The results provide a comparison of changes in VAIC™ values and quantify the additional value generated per unit of invested capital.

Siniša (2018) conducted an empirical analysis of 29 commercial banks operating in the Serbian banking sector during the period 2008–2016 using the VAIC™ methodology. His findings indicate that the efficient utilisation of physical and financial capital has a greater impact on bank profitability than the efficient use of intellectual capital. Furthermore, bank size was not found to influence the relationship between ROA and intellectual capital efficiency significantly.

Nadeem, Dumay, and Massaro (2018) proposed a modification of the original VAIC™ calculation and tested the revised model using data from ten emerging and developed markets worldwide. Their results reveal a significant positive relationship between intellectual capital — particularly human, innovative, and physical capital — and firm performance, thereby supporting the robustness of extended VAIC™ –based models.

Palazzi et al. (2020) examined the moderating effect of technological intensity on the relationship between intellectual capital and enterprise performance over the period 2012–2016, using a dataset of 62,849 Italian small and medium-sized enterprises. Their findings show that profitability is positively influenced by financial and physical capital efficiency, as well as human capital efficiency. However, the effect of human capital efficiency appears weaker in the medium term. The authors argue that human capital may exert a stronger influence over longer time horizons, particularly in technologically intensive industries.

Hermans and Kauranene (2005) explored the relationship between knowledge management, intellectual capital measurement, and expected sales in a sample of Finnish biotechnology SMEs. Their analysis identified two intellectual-capital-related factors that systematically explain future sales expectations. The first factor relates to firms with a highly educated workforce, strong research and development capacity, extensive patent portfolios, and venture capital participation. The second factor reflects enterprises with an ageing but experienced workforce that has already generated stable sales, often characterised by ownership by other companies.

Galeão, Madaleno, and Nogueira (2024) investigated the relationship between VAIC™ and financial performance using ROA and ROE indicators. Their study analysed data from 600 Portuguese companies operating across twelve economic sectors between 2014 and 2019. The findings highlight the importance of physical and financial capital in explaining financial performance, while emphasising the need to focus on developing skilled human capital rather than on formal education alone. The efficiency of the human, structural, and capital-employed components was found to differ between ROA and ROE measures, with most sectors demonstrating the significance of skilled human capital, except in the financial and insurance sectors.

Bassetti et al. (2020) analysed a panel dataset of 50,310 observations from European companies over the period 2000–2017 within an imperfectly competitive environment. Their results suggest that VAIC™ is not directly

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linked to intellectual capital under perfect-competition assumptions. However, the authors argue that VAIC™ remains a practical and transparent indicator of intellectual capital because it relies on readily available accounting data.

Ginesti and Ossorio (2021) applied the VAIC™ methodology to a sample of 85 Italian listed family businesses over the period 2015–2017. They concluded that higher efficiency in human capital, structural capital, and capital employed contributes positively to intellectual capital performance. Their analysis further identified two key determinants: family leadership and ownership involvement, as well as the generational stage of family businesses, both of which positively influence intellectual capital efficiency.

Kamińska, Parkitna, and Siałkowska (2017) proposed a framework for reporting intellectual capital within corporate governance structures. They argue that intellectual capital reports enhance managerial awareness and provide valuable information to potential investors, thereby supporting strategic decision-making and the development of competitive advantage.

Holienka, Pilková, and Kubišová (2016) analysed financial data from 3,311 Slovak SMEs across ten industrial sectors using Return on Capital Employed (ROCE) as a measure of value creation. Their findings indicate that while VAIC™ significantly explains value creation across all sectors, the strength of this relationship varies considerably by industry, underscoring the importance of sector-specific characteristics.

Papík and Papíková (2022) examined data from 24,351 Slovak SMEs during 2019 and 2020 to assess the relationship between intellectual capital and company performance. Their study concludes that physical and financial capital remain crucial for company success in post-communist economies such as Slovakia. During periods of market liquidity constraints, the costs associated with maintaining intellectual capital exceeded its immediate benefits, reflecting either an underestimation of intellectual capital or insufficient crisis management.

Book publishing houses are part of the cultural and creative industries. Their social, cultural and economic significance is explained by Tomašević and Lebeda (2014). The authors of this paper sought to establish a connection between an economically active business entity that produces a book as its final market product for the customer. The creation of a market product, such as a book, requires specific business knowledge, understanding and skills. These are closely related to intellectual work, i.e. intellectual capital. The links between the business's subject and an appropriate method for measuring the intellectual contribution of human capital in a company were sought. The indicator Value added intellectual capital – VAIC™ appears to be suitable. Available scientific sources were examined, and it was found that this indicator has been applied in various economic sectors to quantify the contribution of human intellectual capital. The authors did not find a paper examining this indicator in the book publishing industry. This fact can be considered a research gap, which is directly linked to the specific sector mentioned above - book publishers, economically active enterprises and real financial data from the economic environment of the Slovak Republic in the period under review.

3. Research objective and methodology

The *research objective* of this article is to examine, using a regression model, how selected micro and macro factors affect the indicator Value Added of Intellectual Capital (VAIC™) in a set of enterprises in the book publishing sector in the Slovak Republic. Subsequently, using a regression model, we examine the impact of selected micro- and macro-level factors on the partial indicator, Intellectual Capital Efficiency (ICE), for the same set of companies.

The *subject of the study* is a selected set of enterprises operating in the book publishing sector (NACE class 58.11: Book publishing). This statistical class includes the activities of publishing books in printed, electronic (CDs, electronic displays, etc.), audio, or Internet form. The book publishing sector is part of the creative and cultural industries.

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The *data* comes from the commercial database FinStat, which collects financial data on enterprises in the Slovak Republic. The data were processed using the Gretl software, an open-source computer statistical system. The period under study was 2018 to 2024. The original research sample consisted of 205 enterprises. The following enterprises were excluded from the research:

- that had an inappropriate data structure of published data or reported zero sales in euros (€) in some years of the research period,
- did not carry out continuous business activity in the book publishing industry in the years 2018 to 2024, or ceased their activity in this period,
- annual sales were lower than 15,000 euros (€) and at the same time had a loss from business activity. The condition was chosen because some enterprises have only one employee. The nominal annual gross wage of an employee in the Slovak Republic in 2024 was €12,576. According to the Labour Code, Act No. 311/2001 Coll., Section 120, Paragraph 3, this amount corresponds approximately to the level of work intensity for managerial activities, with an annual gross salary of €12,576, as of 2024. For this reason, we also limited the minimum annual turnover (sales)
- as a result of this selection, 155 enterprises were excluded from the research sample;
- the final number was 50 surveyed enterprises. From 2018 to 2024, we conducted 350 observations.

These indicators, value added intellectual coefficient (WAIC™) and Intellectual capital efficiency (ICE), were created and applied by Professor Ante Pulić. We will use his original concept of the value added indicator of intellectual capital (VAIC™). In our article, we used the following formulas to calculate the *dependent variables of regression analysis*:

1. Value added intellectual coefficient (VAIC™), basic formula:

$$VAIC = HCE + SCE + CEE \quad (1)$$

where: HCE - Human capital efficiency coefficient (HCE); SCE - Structural capital efficiency coefficient; CEE - Capital employed efficiency coefficient.

HCE - Human capital efficiency coefficient (HCE)

$$HCE = \frac{\text{VA}}{\text{HC}} \quad (2)$$

where: VA - Value added; HC - Total salary and wages.

Structural capital efficiency coefficient (SCE)

$$SCE = \frac{\text{VA}-\text{HC}}{\text{VA}} \quad (3)$$

where: VA (Value added) = Operating profit + Employee costs + Depreciation + Amortization;
HC (Human capital) = Total personnel expenses, salaries and wages (employee costs).

Capital employed efficiency coefficient (CEE)

$$CEE = \frac{\text{VA}}{\text{BVofNA}} \quad (4)$$

where: VA - Value added; BVofNA - Book value of the net assets.

2. Intellectual capital efficiency (ICE):

$$ICE = HCE + SCE \quad (5)$$

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where: HCE - Human capital efficiency coefficient (HCE); SCE - Structural capital efficiency coefficient

3. Value added intellectual coefficient (VAIC™), formula with the indicator Intellectual capital efficiency:

$$VAIC = ICE + CEE \quad (6)$$

4. We used the following indicators and calculations in the formulas:

Value added (VA) = Operating profit + Employee costs + Depreciation + Amortization (7)

Human capital (HC) = Total personnel expenses, salaries and wage. (8)

Structural capital (SC) = value added (VA) – Human capital (HC) (9)

5. The EBIT Margin is calculated by dividing Earnings Before Interest and Taxes (EBIT) by total Sales (percentage):

$$EBIT\ Margin = \frac{EBIT}{Total\ Sales}\ x\ 100 \quad (10)$$

EBIT, or Earnings Before interest and Taxes, is a measurement of enterprises' profitability directly related to its sales. EBIT answers the question of whether an enterprise makes a profit from selling its merchandise. EBIT measures profit before interest and tax factors have been subtracted. This demonstrates whether an enterprise is profitable, regardless of the amount it pays in taxes or the amount of debt it owes. Total Sales is the total amount of money generated from sales of goods or services.

6. EBITDA Return on Assets

$$EBITDA\ Return\ on\ Assets = \frac{EBITDA}{Total\ Assets} \quad (11)$$

EBITDA = Net Profit + Interest + Taxes + Depreciation + Amortization (12)

EBITDA Return on Assets – measures how efficiently an enterprise is generating EBITDA (Earnings Before Interest, Taxes, Depreciation and Amortisation). This means capital structure, tax rates, and capex would not affect comparisons between enterprises. EBITDA is an alternative profitability indicator to net profit. It is used to assess an enterprise's financial health, profitability and operational efficiency. Total Assets refers to the sum of the book values of all assets owned by an enterprise.

7. Age: number of years of existence of the enterprise. Age of the enterprise in the year under review.

8. Gross Domestic Product (GDP) growth: GDP growth is the percentage change in a country's real Gross Domestic Product (GDP) over a specific period, measuring the rate at which its economy is expanding. Gross domestic product is the monetary value of all finished goods and services made within a country during a specific period.

9. Inflation: Harmonised Index of Consumer Prices (HICP), harmonised inflation rate, external factor.

Regression models. We used a data panel to build the regression model for a Fixed Effects Model and Random Effects Model, regression analysis of selected factors for the dependent variables VAIC™ (Value Added Intellectual Capital) and ICE (Intellectual Capital Efficiency).

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Specification of Model 1 Fixed Effects and Model 2 Random Effects, dependent variable VAIC™ (Value Added Intellectual Capital):

$$VAIC_{it} = \beta 0 + \beta_1.(EBIT/Sales)_{it} + \beta_2.(EBITDA/Assets)_{it} + \beta_3.\ ln(Sales_{it}) + \beta_4.ln(Assets_{it}) + \beta_5.Age_{it} + \beta_6.GDP_t + \beta_7.Inflation_t + u_i \quad (13)$$

Specification of Model 3 Fixed Effects and Model 4 Random Effects, dependent variable ICE (Intellectual Capital Efficiency):

$$ICE_{it} = \beta 0 + \beta_1.(EBIT/Sales)_{it} + \beta_2.(EBITDA/Assets)_{it} + \beta_3.\ ln(Sales_{it}) + \beta_4.ln(Assets_{it}) + \beta_5.Age_{it} + \beta_6.GDP_t + \beta_7.Inflation_t + u_i \quad (14)$$

Where:
ICE – indicator, Intellectual Capital Efficiency, dependent variable
VAIC – indicator, Value Added Intellectual Capital, dependent variable
i – number of enterprises in the set,
t – specifically analysed period,
β0 – the dependent variable parameter (ICE, VAIC),
β1 to β7 – regression coefficients,
independent variables: EBIT/Sales – EBIT Margin; EBITDA/Assets – Return on Assets; Sales – total Sales, natural logarithm; Assets – total Assets, natural logarithm; Age – Age of the enterprise in the year under review; GDP – Gross Domestic Product growth; Inflation – Harmonised Index of Consumer Prices; u_i – enterprises-specific random effect.

4. Regression analysis results

The basic relationships between individual variables, strength and direction are examined using a *correlation table*, which contains indicators of:

- intellectual capital (ICE, VAIC™),
- performance (EBIT/Sales, EBITDA/Assets),
- size variables (Sales, Assets),
- enterprise age (Age),
- and macroeconomic variables (GDP, Inflation).

The results of the correlation of the above variables are presented below (Table 1).

Table 1. Correlation

Indicators	ICE	VAIC	EBIT_Sales	EBITDA_ Assets	Sales	Assets	Age	GDP	Inflation
ICE	1,0000	0,5935	0,4199	0,0192	-0,0462	-0,0002	-0,2858	-0,0677	-0,0616
VAIC	0,5935	1,0000	0,2244	-0,0037	-0,0324	-0,0136	-0,2009	-0,0290	0,0277
EBIT_Sales	0,4199	0,2244	1,0000	0,0998	-0,0325	0,0100	-0,1699	-0,0635	-0,1371
EBITDA_ Assets	0,0192	-0,0037	0,0998	1,0000	-0,0132	-0,0275	-0,1157	-0,0441	-0,0554
Sales	-0,0462	-0,0324	-0,0325	-0,0132	1,0000	0,9121	0,2641	0,0125	0,0068
Assets	-0,0002	-0,0136	0,0100	-0,0275	0,9121	1,0000	0,3201	0,0374	0,0412
Age	-0,2858	-0,2009	-0,1699	-0,1157	0,2641	0,3201	1,0000	0,1059	0,1203
GDP	-0,0677	-0,0290	-0,0635	-0,0441	0,0125	0,0374	0,1059	1,0000	0,6819
Inflation	-0,0616	0,0277	-0,1371	-0,0554	0,0068	0,0412	0,1203	0,6819	1,0000

Correlation coefficients, using the observations 1:001 - 2:175; 5% critical value (two-tailed) = 0,1049 for n = 350
Source: compiled by the authors

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The most important relationships in the correlation table (see Table 1 above):

a) relationships between intellectual capital (ICE, VAIC™) and performance: Intellectual capital (ICE) is positively correlated with profitability from sales (EBIT/Sales), but almost not at all with profitability from assets (EBITDA/Assets). Higher intellectual capital is related to higher profitability from sales.
b) enterprise size (Sales, Assets): enterprises with higher sales tend to have more assets. Strong correlation between Sales and Assets. Enterprise size (Assets) is not a decisive factor in profitability. Age in relation to Assets expresses that older enterprises tend to be larger.
c) enterprise age: older enterprises have lower intellectual capital or use it less. This may reflect lower innovativeness or a less dynamic environment in older enterprises.
d) age and performance indicators (EBIT/Sales, EBITDA/Assets) show slightly negative correlations. Older enterprises may be less efficient or less flexible.
e) macroeconomic variables (GDP and Inflation) are strongly correlated. In some economies, there may be unidirectional movement, e.g. economic growth associated with a moderate increase in prices. The macro environment does not have a significant direct impact on intellectual capital or on the performance of enterprises in this set. Micro variables are dominant.

The above shows that:

a) Intellectual capital increases efficiency (EBIT/Sales), but not total return on capital (ROA, EBITDA, Assets).
b) Older enterprises have lower intellectual capital and at the same time slightly lower performance.
c) enterprise size (Sales, Assets) does not play a significant role in profitability – it is only related to itself.
d) Macro variables (GDP and Inflation) have a very weak connection with micro variables – the effect is negligible.

Regression analysis of models: through regression analysis we will examine:

– regression Model 1 Fixed Effects (FE1) and Model 2 Random Effects (RE2). The task is to determine the influence of a set of selected indicators on the dependent variable VAIC and, according to the results of statistical indicators, select the most appropriate model for interpreting the regression analysis (FE1/RE2),
– regression Model 3 Fixed Effects (FE3) and Model 4 Random Effects (RE4). The task is to determine the influence of a set of selected indicators on the dependent variable ICE and, according to the results of statistical indicators, select the most appropriate model for interpreting the regression analysis (FE3/RE4).

First research question: "Do the selected indicators of regression Model 1 Fixed Effects and Model 2 Random Effects have an objective impact on the dependent variable VAIC?". We set the assumption: "The selected indicators of regression Model 1 Fixed Effects and Model 2 Random Effects have an objective impact on the dependent variable VAIC. According to the results of the regression analysis, we will select an appropriate Fixed or Random Effects model to interpret the results".

We formulate hypotheses:
Hypothesis (H0): "The set of selected indicators does not affect the dependent variable VAIC".
Hypothesis (H1): "The set of selected indicators affects the dependent variable VAIC".

Regression analysis of enterprises in the book publishing industry (Model 1 and Model 2) is presented below in Table 2.

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Table 2. Regression analysis of enterprises in the book publishing industry. Model 1: Fixed Effects (FE), Model 2: Random Effects (RE). Dependent variable: VAIC – Value Added Intellectual Coefficient

Independent variable	FE Model 1 Coefficient	p-value	significance	RE Model 2 Coefficient	p-value	significance
const	47,2638	0,1131		47,8102	0,0952	*
EBIT_Sales	2,8354	0,2487		4,9343	0,0253	**
EBITDA_Assets	−0,3929	0,3603		−0,3672	0,3590	
Sales	8,7936e-07	0,7280		−2,8144e-07	0,7758	
Assets	−8,4899e-07	0,7790		7,9079e-07	0,6370	
Age	−0,3667	0,4383		−0,3695	0,0210	**
GDP	−36,4111	0,2128		−37,5937	0,1756	
Inflation	0,4531	0,0943	*	0,4660	0,0626	*

Note: *** indicates significance at the 1 % level, ** indicates significance at the 5 % level and * indicates significance at 10 % level.
LSDV - Least Squares Dummy Variable
Source: compiled by the authors

a) Main results of regression analysis - Model 1 Fixed Effects.

This type of model captures individual differences between firms using a fixed dependent variable. The LSDV R^2 value measures the overall accuracy and suitability of the regression model with respect to the actual data. The R^2 indicator = 0.285 indicates that the prediction of the values of the dependent variable according to the regression equation explains the variability of the dependent variable VAIC with an accuracy of approximately 28.5%. None of the explanatory variables emerged as a significant determinant of VAIC, except for inflation, which has a slightly positive effect.

The Within R^2 indicator = 0.018 indicates that the explanation of the changes within units alone is very low. The changes in the dependent VAIC between years within firms are not well explained by the variables listed.

The result of the F-test for the common dependent variables (1.608, p = 0.009) means that we reject the null hypothesis that all units have the same dependent variables, and the use of Model 1 with fixed effects is justified.

The regression analysis identified the variable inflation (p = 0.094) as marginally significant at the 10% level. The other independent variables are statistically insignificant.

Although the model is statistically significant as a whole (F = 2.083, p = 0.00005), it has weak economic power.

b) Main results of regression analysis - Model 2 Random Effects.

The type used assumes that differences between enterprises are random and uncorrelated with the explanatory variables. Significant variables include: EBIT/Sales (p = 0.025), has a positive effect, meaning that higher sales profitability increases the VAIC value. The Age variable (p = 0.021) has a negative effect, meaning that older enterprises have a lower VAIC level. Inflation (p = 0.063) is again marginally significant at the 10% level.

The model's suitability was verified by the Breush-Pagan and Hausman tests.

The joint test (Chi^2 = 14.709, p = 0.0399) means that the model as a whole is statistically significant.

According to the Breusch-Pagan test (p = 0.0387), we reject the null hypothesis that the variance of the unit-specific error is zero. This means that random effects is more suitable than ordinary OLS.

The result of the Hausman test (p = 0.179) means that there is no reason to reject the null hypothesis. So, random effects are consistent and, therefore, more suitable than fixed effects.

Based on the results of Model 1 Fixed Effects and Model 2 Model 2 Random Effects, we will use Model 2 Random Effects as a working one. Model 2 Random Effects is a statistically and economically more suitable model. The analysis shows that the most significant factors affecting VAIC are profitability (positive) and enterprise age (negative), while inflation has an additional (marginal) effect.

Regression analysis result and model selection: Selected indicators of regression Model 1 Fixed Effects and Model 2 Random Effects have an objective impact on the dependent variable VAIC (Value Added Intellectual Capital). According to the regression analysis results above, Model 2 Random Effects is more suitable for interpreting the results.

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The second research question: "Do the selected indicators of the regression Model 3 Fixed Effects and Model 4 Random Effects have an objective impact on the change in the dependent variable ICE?" We set the assumption: "The selected indicators of the regression Model 3 Fixed Effects and Model 4 Random Effects have an objective impact on the dependent variable ICE. According to the results of the regression analysis, we will select an appropriate Fixed or Random Effects model for interpreting the results".
We formulate the hypotheses:
Hypothesis (H0): "The set of selected indicators does not affect the dependent variable ICE".
Hypothesis (H1): "The set of selected indicators affects the dependent variable ICE".

Regression analysis of enterprises in the book publishing industry (Model 3 and Model 4) is presented below in Table 3.

Table 3. Regression analysis of enterprises in the book publishing industry. Model 3: Fixed Effects (FE), Model 4: Random Effects (RE). Dependent variable: ICE – Intellectual Capital Efficiency

Independent variable	FE Model 3 Coefficient	p-value	significance	RE Model 4 Coefficient	p-value	significance
const	20,2512	0,1221		20,3766	0,1106	
EBIT_Sales	2,5931	0,0167	**	3,5124	0,0006	***
EBITDA_Assets	−0,3253	0,0851	*	−0,3098	0,0886	*
Sales	3,8287e-07	0,7303		−3,8006e-07	0,5338	
Assets	3,1994e-07	0,8097		1,0099e-06	0,3089	
Age	−0,3152	0,1299		−0,3104	0,0045	***
GDP	−11,2171	0,3818		−11,4676	0,3540	
Inflation	0,0270	0,8204		0,0313	0,7805	

Note: *** indicates significance at the 1 % level, ** indicates significance at the 5 % level and * indicates significance at 10 % level.
LSDV - Least Squares Dummy Variable.
Source: compiled by the authors

c) Main results of regression analysis - Model 3 Fixed Effects.

The significant variables of the model (at the 5% level) are the data for EBIT/Sales, a positive and statistically significant effect (p = 0.0167) and for EBITDA/Assets a weaker one (at the 10% level, p = 0.0851). This means that profitability measured by EBIT/Sales positively affects the dependent variable ICE, while a higher EBITDA/Assets ratio has a slightly negative effect. The other variables (Sales, Assets, Age, GDP, Inflation) are not statistically significant.
The LSDV R^2 indicator has a high value of 0.606, the total explanation share including fixed effects.
The Within R^2 indicator with a value of 0.05 means that the model captures only 5% of the variability within units.
The F-test for common dependent variables is significant ($p < 0.001$) and also statistically confirms that companies have different fixed effects. Therefore, a fixed effects model is appropriate.

d) Main results of regression analysis - Model 4 Random Effects.

We identified significant variables: EBIT/Sales (p = 0.0006) has a positive and highly significant effect. EBITDA/Assets (p = 0.089) has a negative and weakly significant effect. Age (p = 0.0045) has a negative and significant effect. We conclude that profitability (EBIT/Sales) increases ICE, and older companies (Age) have lower ICE.
The quality of the model fit at S.E. of regression = 8.19 (higher than with FE) indicates a worse fit to the data. Therefore, it confirms that the model with FE is more appropriate. The joint test $Chi^2(7) = 28.83$, $p<0.001$ shows that both models as a whole are significant.
The result for the Hausman test, the null hypothesis states that the RE estimates are consistent, i.e. there is no correlation between the dependent and independent variables). Since p = 0.00115 < 0.05, we reject the null hypothesis and use the preferred Fixed Effects model.

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Regression analysis result and model selection: The selected indicators of regression Model 3 Fixed Effects and Model 4 Random Effects have an objective impact on the dependent variable ICE (Intellectual Capital Efficiency). According to the above regression analysis results, Model 3 Fixed Effects is suitable for interpreting the results.

e) Summary of the economic interpretation of regression analysis.

EBIT/Sales (profitability of sales) positively affects ICE in both models. This means that the more profitable a company is (relative to sales), the higher its ICE value. It has a consistently strong positive effect on ICE.
EBITDA/Assets negatively affects ICE, perhaps suggesting that higher operating efficiency (relative to assets) is associated with a lower need for increased ICE value (perhaps more efficient use of resources). Internal company factors – especially profitability and asset utilisation efficiency – are most important for ICE.
Age has a negative effect in the RE model. The explanation is that older companies may be less flexible, less innovative, or have a lower ICE value compared to younger ones.
Macroeconomic variables (GDP, Inflation) do not have a significant effect.

Discussion

The results of the analysis provide important insights for managers seeking to improve the efficiency of intellectual capital and understand its link to business performance.

We found that, profitability is closely related to the efficient use of intellectual capital. The significant role of profitability is consistent with previous studies linking intellectual capital efficiency to financial performance. Pulić (2000) introduced the VAIC™ methodology and emphasised the relationship between intellectual capital and profitability. Subsequent studies by Maditinos et al. (2011) confirmed that higher intellectual capital efficiency contributes positively to profitability indicators, including EBIT. These findings are also aligned with Kaplan and Norton (1992), who identified learning and growth assets as key drivers of long-term financial performance. Systematic investments in knowledge, processes, capabilities and organisational know-how can directly contribute to profit generation and should be viewed as investments with measurable economic returns, rather than simply as costs (Barney, 1991; Kaplan and Norton, 1992).

Another key finding is that enterprise size, as measured by revenue or total assets, is not a determinant of intellectual capital efficiency. Both smaller and larger enterprises can achieve high Intellectual capital efficiency (ICE) values if they implement effective knowledge management strategies and internal processes (Chen et al., 2005; Bontis, 1998; Youndt et al., 2004). Competitive advantage depends more on the effective management of knowledge resources than on the volume of physical or financial assets. This finding is particularly relevant for the publishing industry, where creativity, expertise, and intellectual capabilities represent essential sources of value creation.

The negative association between EBITDA/Assets and ICE suggests that companies with a strong focus on physical capital may face constraints in effectively utilising intellectual capital. The role of intellectual capital differs substantially between capital-intensive and knowledge-intensive sectors. From a managerial perspective, this highlights the need to reassess the balance between investments in tangible and intangible assets (Marzo, 2022). It also points to the need to transform traditional capital-intensive business models into more flexible, knowledge-driven configurations (Palazzi et al., 2020).

Intellectual capital is independent of the size of the company. Smaller companies can achieve the same high intellectual capital as large companies. Processes, not capital, are decisive. The negative effect of age on VAIC™ points to the need for constant modernisation, innovation, and adaptability, as rigidity can reduce the ability to create added value effectively. The negative impact of company age may be influenced by unobserved factors such as organisational inertia, legacy systems, or outdated business models, which were not directly measured in this article (Loderer et al., 2017).

The results indicate that the ICE indicator is better suited for fixed-effects analysis, whereas VAIC™ is more effectively explained through random-effects models. Profitability, measured by EBIT margin, emerged as a

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consistent and statistically significant determinant of intellectual capital efficiency, suggesting that firms with stronger profitability are more capable of utilising their knowledge resources effectively (Nadeem et al., 2018).

The analysis further revealed that macroeconomic variables, particularly GDP growth and inflation, do not significantly affect intellectual capital efficiency. This finding suggests that intellectual capital is primarily influenced by internal organisational factors rather than external economic conditions. The results support the view that knowledge-based resources constitute a relatively stable source of competitive advantage and are less sensitive to short-term macroeconomic fluctuations.

Company-specific characteristics proved to be considerably more important. The findings indicate that organisational culture, managerial capabilities, internal processes, and the overall ability to transform knowledge into value are key determinants of intellectual capital efficiency (Alipour, 2012). In addition, the results confirm that intellectual capital efficiency is largely independent of company size, implying that both small and large publishing companies can achieve high levels of intellectual capital performance when effective knowledge management practices are implemented.

Overall, the empirical evidence confirms that intellectual capital is a measurable, manageable asset that directly contributes to value creation and organisational performance in the book publishing industry. The findings underline the crucial role of human capital, structural capital, and capital employed efficiency in supporting innovation, operational effectiveness, and long-term competitiveness.

The results also highlight the practical importance of intellectual capital management. According to Komnenić and Pulić (2021), the application of the VAIC™ methodology enables companies to identify key value-creating factors and understand their interactions. Intellectual capital should no longer be considered a cost, but rather a strategic investment. While traditional financial indicators may indicate positive performance, ineffective management of intellectual capital may signal value erosion rather than value creation (Pulić, 2004). Effective management of human capital, organisational knowledge, and innovation processes can contribute significantly to long-term value creation and sustainable competitive advantage (Mention & Bontis, 2013).

This approach brings tangible economic benefits, as demonstrated by numerous empirical studies linking the measurement, reporting, and management of intellectual capital to improved productivity, profitability, and value creation (Xu & Wang, 2018; Smriti & Das, 2018). Overall, the results support the view that intellectual capital constitutes a fundamental source of competitiveness regardless of company size or macroeconomic conditions (Bontis et al., 2015). For both managers and researchers, intellectual capital remains a field for future investigation, particularly regarding dynamic processes, innovation, and the qualitative dimensions of human capital.

5. Conclusions, limitations and future research

The findings of this study confirm a growing body of literature that highlights intellectual capital as a fundamental factor influencing the performance and competitiveness of businesses. Overall, the study demonstrates that intellectual capital is not merely an abstract concept but a strategic resource that can be measured, managed, and leveraged to enhance company performance. The significance of these findings is particularly pronounced in cultural and creative industries, where intellectual assets play a central role in the creation of products, services and business value.

The research objective of this study was to examine the impact of selected microeconomic and macroeconomic indicators on the Value Added Intellectual Capital (VAIC™) and Intellectual Capital Efficiency (ICE) indicators in Slovak book publishing companies. The research addresses a significant gap in the literature, as studies specifically focusing on intellectual capital in the book publishing industry remain limited despite the sector's strong dependence on creativity, knowledge, and intellectual capabilities.

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The study focused on a selected set of enterprises operating in the book publishing sector. The book publishing sector is part of the creative and cultural industries. We surveyed 50 enterprises that were continuously operating from 2018 to 2024 and conducted a total of 350 observations.

The results of this study provide important implications for managers seeking to improve intellectual capital efficiency (ICE) and strengthen business performance. The first important finding is that profitability is closely related to the effective use of intellectual capital. Higher EBIT margins, reflecting stronger operating performance, are linked to higher levels of ICE, suggesting that systematic investments in knowledge, employee capabilities, organisational processes, and innovation contribute directly to value creation and profit generation. Rather than being viewed as operating costs, such investments should be regarded as strategic assets with measurable economic returns.

A second important finding is that intellectual capital efficiency is not determined by company size. Neither sales nor total assets significantly influence ICE, indicating that both small and large firms can achieve high levels of intellectual capital efficiency when supported by effective knowledge management, well-designed internal processes, and strong organisational capabilities. These results suggest that competitive advantage depends less on the scale of available resources than on how effectively these resources are organised, developed, and utilised.

The negative relationship between return on assets (EBITDA/Assets) and ICE suggests that firms that rely heavily on physical capital may face limitations in exploiting intellectual capital. This finding suggests that managers should critically reassess the balance between investments in tangible assets and investments in human, organisational, and innovation capital. It also supports the strategic transformation of traditional capital-intensive business models towards more flexible, knowledge-based approaches that emphasise the creation of intangible value.

The analysis further revealed that macroeconomic conditions, represented by GDP growth and inflation, do not significantly affect intellectual capital efficiency. This suggests that ICE is driven primarily by internal managerial decisions rather than by cyclical economic fluctuations. Consequently, organisations can strengthen their resilience and maintain competitive performance even during periods of macroeconomic uncertainty by systematically developing learning capabilities, encouraging knowledge sharing, supporting innovation, and fostering a culture of continuous organisational learning.

The results also indicate that company age has a negative effect on the VAIC™ indicator, implying that older firms may experience declining efficiency in creating value from intellectual capital if they fail to adapt to changing business conditions. This finding highlights the importance of continuous modernisation, organisational renewal, innovation, and strategic flexibility to prevent organisational rigidity from reducing intellectual capital performance.

Finally, the results emphasise the importance of company-specific factors, including organisational culture, management practices, long-term strategic orientation, leadership quality, and human capital development. These internal characteristics are fundamental drivers of intellectual capital efficiency and sustainable competitive advantage. Managers should therefore prioritise long-term investments in employee development, leadership capabilities, talent management, and organisational learning. Firms adopting such an internally focused strategy are more likely to achieve higher intellectual capital efficiency regardless of their size or the prevailing macroeconomic environment.

Several limitations of this study should be acknowledged. *First*, the measurement of intellectual capital efficiency relies on the VAIC™ methodology. Although VAIC™ is one of the most widely applied approaches in intellectual capital research, it has been criticised for its limited ability to capture the multidimensional nature of intellectual capital, particularly qualitative aspects such as innovation capacity, organisational culture, creativity, and knowledge-sharing processes. Since the methodology is primarily based on accounting data, it may not fully reflect the dynamic and intangible characteristics of knowledge assets.

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Second, company performance was evaluated using financial indicators such as EBIT and EBITDA/Assets. While these indicators are widely accepted measures of financial performance, they may not adequately capture long-term value creation, especially in knowledge-intensive industries where the benefits of intellectual capital often materialise over extended periods. This limitation partly explains some of the mixed relationships observed between intellectual capital efficiency and financial performance indicators.

Third, the study does not fully account for potential industry-specific effects. Previous research suggests that the role of intellectual capital differs substantially between capital-intensive and knowledge-intensive sectors. The absence of a deeper sectoral comparison limits the broader generalizability of the findings.

Finally, the analysis is based exclusively on quantitative methods and financial data. While this approach provides objective and comparable measures, it does not offer deeper insights into the organisational mechanisms through which intellectual capital is developed, managed, and transformed into competitive advantage.

Future research should address these limitations by adopting alternative approaches to measuring intellectual capital. Survey-based instruments, hybrid models, and multidimensional frameworks could provide a more comprehensive assessment of intellectual capital by incorporating qualitative dimensions such as employee competencies, innovation capabilities, organisational learning, and knowledge-sharing intensity.

Longitudinal studies would also be valuable for examining the causal relationship between intellectual capital and firm performance over time. Such research could provide deeper insights into the dynamic processes through which intellectual capital contributes to sustainable value creation.

Further investigation should explore the moderating role of industry characteristics, technological intensity, digital transformation, and organisational life-cycle stages in shaping intellectual capital efficiency and its impact on company performance. Comparative studies across different sectors could help identify industry-specific patterns and improve the generalizability of intellectual capital research.

Given the negative relationship observed between company age and intellectual capital efficiency, future studies should examine the mechanisms by which mature organisations maintain flexibility, innovation, and knowledge renewal. Particular attention should be devoted to organisational practices that help overcome structural rigidity and support continuous adaptation.

Finally, qualitative and mixed-method approaches, including case studies and interviews, complement quantitative findings by providing a richer understanding of how organisations create, manage, and leverage intellectual capital in different contexts. Such approaches may be particularly useful within cultural and creative industries, where intangible assets, creativity, and innovation play a central role in organisational success.

Future academic research should therefore focus on the dynamic, qualitative, and transformational aspects of intellectual capital, especially in relation to digital transformation, innovation processes, and emerging models of value creation in creative industries.

Given the inherently knowledge-intensive nature of the publishing sector, intellectual capital becomes a particularly important source of competitiveness, innovation, and market success. Continuous modernisation, organisational learning, and adaptation are necessary to maintain the efficiency of intellectual capital over time.

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THE RELATIONSHIP BETWEEN BUSINESS STRATEGY AND SMES' PERFORMANCE: DOES CSR MATTER? EVIDENCE FROM AN EMERGING MARKET

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Abstract. This study aims to measure the relationship between business strategy and SMEs' performance in the Kingdom of Saudi Arabia (KSA). In addition, we examine the moderating role of corporate social responsibility (CSR) on this relationship, focusing on prospector and defender strategies. Data was collected depending on questionnaires handed to SMEs in KSA with a response rate was 73.6% (184 of 250 questionnaires were received). Data was analyzed using descriptive and multivariate analysis. Results revealed a significant positive effect of business strategy on SMEs' performance. CSR has a significant positive effect on SMEs' performance. In addition, we found that CSR has a significant positive effect on the relationship between prospector strategy and SMEs' performance. However, CSR has a significant negative effect on the relationship between defender strategy and SMEs' performance. Additional analysis ensures that integrating CSR towards environmental, customers' and employees' perspectives with prospector firms enhances financial performance of SMEs. Integrating CSR towards customers with defender firms enhances SMEs' performance. However, integrating CSR towards society, environment, and employees mitigates the positive effect of defender firms on SMEs' performance. This study enriches literature in the field of business strategy and CSR in SMEs by focusing on the importance of integrating business strategy and CSR to enhance SMEs' performance.

Keywords: Business strategy; CSR; financial performance; SMEs; KSA

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1. Introduction

Corporate performance is an important factor in maintaining success and long-term market survival. This view is dependent on several factors, the most important of which are the type of business strategy implemented, the level of human resource efficiency, and the effectiveness of financial management (Salamah, 2023). Companies seek to improve their performance by enhancing their business strategies. These strategies are related to managing the company's operations, activities and services extended to internal and external stakeholders, such as consumers, suppliers, and competitors (Visedsun & Terdpaopong, 2021). In this study, we depend on Miles

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and Snow's (1978) typology of business strategies as prospectors and defenders. Prospectors rely on continuous change in their product mix and actively exploring environmental changes in search of new opportunities to become market leaders. in doing so, they should prioritize research and development, with less emphasis on exploitation and capital intensity (Maury, 2022). In other words, prospectors are characterized by a strong innovation orientation, requiring a high degree of dynamism in organizational design, structure, and processes that embrace continuous change (Moses et al., 2026). In contrast, defenders target a specific, stable market to achieve maximum operational efficiency. Hence, they are expected to have a narrow market reach, make limited efforts to develop new products and explore new markets. Moreover, these companies maintain cost-effective technologies to establish a market position that offers customers limited product choices (Osorio-Londono et al., 2020).

In today's dynamic business environment, examining the relationship between business strategies and financial performance is of great importance (Ghamizadeh & Eghbali-Zarsh, 2024). Many researchers indicate the existence of a significant effect of business strategy on market share and firms' financial performance (Hambrick, 1983; Dess & Davis, 1984; Thornhill & White, 2007; Banker et al., 2014; Ghaemi-Zadeh & Eghbali-Zarch, 2024). However, how business strategies contribute to enhancing a SMEs' financial performance is insufficiently explored in the literature, especially within emerging markets such as the Kingdom of Saudi Arabia (KSA). Therefore, it is essential to accurately evaluate financial performance considering small and medium-sized enterprises' (SMEs) business strategies (Nurunnabi, 2017, 2020; Nurunnabi et al., 2022).

Furthermore, CSR has recently become a key factor in business strategies (Meng et al., 2024). Nowadays, companies face increasing pressures related to social, environmental, and legal aspects, requiring them to focus on their social responsibilities alongside maximizing their profits (Wang et al., 2025). Many large companies adopt several initiatives and goals within the framework of social responsibility, such as the Global Reporting Initiative (GRI) and the United Nations Sustainable Development Goals (SDGs) (Qasim et al., 2024). However, effective strategic management and engagement in social activities should also be perceived as a critical component of SMEs' success, especially those operating in emerging economies (Nguyen et al., 2023). Globally, SMEs are considered the backbone of the economy in many developed and developing countries, such as the USA, the UK, Germany, and Asian countries, accounting for around 90% of all companies and providing up to 70% of available jobs (Garrido-Ruso et al., 2024). That is to say, SMEs contribute significantly to economic growth, competitiveness, GDP, and job creation (Mahboub & Zaidi, 2024). Considering the value of effective strategic management in the success of SMEs in emerging economies as well as the increased interest in sustainable development, it has become imperative for companies to go beyond profitability goals and integrate social responsibility initiatives into their strategies to enhance their sustainable performance (Choi et al., 2018; Dzomonda, 2022; Nguyen et al., 2023). Against this background, we seek to examine the association between SMEs' business strategies and financial performance and how CSR might affect such a relationship.

We focus on the SMEs' sector because they have a set of unique characteristics that motivated us to conduct this study. Although SMEs represent the largest part of the private sector and play a pivotal role in improving the national product and creating job opportunities, there are some challenges and difficulties that hinder their adoption of sustainable development practices such as CSR (Lam et al., 2025). This limitation restricts their ability to develop sustainable policies and practices that improve their financial performance (Boakye et al., 2020). This is due to several reasons, including the lack of resources and incentives for companies to implement effective environmental and social initiatives (Garrido-Russo et al., 2024; Choi et al., 2018). In addition, these companies face limited pressure from stakeholders and society (Lam et al., 2025). They also face significant difficulties in preparing appropriate environmental and social reports due to the lack of knowledge, experience, and necessary skills among these companies compared to large companies, which pushes them to participate in "voluntary social and environmental initiatives" (Lam et al., 2025). Hence, decisions regarding SMEs' social and environmental policies are likely to be largely influenced by the beliefs and personal characteristics of their owners and managers (Choi et al., 2018), which may diminish active engagements in such policies.

In Saudi Arabia, the SMEs sector plays a pivotal role in achieving the goals of their Vision 2030, which seeks to create more job opportunities and achieve comprehensive economic development. Monshaat—the General Authority for Small and Medium Enterprises in KSA — revealed a 3.1% increase in SMEs in the country by

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the end of 2023, reaching a total of 1.3 million establishments, most of which are concentrated in Riyadh (43.7%) and Makkah (18.1%). Regarding the economic effect of SMEs in KSA, the Saudi Arabian Monetary Authority (SAMA) has recently reported that the total facilities provided to financing companies reached SAR 307.4 billion by the end of the second quarter of 2024, a 17% increase compared to the same period in 2023. Further, the financial resources provided by the banking sector to these entities amounted to SAR 289.8 billion (Driss & Jaballah, 2025).

The current study is based on the stakeholder theory and a natural resource perspective (NRBV), which links the company's ability to use its resources effectively and adopt sustainable social and environmental practices to explain the study findings (Boakye et al., 2020). By analyzing the data collected through the survey instrument, the findings of this study indicate that CSR, as a tool for enhancing reputation and building trust with stakeholders, positively impacts SMEs' financial performance. Further, we found that the interaction between prospector strategy and CSR has a significant positive effect on financial performance. However, the interaction between defender strategy and CSR has a significant negative effect on financial performance.

The study contributes to literature in some respects. It examines the social responsibility-financial performance relationship in SMEs. This examination is vital because most of the literature focuses on large companies (e.g., Alodat & Hao, 2025; Dwibedi et al., 2025; Agnese et al., 2025). SMEs are worthy of special examination because they have recently shown a growing interest in implementing social, environmental, and governance (ESG) practices, which call for examining the impact of such societal activities on corporate performance (Vu et al., 2021; Dasanayaka et al., 2022). Additionally, the current study presents an integrated framework that demonstrates the effect of integrating competitive strategies with CSR on financial sustainability. Finally, this study contributes to knowledge by exploring a Saudi economic environment undergoing rapid transformations under Vision 2030, as an example of emerging markets. By doing so, this study provides practical guidance for entrepreneurs and decision-makers on the importance of integrating social and environmental practices and policies into business strategies, alongside economic objectives, to enhance the competitiveness of SMEs, particularly in emerging economies.

The remainder of the study is structured as follows. Section 2 provides literature review and develops the study hypotheses. Sections 3 and 4 summarize the study methodology and sample. Section 5 shows findings and discussions. Finally, section 6 concludes the study.

2. Literature review and hypothesis development

From the stakeholder theory perspective, firms are required to align their activities and practices in line with various stakeholders, including the surrounding community, the environment and the regulatory authority (Dunham et al., 2006; Zheng et al., 2014; Zhang & Liu, 2023). CSR is one of such mechanisms that can enhance companies' social and environmental performance. Therefore, firms' engagements in CSR activities are anticipated to send important and positive signals to various stakeholders about corporate performance and behavior (Zerbini, 2017; Zhang & Liu, 2023). Such signals may eventually be translated into better firm performance (Rini et al., 2017). Supporting this view, many studies noted that better CSR performance is likely to be associated with enhanced financial transparency, improved market reputation and lower levels of corporate risk (Nejati et al., 2017; Driss & Jaballah, 2025; Saleh et al., 2025).

In this context, it is beneficial to incorporate stakeholder requirements while setting and applying corporate strategies as well as companies' social activities, such as CSR, to attain the anticipated benefits of applying them (Dzomonda, 2022). In other words, it is crucial to combine CSR with business strategies to enhance firm competitiveness in line with stakeholder expectations (Marín et al., 2012). In other words, CSR should be perceived more as a strategic technique—not only as a philanthropic activity — to advance corporate performance and sustainability (Maccarrone & Contri, 2021). In this way, adopting CSR can help transform the existing social challenges into strategic opportunities, where stakeholder groups are anticipated to play a vital role in this regard.

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2.1 The effect of business strategy on firm performance

Adopting the appropriate business strategy can be regarded as a means of enhancing corporate performance. This is because business strategies can play a part in how firms compete in the market and achieve their long-term business objective, which may influence their future performance (Park et al., 2019). Therefore, comprehending the business strategy-firm performance link can assist companies in aligning their strategic decisions with financial aims. Generally, previous research supports a positive association between well-designed firm strategies and corporate financial performance (Handoyo et al., 2023; Ghaemi-Zadeh & Eghbali-Zarch, 2024). Yet, some studies indicate that such a relationship is likely to be context-dependent—that is, economic and societal conditions may significantly affect the corporate strategy–financial performance link.

For instance, by focusing on Omani's nonfinancial companies, Dalwai & Salehi (2021) revealed a negative association between the analyzer-type of business strategy and financial performance, as represented by return on equity (ROE). However, they reported a positive link between defender strategy and financial performance. Focusing on Indonesian firms, Ricardianto et al. (2023) reported a direct influence of business strategy on financial performance. In the same context, Handoyo et al. (2023) found that business strategy is positively related to manufacturing performance. In particular, proactive business strategy firms were found to perform better than defenders and reactors, i.e., defensive strategy firms. Focusing on Tehran, Ghaemi-Zadeh and Eghbali-Zarch (2024) supported the positive impact of analyzed business strategy for the concerned beneficiaries, i.e., investors, loan-holders, and stockholders.

Considering the anticipated various impacts of the different kinds of business strategies (i.e., prospector and defender strategies), we believe that the influence of the business strategy on financial performance can vary depending on the type of strategy. While the prospector strategy directs firms towards seeking new market opportunities and product innovation, the defender strategy encourages stable and well-defined markets by ensuring cost control and operational efficiency. Considering the above discussion, we set the first hypothesis as follows:

H1: Business strategy has a significant effect on corporate performance.

H1.1: Prospector strategy has a positive effect on corporate performance.

H1.2: Defender strategy has a negative effect on corporate performance.

2.2 The effect of CSR on financial performance

How CSR influences financial performance has recently gained increasing importance within the business environment and literature (Coelho et al., 2023). CSR can contribute to improved financial performance by reducing risk, increasing profitability, and lowering production costs (Maome & Zondo, 2024). This is because active engagement with CSR activities is noted to yield better satisfaction of various company stakeholders, including customers and employees (Chung et al., 2015). Such an improved satisfaction can result in more sales revenues and higher employee productivity, i.e., an improved financial performance (Nyame-Asiamah & Ghulam, 2020).

However, the existing research on the CSR-financial performance link has reported mixed results. Many studies supported a positive impact of CSR on firm performance (e.g., Rini et al., 2017; Driss & Jaballah, 2025; Tasnia et al., 2025; Saleh et al., 2025; Alodat & Hao, 2025). However, a few studies reported a negative association between CSR and financial performance (e.g., Truong, 2025). Yet, some studies didn't support an association between CSR and firm performance (e.g., Adamkaite et al., 2022; Garrido-Ruso et al., 2024; Brunella et al., 2024). For instance, Crisotomo et al. (2011) didn't find a link between social responsibility and Brazilian firms' financial performance. However, they reported that social responsibility negatively affects firm value. Using UK data, Boakye et al. (2020) reported a nonlinear association between environmental activities and corporate performance.

The above-mentioned mixed evidence indicates the need for further evidence on the CSR-firm performance relationship on the premise that such a relationship is likely to be a context-based relationship influenced by context-specific factors such as the size of the organization and the type of its activities (Dwibedi et al., 2025; Agnese et al., 2025).

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Therefore, this study proposed the following hypothesis:
H2: CSR has a positive effect on corporate performance.

2.3 The effect of CSR on the relation between business strategy and financial performance

A wide range of studies points to the importance of integrating CSR activities into corporate strategies, given their role in enhancing financial performance (Martinez-Conesa et al., 2017; DiSegni et al., 2015; Garrido-Ruso et al., 2024). The existing research suggests that prospector companies (i.e., innovation-oriented companies) might better benefit from engaging in CSR practices linked to differentiation and stakeholder co-creation. Yet, defender firms, which compete on efficiency and stabilized markets, can better benefit from CSR practices that minimize operational risk, reduce costs, and improve stakeholders' relationships (see Ho et al., 2022). However, a few existing studies apparently examine the firm strategy-CSR interaction and reveal the varying impact of each type on financial performance. Considering this discussion, we set the last hypothesis as follows:
H3: CSR moderates the relationship between business strategy and firm performance.
H3.1: CSR moderates the relationship between prospector strategy and firm performance.
H3.2: CSR moderates the relationship between defender strategy and firm performance.

3. Sample and data collection

Although several definitions of SMEs exist, the official classification used in KSA has been adopted in this study. According to this classification, medium-sized enterprises are defined as those firms with revenues ranging between 40 and 200 million Saudi riyals, or with 50 to 249 employees. Small enterprises are defined as those firms with annual revenues ranging between 3 and 40 million riyals, or with 6 to 49 employees. Micro-enterprises are classified as those firms with annual revenues less than 3 million riyals and fewer than 5 employees. Investigating the relationship between business strategy, CSR, and SMEs' performance mostly depends on surveys and case studies. Consequently, we depend on the survey method due to the lack of accurate secondary data regarding CSR, business strategy and financial performance (Xiliang et al., 2023; Mehboob and Zaidi, 2024; Lam et al., 2025). We depend on questionnaires designed to measure our variables as mentioned in section 4. The questionnaire was arbitrated by 3 academic professors with experience in the study topic to enhance the study validity and reliability. Questionaries have been distributed to participants in October 2025, where consent was obtained from them in writing. Participants are requested to scan QR code to complete the survey through an online platform. 250 questionnaires are delivered using a stratified random sampling method. We received 195 complete questionnaires, and the final dataset included responses from 184 Saudi SMEs with a response rate of 73.6%.

4. Variables' measurement and models

Business strategies are usually measured depending on three strategic types—prospector, analyst, and defender, as proposed by Miles and Snow (1978). This study depends on two common strategies: prospector and defender. Prospector is measured using 10 statements in our survey (Q6-Q15). Defender is measured using 9 statements (Q16-24) (see Appendix A). On a five-point Likert scale, from "1" Strongly disagree to "4" Strongly agree, each respondent was asked to identify whether they agreed or disagreed with each statement about their organization. All statements were formulated depending on literature (e.g., Jusoh & Parnell, 2008; Anwar & Shah, 2021). The questions did not use the labels of prospector or defender strategies, so as not to suggest that they inherently reflect good or poor strategies. CSR performance is measured in line with previous research (e.g., Bahta et al., 2021; Ma et al., 2023). The CSR model used in this study comprised twenty-six items that are classified into four groups, as follows: society, environment, customers, and employee. The extent to which firms are involved in CSR is measured depending on a 5-point scale, ranging from strongly agree that equals 5 to strongly disagree that equals 1.

For measuring financial performance, we depend on five performance-related items derived from previous research (e.g., Xiliang et al., 2023; Bahta et al., 2021). SMEs' performance was scored on a Likert scale ranging from 1 to 5, with 1 representing highly unsuccessful performance and 5 representing exceptionally successful performance. There is a lack of objective data regarding SMEs' financial performance as these firms' owners

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and managers are unwilling to provide it. Therefore, scales are perceived as a preferable alternative to real figures for measuring the performance of SMEs (Wall et al., 2004).

Finally, as control variables, we depend on firm size, age, CEO attributes (gender, tenure, and expertise), and industry type, which are more likely to affect financial performance (Wagner, 2010; Xiliang et al., 2023). Firm size is measured as the natural logarithm of the number of workers (Bahta et al., 2021). Firm age is measured as the natural logarithm of one plus the years since its foundation (Hamdy et al., 2024; Diab et al., 2025). CEO gender is a dummy variable that equals one if the CEO is female and zero otherwise (Eissa et al., 2024). CEO tenure, age, and expertise are measured depending on a Likert scale as noted in Appendix. Finally, industry type is classified as either industrial, commercial, or service industries.

Accordingly, our dependent variable is financial performance (*FP*), and the independent variables are business strategy (*STG*), measured depending on Miles and Snow's (1978) typology, and CSR. Consequently, we test our hypotheses depending on the following proposed model:

$$Performance_{it} = \alpha + \beta 1\ \text{STG (prospector \& defender)}_{it} + \beta 2\ CSR_{it} + \beta 3\ \text{Firm Size}_{it} + \beta 4\ \text{Firm Age}_{it} + \beta 5\ \text{CEO Gender}_{it} + \beta 6\ \text{CEO Tenure}_{it} + \beta 7\ \text{CEO Age}_{it} + \beta 8\ \text{CEO Expertise}_{it} + \beta 9\ \text{Industry Effect}_{it} + \varepsilon_{it}\ \text{Model 1}$$

$$Performance_{it} = \alpha + \beta 1\ \text{STG (prospector \& defender)}_{it} + \beta 2\ CSR_{it} + \beta 3\ CSR_{it} * STG_{it} + \beta 4\ \text{Firm Size}_{it} + \beta 5\ \text{Firm Age}_{it} + \beta 6\ \text{CEO Gender}_{it} + \beta 7\ \text{CEO Tenure}_{it} + \beta 8\ \text{CEO Age}_{it} + \beta 9\ \text{CEO Expertise}_{it} + \beta 10\ \text{Industry Effect}_{it} + \varepsilon_{it}\ Model\ 2$$

5. Empirical results

5.1 Descriptive analysis

Table 1 shows descriptive statistics. The study sample is distributed across different SMEs' sectors as follows, the industrial sector (15.22%), the commercial sector (45.11%) and the service sector (39.67%). The mean value of Performance is 3.96 with standard deviation 0.86, and it ranges from 2 to 5. This finding reflects the high level of SME's performance in our sample. This outcome is consistent with the notion that these firms operate in one of the largest emerging economies in Asia and one of the richest countries in the Arabian Gulf region that gives significant support for SMEs according to their vision 2030. The mean values of *Prospector* and *Defender* are 3.29, and 3.65 with standard deviations (SD) of 0.53, and 0.64 and ranges from 1.80 to 5 and from 2 to 5, respectively. These results suggest that SMEs have a comparatively stronger orientation towards defender strategy compared to prospector strategy. The mean value of *CSR* is 4.41 (with SD=0.53), and it ranges from 3 to 5. These results show that SMEs are increasingly interested in CSR and increasingly involved in social activities. They ensure that SMEs receive the necessary support from the state. Thus, SMEs are committed to performing their activities within a framework of social and ethical responsibility.

Table 1. Descriptive statistics

Continuous variables (n=184)	Mean	Median	SD	Minimum	Maximum
Performance	3.96	4.00	0.86	2.00	5.00
Prospector	3.29	3.40	0.53	1.80	5.00
Defender	3.65	3.78	0.64	2.00	5.00
CSR	4.41	4.50	0.53	3.00	5.00
Firm Size	3.58	3.53	1.46	1.79	5.95
Firm Age	2.59	2.64	0.74	0.69	4.43
Dichotomous variables (n=184)	Frequency			%	
CEO Gender	38			20.70%	
CEO Tenure					
≤ 3 years	44			23.91%	
> 3 years up to 6 years	61			33.15%	
> 6 years up to 10 years	31			16.85%	
> 10 years	48			26.09%	

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Total	184	100%
CEO Age		
≤ 30 years	25	13.59%
> 30 up to 40 years	39	21.20%
> 40 up to 50 years	94	51.09%
> 50 up to 60 years	11	5.98%
> 60 years	15	8.15%
Total	184	100.0
CEO Expertise		
≤ 3 years	38	20.65%
> 3 up to 6 years	39	21.20%
> 6 up to 10 years	36	19.57%
> 10 years	71	38.59%
Total	184	100.0
Industrial sector	28	15.22%
commercial Sector	83	45.11%
Service Sector	73	39.67%
Total	184	100.0

Table 2 shows Cronbach's alpha test. The alpha scores are 0.929, 0.838, 0.886, and 0.949 for *Performance, Prospector, Defender, and CSR*, respectively. This result reflects high degrees of internal consistency, ensuring the reliability of the research instrument. The overall alpha coefficient is 0.939, which confirms the high reliability of the research instrument.

Table 2. Alpha Cronbach test

	Cronbach's alpha
Performance	0.929
Prospector	0.838
Defender	0.886
CSR	0.949
Overall alpha score for all questions	0.939

In addition, we conducted a factor analysis (FA) for the variables used in the study. Table 3 indicates that all four variables (Financial Performance, Prospector, Defender, and CSR) have high values in the first factor, with a loading value reaching 0.70, indicating a strong relationship between these variables and the common latent factor. The high values indicate that the variables contribute equally to representing the latent dimension measured by the first factor, reflecting a good internal consistency among the different items. This consistency implies that each variable plays an important role in forming the conceptual structure of the scale without losing essential information. Put differently, values > 0.40 are a strong indicator of the validity of the research variables in representing the latent dimension, i.e., these variables are well interrelated and can be confidently used in subsequent statistical analyses. This level of loadings reflects the quality of the research instrument's design and that the selected items are appropriate for measuring the targeted concept.

Table 3. Factor Analysis

Factor Analysis for variables	Component (1)
Performance (Q1-Q5)	0.40 >
Prospector (Q6-Q15)	0.40 >
Defender (Q16-Q24)	0.40 >
CSR (Q25-Q50)	0.40 >

Table 4 below presents the correlation between business strategies, *CSR*, and *performance*. The results show a significant positive relationship between *Prospector and Defender* and *Performance* at the 1% level, consistent with H1. This finding indicates that Saudi SMEs, which are more oriented towards prospector or defender strategies, are correlated with higher financial performance. SMEs in KSA are benefiting from exploratory and innovative initiatives, reducing operating costs, and maintaining operational stability. This improvement confirms the importance of adopting one of business strategies (prospector or defender) as an effective tool for enhancing firm performance and achieving sustainable growth in financial results (Lee et al., 2010; Bryan et al., 2013).

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In addition, the results reveal a positive relationship between *CSR* and *Performance* at the 1% level, consistent with H2. This result highlights the importance of CSR for SMEs in KSA and stresses its role in enhancing financial performance of these firms. CSR activities can enhance SMEs' mental image among customers and achieve their satisfaction and loyalty, which enhances their financial performance in the long-term (Ansong, 2017; Bahta et al., 2021; Eissa et al., 2024). Consequently, CSR is perceived as an effective tool that enhances SMEs' financial performance and achieves SMEs' sustainable growth.

Table 4. Correlation matrix

	FP	Prospector	Defender	CSR	Firm Size	Firm Age	CEO Gender	CEO Tenure	CEO Age	CEO Expertise
Performance	1	0.555***	0.452***	0.476***	0.029	-0.103	-0.027	0.427***	0.096	0.253***
Prospector	0.575***	1	0.236***	0.589***	-0.026	-0.074	-0.133*	0.237***	0.192***	0.124*
Defender	0.392***	0.247***	1	0.140*	0.035	-0.128*	0.027	0.161**	0.167**	0.189**
CSR	0.526***	0.587***	0.192***	1	-0.320***	-0.038	-0.074	0.299***	0.007	0.271***
Firm Size	-0.014	-0.062	-0.031	-0.320***	1	0.376***	0.167**	-0.090	0.399***	0.012
Firm Age	0.008	-0.061	-0.105	-0.053	0.426***	1	0.098	0.125*	0.393***	0.083
CEO Gender	-0.048	-0.143*	0.038	-0.089	0.171**	0.094	1	0.034	0.091	0.001
CEO Tenure	0.418***	0.229***	0.134	0.259***	-0.084	0.162**	0.029	1	0.175**	0.232***
CEO Age	0.142*	0.194***	0.158**	-0.012	0.423***	0.397***	0.110	0.195***	1	-0.012
CEO Expertise	0.285***	0.143*	0.197***	0.238***	0.007	0.141*	0.002	0.240***	0.010	1
Where: *,**,*** are significant at 10%, 5%, 1% levels, respectively.										

5.2 Testing hypotheses

To test our hypotheses, we run linear regressions for model 1, regressing Performance on Business Strategy and CSR. Table 5 (model 1) indicates that the Prospector and Defender strategies have a positive effect on Performance (coefficients = 0.464, 0.399 $p< 0.01$, respectively). This finding indicates that orientation of SMEs towards a prospector or a defender strategy contributes to improving the SMEs' financial performance, as SMEs' adoption of the methodology of innovation and exploration of new opportunities (Prospector), or the methodology of maintaining stability, reducing costs and enhancing the use of resources while maintaining a certain level of quality (Defender), significantly enhances financial performance, supporting our first hypothesis. This result is consistent with previous research such as Lee et al. (2010), Bryan et al. (2013), and Teeratansirikool et al. (2013).

In addition, consistent with our first hypothesis, the results reveal a positive effect of CSR on Performance (coefficient= 0.346, $p< 0.01$), which means that SMEs' integration of CSR in their activities, in line with the KSA Vision 2030, significantly improves their performance. This outcome is consistent with the noting a positive effect of CSR on the financial performance in SMEs in Ghana (Ansong, 2017) and Eritrea (Bahta et al., 2021). Hence, CSR should not be perceived as just a moral responsibility, but it is a strategic tool that enhances SMEs' performance by improving reputation and increasing stakeholder satisfaction and loyalty, which ultimately improves financial performance. These results are consistent with H2.

Model 2 in Table 5 shows the interaction effect of CSR with business strategies as follows. *Prospector*CSR* has a positive effect on Performance (coefficients = 0.430, $p < 0.05$). This result notes that integrating CSR activities into SMEs that are oriented towards a prospector strategy enhances their performance. This finding is consistent with Ho et al. (2022), who reported that the interaction between prospector strategy and CSR

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activities positively affects firms' financial performance. However, the results show that *Defender*CSR* has a negative effect on *Performance* (coefficients = -0.253, $p < 0.05$). This result indicates that integrating CSR activities into SMEs oriented towards a defender strategy mitigates the positive effect of defender on SME's performance. This outcome implies that integrating CSR with defender strategy reduces SMEs' financial performance. This result is consistent with Ho et al. (2022), who showed that the interaction between defender strategy and CSR activities may not be reflected positively on a firm's financial performance. It also echoes Choi et al. (2010) who noted that achieving a positive impact on financial performance depends on effective management of CSR. Further, Porter and Kramer (2007) noticed that there are many CSR issues facing firms, but only a few of them represent real opportunities to make a fundamental change in society and achieve competitive advantages for these firms. Consequently, defender SMEs should reconsider how to integrate CSR with strategy to achieve a positive effect and avoid the negative ones of CSR on financial performance. This issue requires careful planning to avoid increasing costs without a clear financial return. This interaction poses a strategic challenge for SMEs seeking to achieve financial stability while adhering to CSR.

Table 5. Linear regression results (regressing financial performance on business strategy and CSR)

Variables	Model (1)		Model (2)	
	Dependent "Performance"		Dependent "Performance"	
	B	t	B	t
Constant	-1.473***	-2.770	-1.098*	-1.960
Prospector	0.464***	4.136	0.404***	3.670
Defender	0.399***	5.397	0.489***	6.346
CSR	0.346***	2.858	0.285**	2.360
Prospector*CSR			0.430**	2.471
Defender*CSR			-0.253**	-2.311
Firm Size	0.115***	2.948	0.127***	3.347
Firm Age	-0.151**	-2.079	-0.184**	-2.533
CEO Gender	-0.027	-0.240	-0.070	-0.636
CEO Tenure	0.227***	5.018	0.217***	4.832
CEO Age	-0.077	-1.539	-0.084*	-1.729
CEO Expertise	0.014	0.343	-0.006	-0.144
Industries	Included		Included	
F. Test	19.071***		18.133***	
Adjusted R^2	51.10%		54.9%	
Observations	184		184	
VIF	Less than 4		Less than 4	
Where: *,**,*** are significant at 10%, 5%, 1% levels, respectively.				

Besides, we re-estimated models 1 and 2 depending on the industry's adjusted score of financial performance. The results are presented in Table 6, and they are consistent with the previous analysis shown in Table 5.

Table 6. Linear regression results (regressing financial performance on business strategy and CSR)

Variables	Model (1)		Model (2)	
	Dependent "Industry adjusted Performance"		Dependent "Industry adjusted Performance"	
	B	t	B	t
Constant	-5.518***	-10.681	-5.209***	-9.523
Prospector	0.456***	4.066	0.409***	3.710
Defender	0.394***	5.294	0.478***	6.170
CSR	0.370***	3.123	0.311***	2.627
Prospector*CSR			0.373**	2.132
Defender*CSR			-0.257**	-2.329
Firm Size	0.119***	3.123	0.129***	3.453
Firm Age	-0.122*	-1.710	-0.141*	-1.963
CEO Gender	-0.006	-0.054	-0.043	-0.389
CEO Tenure	0.218***	5.019	0.199***	4.549

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CEO Age	-0.077	-1.586	-0.079*	-1.653
CEO Expertise	0.022	0.546	0.009	0.217
Industries	No		No	
F. Test	22.09***		20.078***	
Adjusted R^2	50.9%		53.4%	
Observations	184		184	
VIF	Less than 4		Less than 4	
Where: *,**,*** are significant at 10%, 5%, 1% levels, respectively.				

5.3 Additional analyses

We re-run models 1 and 2 after considering the scores of CSR dimensions (i.e., society, environment, customer, employees). Model 1 (column 1) in Table 7 shows that *Society* has a positive effect on *Performance* (coefficient = 0.173, $p < 0.05$). Column 2 reveals that the interaction variable *Prospector*Society* has an insignificant negative effect on *Performance* (coefficients= -0.197, $p > 0.10$). These results suggest that integrating CSR oriented towards society with the prospector strategy is not sufficient to generate a tangible financial effect for SMEs. This may reflect poor management of CSR towards society in prospector firms (Porter and Kramer, 2007; Choi et al., 2010). However, the interaction variable of *Defender*Society* has a significant negative effect on *Performance* (coefficient = -0.259, $p < 0.05$). This result indicates that integrating CSR towards society with the defender strategy negatively affects financial outcomes. This context implies that the costs of implementing CSR in SMEs classified as defender firms outweigh the anticipated financial gains. Consequently, this interaction can be considered a strategic challenge that must be carefully addressed to achieve a balance between financial performance and social sustainability in defender firms.

Column 3 in Table 7 shows that CSR oriented towards the environment (*Environment*) has an insignificant effect on *Performance* (coefficient = 0.029, $p > 0.10$). Column 4 reveals that the interaction variable *Prospector*Environment* has a significant positive effect on *Performance* (coefficient= 0.413, $p < 0.01$). This result explains that SMEs that integrate CSR activities towards the environment with the prospector strategy have better financial performance (Porter and Kramer, 2007; Choi et al., 2010). However, the interaction variable *Defender*Environment* has a significant negative effect on *Performance* (coefficient = -0.204, $p < 0.05$). This result denotes that integrating CSR activities oriented towards the environment with the defender strategy leads to a significant decline in SME's financial performance. Hence, the costs of implementing environmental initiatives in defender SMEs outweigh the financial gains.

Column 5 shows that CSR initiatives focusing on customers (*Customer*) positively affect *Performance* (coefficient= 0.433, $p< 0.01$). Column 6 indicates that the interaction effect of *Prospector*Customer* has a significant positive effect on *Performance* (coefficient= 0.156, $p< 0.01$). Accordingly, prospector firms that introduce CSR initiatives oriented towards customers achieve better financial results. In addition, the results reveal that *Defender*Customer* has a significant positive effect on *Performance* (coefficient= 0.162, $p< 0.05$). This indicates that defender firms that introduce CSR initiatives oriented towards customers benefit from this initiative and achieve better financial performance (Porter & Kramer, 2007; Choi et al., 2010).

Column 7 shows that CSR initiatives oriented towards employees (*Employees*) have a positive effect on *Performance* (coefficient = 0.430, $p< 0.01$). Column 8 clarifies that *Prospector* Employees* has a significant positive effect on *Performance* (coefficient= 0.197, $p< 0.01$). Accordingly, prospector firms that introduce CSR initiatives oriented towards employees benefit from the employee initiative, achieving better financial results. However, the results reveal that *Defender*Employees* has a significant negative effect on *Performance* (coefficient= -0.170, $p< 0.05$). This result indicates that defender firms with CSR initiatives oriented towards employees are not benefiting from this initiative. Thus, defender SMEs incur additional costs when implementing employee initiatives without immediate financial returns.

Overall, we observe that most CSR efforts in defender SMEs are counterproductive for two main reasons. They pit SMEs against society, when the two are interdependent. SMEs with a defender strategy think of CSR in generic ways, instead of managing and crafting CSR initiatives appropriate to their individual strategies. CSR

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should be perceived as more than just a cost, constraint, or charitable deed (Porter and Kramer, 2007). In contrast, prospector SMEs approached CSR strategically, crafting CSR initiatives appropriate to their individual strategies. This context generates opportunities, innovation, and competitive advantage for prospector firms, while solving pressing social problems.

Table 7. Regressing financial performance on business strategy and CSR-Additional analysis

Variables	Model (1)		Model (2)		Model (1)		Model (2)		Model (1)		Model (2)		Model (1)		Model (2)	
	Dependent "Performance"		Dependent "Performance"		Dependent "Performance"		Dependent "Performance"		Dependent "Performance"		Dependent "Performance"		Dependent "Performance"		Dependent "Performance"	
	Column (1)		Column (2)		Column (3)		Column (4)		Column (5)		Column (6)		Column (7)		Column (8)	
	B	t	B	t	B	t	B	t	B	t	B	t	B	t	B	t
Constant	-0.986**	-1.974	-0.351	-0.658	-0.735	-1.472	-0.246	-0.480	0.252	0.641	0.678	1.378	0.160	0.396	0.482	0.960
Prospector	0.595***	6.201	0.582***	6.046	0.631***	5.815	0.567***	5.288	0.272***	3.244	0.308***	3.719	0.228**	2.511	0.321***	3.429
Defender	0.371***	4.888	0.257***	2.955	0.399***	5.268	0.466***	6.108	0.100	1.477	0.039	0.571	0.138**	2.000	0.008	0.097
Society	0.173**	2.080	0.162**	1.982												
Prospector*Society			-0.197	-1.515												
Defender *Society			-0.259**	-2.561												
Environment					0.029	0.336	-0.005	-0.058								
Prospector*Environment							0.413***	2.990								
Defender * Environment							-0.204**	-2.045								
Customer									0.433***	9.876	0.346***	4.801				
Prospector*Customer											0.156***	2.657				
Defender * Customer											0.162**	2.351				
Employees													0.430***	8.919	0.388***	5.881
Prospector* Employees															0.197***	3.021
Defender * Employees															-0.170**	-2.451
Firm Size	0.094**	2.489	0.103***	2.754	0.071*	1.915	0.078**	2.179	0.080***	2.760	0.072**	2.555	0.120***	3.931	0.089***	2.745
Firm Age	-0.185**	-2.362	-0.239***	-3.025	-0.132*	-1.742	-0.174**	-2.305	-0.197***	-3.320	-0.184***	-3.118	-0.146**	-2.389	-0.139**	-2.238
CEO Gender	-0.034	-0.302	-0.044	-0.398	-0.013	-0.112	-0.058	-0.514	-0.090	-0.975	-0.095	-1.047	-0.061	-0.637	-0.032	-0.346
CEO Tenure	0.234***	5.124	0.243***	5.411	0.235***	5.087	0.231***	5.126	0.219***	5.922	0.205***	5.608	0.209***	5.448	0.206***	5.465
CEO Age	-0.080	-1.563	-0.078	-1.563	-0.072	-1.398	-0.083*	-1.665	0.005	0.112	0.004	0.092	-0.018	-0.415	-0.029	-0.680
CEO Expertise	0.033	0.802	0.031	0.755	0.037	0.887	0.007	0.178	-0.035	-1.034	-0.018	-0.535	-0.008	-0.214	0.005	0.159
Industries	Included		Included		Included		Included		Included		Included		Included		Included	
F. Test	18.331***		16.832***		17.519***		16.807***		36.285***		33.014***		32.823***		30.440***	
Adjusted R^2	51%		52.9%		49.80%		52.9%		68%		69.5%		65.7%		67.7%	
Observations	184		184		184		184		184		184		184		184	
VIF	Less than 4		Less than 4		Less than 4		Less than 4		Less than 4		Less than 4		Less than 4		Less than 4	
Where: *,**,*** are significant at 10%, 5%, 1% levels, respectively.																

6. Conclusion

In this study, we examined the effect of business strategy on firm performance. In addition, we investigated if CSR could moderate such a relationship by bringing evidence from the SMEs sector in KSA. We depended on the survey instrument in data collection and used the stakeholder theory to interpret our findings. Using

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descriptive and multivariate analysis, our results revealed a significant positive effect of business strategies on SMEs' performance. Further, CSR is found to have a significant positive effect on SMEs' performance. Moreover, we found that CSR has a significant positive effect on the relationship between prospector strategy and SMEs' performance. However, CSR has a significant negative effect on the relationship between defender strategy and SMEs' performance. To corroborate our main findings, we conducted an additional analysis to assess the moderating effects of the various CSR dimensions (i.e., society, customers, employees, the environment). The results showed that prospector strategy when combined with the customers, the employees, and the environmental dimensions of CSR yields better financial performance. However, the defender strategy integrated with the society, employees and environmental dimensions of CSR results in lower financial performance. In contrast, the defender strategy integrated with the customer dimension of CSR results in improved financial performance. Overall, the current findings indicate that managers in SMEs should manage and prioritize CSR practices in the light of the adopted type of business strategy in order to attain the best benefit of such practices.

This study contributes to literature in some respects. It explores a Saudi economic environment undergoing rapid transformations under Vision 2030, as an example of emerging markets which are rarely examined in literature. Further, we focused on the SMEs' sector due to its unique value and significant contribution to the economy of emerging markets. While doing so, we presented an integrated framework that shows the influence of combining distinct types of corporate strategies with CSR activities on SMEs' financial performance. Moreover, the findings of this study provided guidance to regulators and policymakers concerning the extent to which the structure of corporate strategies that combine CSR perspectives can have implications for firm competitiveness and sustainability. Such guidance can help them develop effective policies that support SMEs operating in emerging markets and enhance their contribution to economic and societal development.

Finally, this study is not without limitations. Because we focus on Saudi SMEs, the findings of this study shouldn't be generalized to larger firms working in advanced markets such as the USA and the UK. Future research can examine other developing countries to confirm the reliability of the current findings. Moreover, in this research, we depended on the survey instrument to collect the study data. Hence, we suggest that future research can use other research methods, namely qualitative research methods, to help gain insights into the interrelationships among the variables examined in the current study, i.e., firm strategy, CSR, and firm performance.

Appendix. Survey questions

Background information

1. **Firms name** (*Optional*)
2. **Firm's age** (*Years since its foundation*)
3. **Firm's size** (*Number of Employees*).
4. **CEO's Gender** (*Male- Female*).
5. **CEO's tenure** (Number of years he has the current position)? *(≤3 years, more than 3 years and up to 6 years, more than 6 years and up to 10 years, more than 10 years*).
6. **CEO's age** (*≤30 years, more than 30 up to 40 years, more than 40 up to 50 years, more than 50 up to 60, more than 60 years*).
7. **CEO's expertise in the industry** *(≤3 years, more than 3 up to 6 years, more than 6 up to 10 years, more than 10 years*).
8. **Industry** (*Industrial, commercial, Service industry*).
9. ***Financial Performance***

1.	We achieve better returns on service sales than competitors.
2.	We have achieved better profits on investment than competitors int the industry over the past three years.
3.	We achieve better asset growth compared to competitors int the industry.
4.	We have achieved better revenue growth than competitors int the industry over the past three years.
5.	We achieve better net profit growth than competitors int the industry.

10. ***Strategy survey items***

Prospector	
6.	Considering our products and services, we primarily seek to differentiate our products and services from those of our competitors.
7.	If asked about our firm, consider us to be highly innovative.
8.	Most current and prospective customers probably see our products and services as considering our products and services to be among the most unique.
9.	In the future, we primarily plan to focus on high innovation.
10.	One of our goals for the future is to offer products and services that are easily differentiated from those of our competitors.
11.	Our firm concentrates most on innovation.
12.	We create customer value through services supporting the products.
13.	We take advantage of selling products at higher prices than in the market.
14.	We create special products or brand images.

15.	We are adapting products to changing needs of customers.
Defender	
16.	Considering our products and services, we primarily seek to provide our products and services at the lowest possible price.
17.	If asked about our firm, most current and prospective customers would consider us to be an efficient producer of goods and services.
18.	Most current and prospective customers probably see our products and services as among the lowest priced ones available.
19.	In the future, we primarily plan to focus on improving our efficiencies.
20.	One of our goals for the future is to offer products and services that are like those of our competitors, but at a lower cost.
21.	Our firm concentrates most on high efficiency.
22.	We work with lowest costs as a result of gaining efficiency in activities.
23.	We try to gain cost advantage in supply of raw material.
24.	We are gaining economies of scale.

11. CSR performance:

11.1 CSR (Toward society)

25.	We make sufficient financial contributions to charitable organizations.
26.	We maintain transparent relationships with local authorities.
27.	We are part of the local society, and we are concerned about its development and infrastructure improvement.
28.	We contribute to campaigns and projects that promote society welfare.
29.	We encourage employees to participate in volunteer and charitable work.
30.	We are financially supporting activities (arts, culture, sports) in the societies where we operate.

11.2 CSR (Toward environment)

31.	We participate in activities that enhance and improve the environment.
32.	We invest in creating a better life for future generations.
33.	We implement programs to mitigate its negative impact on the environment.
34.	We target sustainable growth to consider the future generations.
35.	We consider regulations, laws and government requirements to protect the environment.
36.	We participate in energy conservation efforts.
37.	We implement programs to reduce water consumption.

11.3 CSR (Toward customers)

38.	We respect consumer rights in compliance with legal requirements.
39.	We provide customers with accurate and complete information about our products.
40.	Customer satisfaction is one of the most important priorities.
41.	We are committed to providing quality that fits the product's price to improve customer satisfaction.
42.	Customer complaints are monitored and analyzed continuously to resolve to achieve customer loyalty.

11.4 CSR (Toward Employees)

43.	Employees' interests are considered when making decisions.
44.	Current organizational policies encourage developing employees' skills and careers.
45.	Employees' needs and desires are considered as one of the most important priorities for a firm's management.
46.	We implement flexible policies to ensure a good work-life balance.
47.	Management decisions related to employees are usually fair.
48.	We always support employees who wish to pursue further education.
49.	We help employees achieve a balance between their professional and personal lives.
50.	We provide procedures that help ensure employees' health and safety.

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INTEGRATING INDUSTRY 4.0 TECHNOLOGIES INTO HUMAN CAPITAL MANAGEMENT: A CONCEPTUAL FRAMEWORK*

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Abstract. Industry 4.0, together with its elements, represents a new challenge for companies in human capital management (HCM). The article aims to provide an overview and comparison of the research published so far regarding the intersection of the Industry 4.0 elements with HCM and to point out their impact. It provides a conceptual basis for other authors and researchers and is a source of ideas for future research. The study applies a narrative literature review and conceptual synthesis approach to identify Industry 4.0 technologies applicable to HCM and to develop a conceptual framework linking these technologies with HCM phases. The findings identify cloud computing, social media, chatbots, virtual and augmented reality, blockchain, Big Data, artificial intelligence, and business intelligence as the most relevant Industry 4.0 technologies applicable to HCM. If these elements are implemented correctly, labour productivity, process efficiency, performance, and competitiveness of the enterprise on the market can be increased. The benefit of the theoretical overview is also the suggestion of areas of managerial implications that could help in the effective integration of Industry 4.0 technologies into human capital management processes.

Keywords: human capital management; education; Industry 4.0; Industry 4.0 elements digitalization

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1. Introduction

The current era is influenced by using digital technologies, which are meant to make people's personal and work lives easier. On the one hand, such technologies bring positives in the form of speeding up and facilitating work and business processes, reducing the risk of accidents at the workplace, or increasing the competitiveness of companies on the market and increasing the quality of services and products provided. On the other hand, it is possible to register risks that consist of higher initial costs for the acquisition of digital technology, the need to employ highly qualified personnel, which will often lead to retraining or layoffs.

Digital technologies can be used in various economic spheres and in various business processes (Lojda et al., 2020). Personnel processes are no exception, i.e., those processes in the company that concern people - employees. It is possible to digitize all activities, from the acquisition and selection of employees, through the remuneration of employees to their release or reassignment to another job (Blstakova et al., 2020).

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In this paper, the term Human Capital Management (HCM) is used instead of Human Resource Management (HRM), because HCM emphasizes employees as strategic assets whose knowledge and competencies create organizational value, while HRM traditionally focuses on administrative and operational personnel processes. A more detailed explanation is provided in Section 2.2. Due to the changes brought about by digital technologies, it will be necessary to pay more attention to people and their human capital (HC), i.e., their knowledge, skills and competences. Businesses should avoid mass layoffs and rather, if possible, invest in the education of their employees.

Despite the growing body of literature on Industry 4.0 and human resource management, limited attention has been paid to the systematic integration of Industry 4.0 technologies across all phases of human capital management. Existing studies usually focus on individual technologies or selected HR processes, while a comprehensive framework linking Industry 4.0 elements with HCM phases remains underdeveloped. Therefore, this paper addresses this research gap by proposing a conceptual model integrating Industry 4.0 technologies into the HCM framework.

The aim of this paper is to develop a conceptual model linking Industry 4.0 technologies with the individual phases of human capital management based on a narrative literature review. The proposed model integrates dispersed knowledge on digital technologies applicable to HCM and provides a structured framework for future empirical research.

The article was inspired by several previous surveys in other countries and business areas that focused on digitalization in various areas, such as small and medium-sized industrial enterprises in Austria (Ranacher et al., 2023), agriculture in Azerbaijan (Valiyev et al., 2022), processes in the food industry in the European Union (Kosior, 2022), waste management in Germany (Borchard et al., 2022), education (Mabungela et al., 2025) small and medium enterprises in Ukraine (Shevtsova et al., 2020), use of HRIS in Europe (Barisic et al., 2019). Likewise, the article is an extension of knowledge from the conclusions obtained in the article Pandya and Wang (2024), Ghosh et al. (2024), Pereira et al., (2021), PB (2019), Ndamase et al. (2026).

We see the further direction of the article in the framework of the investigation of relationships, factors, opportunities and threats of the connection of human capital management with digitalization in economic entities in Slovakia. This would contribute to the expansion of knowledge in the field of human capital management (HCM), human resource management (HRM) and digitalization, and would follow on from studies such as digitalization and development of HC in EU countries, HC during digital transformation in Ukraine (Rodchenko et al., 2021).

2. Theoretical background

2.1 Industry 4.0 and its elements

Industry 4.0 is characterized by the rapid pace of technological progress, the speed of the emergence and spread of digital technologies and innovations, which changes the previously used ways and paradigms of the functioning of people and businesses (Zhang et al., 2023). Although it is a concept that was originally developed mainly for manufacturing companies, its elements are increasingly becoming part of other areas, such as marketing, finance, HR, education.

Industry 4.0 is a concept of the fourth industrial revolution that originated in Germany around 2011 and is based on the systematic digitization and integration of modern digital technologies (especially the Internet of Things, cyber-physical systems and cloud solutions) into production and business processes. Its goal is to increase efficiency, speed and safety of work, optimize production processes, improve the quality of products and services and strengthen the competitiveness of companies by enabling new business models and a higher degree of interconnection of devices and systems (Zakharov et al., 2020; Sima et al., 2020; Pilichowska, 2021; Neumann et al., 2021; Raddi-Mira et al., 2024; Hawaou et al., 2024).

Industry 4.0, i.e., the fourth industrial revolution, represents one of the relatively new concepts that was introduced in Germany in 2011 and whose goal is to connect all devices in the company via the Internet of

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Things and thus create smart devices out of them. Its typical feature is also the use of information systems and information and communication technologies (ICT) in industrial areas. The challenge in this area is the use of this concept in other than production areas of the company.

The fourth industrial revolution is based on various pillars, such as digitalization, internet of things, additive manufacturing, Big Data analysis, autonomous robots, simulations, horizontal and vertical system integrations, additive manufacturing (3D printing), cloud systems, augmented reality, cyber data protection, sensors, artificial intelligence, or Business Intelligence (Dragičevic & Bošnjak, 2019; Kurt, 2019; Machado et al., 2020; Oztemel & Gursev, 2020; Jamwal et al., 2021).

Digitalization (Figure 1) is one of the tools of Industry 4.0, which is very important for companies operating in different areas and different spheres of the national economy. It is about the possibility of optimizing various business parameters, such as performance, efficiency, or competitiveness (Slusarczyk, 2018; Lachvajderová et al., 2021). Managers must respond effectively and quickly to changes related to the arrival of digital technologies, because this is the only way to ensure the competitiveness of businesses. One form of digitalization is the digitization of analog data through a Human Resources Information System (HRIS). This system ensures the collection, analysis, and storage of information about employees throughout their entire life cycle in the organization (Tursunbayeva, 2019). Research confirms that HRIS positively affects the efficiency of HCM processes and supports the fulfillment of corporate strategy (Akoyo & Muathe, 2017; De Silva & Da Silva Lima, 2017; Barisic et al., 2019). Its main benefits include more efficient planning and decision-making, reducing administrative burden, employee development, and strengthening the strategic importance of HCM. Although HRIS is mainly used in large enterprises, solutions for small and medium-sized enterprises are also available (Baswardono et al., 2019).

Another form is the digitization of biometric data, which uses human characteristics such as face, voice, eyes or fingerprints for identification and access control purposes (Royakkers et al., 2018). Biometric technologies also enable the analysis of emotions through non-verbal communication. However, their use raises questions about the protection of privacy and personal data.

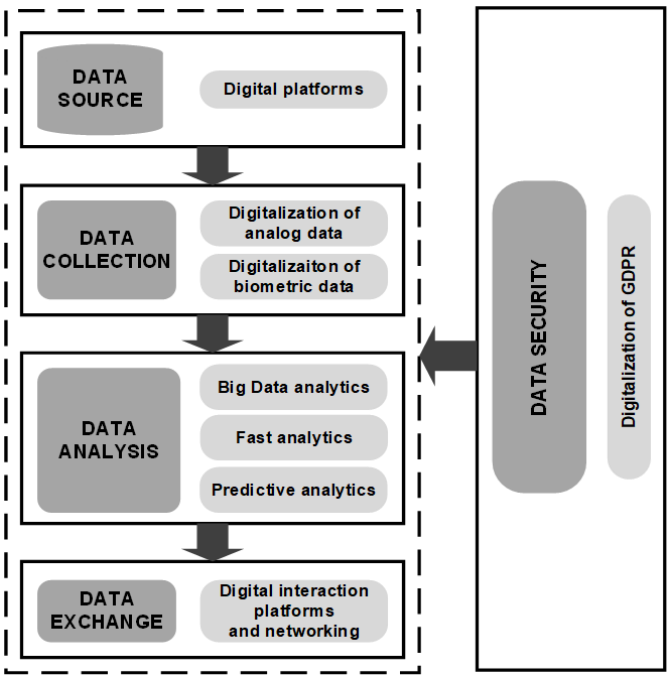


Figure 1. Forms of digitalization towards company employees
Source: own processing

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A significant area of digitization is Big Data, which enables the processing of large volumes of diverse data characterized by the volume, speed of creation and diversity of data (Kubina et al., 2015). In the field of HCM, it is used, for example, in the analysis of employee motivation or in smart factories (Polat & Erkollar, 2021; Koman et al., 2018). It is important not only to collect data, but also to evaluate it effectively. Also related to Big Data is rapid analytics, which allows for the analysis of smaller data sets in real time and supports operational decision-making, for example when providing feedback to employees or job applicants (Eva et al., 2019). Predictive analytics uses Business Intelligence technologies to identify relationships between data and predict future events, thereby supporting the optimization of business processes.

Digitalization is also reflected in the use of digital interaction platforms and network solutions, such as intranets, which enable effective communication and information sharing within an organization. These tools increase work productivity, speed up communication, and improve data availability. An integral part of digitalization is data security. In the European Union, the processing of personal data must be in accordance with the GDPR, which regulates the protection of personal data and the free movement of data (Jakobi et al., 2020; Trocin et al., 2021). The GDPR was adopted by the European Parliament in 2016 (Eur-lex, 2023). The importance of data protection increased especially during the COVID-19 pandemic, when companies digitized processes related to the recording of employee health data (Beňová, 2021).

2.2 Human capital, human capital management and its connection with Industry 4.0

Human capital management differs from traditional human resource management by emphasizing the strategic value of employees and the contribution of human capital to organizational performance and value creation. While HRM focuses primarily on administrative and operational personnel processes, HCM considers employees as strategic assets whose knowledge, competencies and capabilities contribute directly to achieving organizational objectives (Kianto et al., 2017; Debrah et al., 2018).

The basis of the concept of human capital management (HCM) is human capital (HC), which represents the sum of an individual's knowledge, skills, abilities and experiences acquired during life. According to Goldin (2016), it also includes education, health, expertise, talent and creativity. Human capital is also understood as a set of abilities, skills and motivation that enable the practical use of knowledge and the creation of value (Zhang, 2023). Its level is mainly influenced by education, health, working conditions and lifelong learning (Pilichowska, 2021; Sultana et al., 2022; Khalid & Syed, 2024).

Human capital management is a modern approach focused on the development and effective use of human capital to increase the performance of the organization and support its long-term development (Kianto et al., 2017). An important part of HCM is the education of employees and the development of their competencies, while continuous education should be a natural part of the corporate culture (Vochozka et al., 2018; Tuncdogan, 2021; Chang, 2023; Mugunzva & Manchidi, 2024).

HCM includes the processes of planning, acquisition, adaptation, development, evaluation and retention of employees. It consists of seven interconnected phases: identification of key knowledge and skills, quantification of the value of human capital, measurement of its effectiveness, analysis of impacts on performance, identification of shortcomings, adoption of corrective measures and reporting.

The importance of human capital has become even more pronounced in connection with digitalization and Industry 4.0, as it is employees who, with their knowledge, skills and competencies, decide on the success of the implementation of digital technologies (Stachová et al., 2020; Adams, 2018; Debrah et al., 2018). Digitalization contributes to increasing productivity, competitiveness and efficiency of processes (Bayram & İnce, 2017; Valiyev et al., 2022), but at the same time it changes the nature of work, work habits and requirements for employees (Renn et al., 2024).

The introduction of digital technologies may lead to the disappearance of some jobs, especially routine administrative and production activities, while the importance of retraining and further education of employees is growing (Pak et al., 2023; Radosavljević et al., 2020; Gonzalez Vazquez et al., 2019; Kicová, 2019; Lauring

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& Jonasson, 2023). Industry 4.0 requires qualified workers with digital and ICT competencies, which are a prerequisite for the effective use of modern technologies (Polat & Erkollar, 2021; Woerkom et al., 2023; Agolla, 2018; Pereira et al., 2020).

The most important competencies in Industry 4.0 are digital skills, including information and data literacy, communication and collaboration, digital content creation, security and problem solving (Flores et al., 2020). Alongside them, the importance of emotional skills and emotional intelligence is growing, which represents one of the main competitive advantages of a person over technology and affects his professional development (Pirsoul et al., 2023).

3. Research objective and Methodology

The article is based on a qualitative research design using a narrative literature review and content analysis of scientific publications focused on Industry 4.0 technologies and human capital management (HCM).

The first phase was a systematic literature review in Web of Science (Table 1). The search was based on combinations of keywords "Industry 4.0", "fourth industrial revolution", "human capital management", "human resource management", "human", "digitalization", "content analysis", "performance".

The search was conducted in several iterations. The initial search focused on the combination of "Industry 4.0" and "human capital management" identified only 8 publications, with only one being a review study. Due to the low number of relevant results, the search terms were subsequently expanded to include broader terms related to digitization and content analysis, identifying over 400 publications. After reviewing the titles, abstracts and methodology, empirical studies unrelated to the aim of the work were excluded and publications focused on the use of Industry 4.0 technologies in the field of HCM/HRM were retained. The last search was focused on the connection between human capital management, digitalization and performance, from which 14 additional relevant studies were identified.

Table 1. Results of literature search

Search query	Records found	Relevant after screening	Focus
Industry 4.0 + Human capital management	8	1	Literature review
Industry 4.0 + Human + Content analysis	405	4	Industry 4.0 & HCM
Human capital management + Digitalization + Performance	48	14	HCM digitalization
Industry 4.0 + Human capital + Digitalization + Fourth industrial revolution	378	202	Industry 4.0 & HCM
Human capital management + Human resource management	660	7	HCM vs. HRM

Overall, the literature review confirmed that research linking Industry 4.0 technologies with all phases of human capital management is still limited and most publications focus on individual technologies or selected HR processes, which supports the existence of the identified research gap.

In the second phase, the identified publications were subjected to content analysis. The analysis focused on identifying Industry 4.0 technologies applicable to human capital management and examining their impacts on individual HCM activities. Special attention was paid to recruitment, training and development of employees, performance appraisal, communication, workforce planning and decision-making processes.

In the third phase, the findings obtained from the literature review were synthesized and used to develop a conceptual model illustrating the relationships between selected elements of Industry 4.0 and the phases of human capital management. The model also includes the influence of the external environment and key stakeholders influencing the implementation of digital technologies in organizations. The proposed model represents a conceptual framework that can serve as a basis for future empirical research aimed at verifying the relationships between Industry 4.0 technologies and human capital management practices in enterprises.

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Subsequently, the identified technologies were categorized according to their potential application within the seven phases of human capital management. The categorization served as the basis for developing the conceptual framework presented in Figure 2.

4. Results

Figure 2 presents the conceptual model linking Industry 4.0 technologies with the individual phases of human capital management. The model consists of three interconnected components: the HCM process supported by HCMS, the Industry 4.0 technologies applicable across HCM phases, and contextual factors represented by stakeholders and the external environment.

The model consists of three interconnected blocks. The core of the model is business itself. Its functioning is based on a defined mission, vision, goals, strategy and corporate culture. These elements determine the direction of the organization and create the prerequisites for effective human capital management. The HCM concept is therefore closely linked to the overall strategy of the business and supports the achievement of its long-term goals.

The proposed model covers all phases of human capital management. In the phase of identifying key knowledge and skills, digital technologies support competency mapping and workforce planning. During the phase of quantification and measurement, Big Data, Business Intelligence and HCMS enable data collection, analysis and performance measurement. The analysis phase is supported by artificial intelligence and predictive analytics, which facilitate trend identification and decision-making. The identification of deficiencies and the implementation of corrective measures are improved through analytical tools, digital learning platforms and virtual or augmented reality. Finally, the reporting phase is supported by HCMS and Business Intelligence, which provide real-time visualization and reporting of human capital indicators.

The basis for integrating Industry 4.0 technologies across HCM phases is the HCMS information system, which supports all phases of human capital management. It enables centralized management of employee data, automation of administrative processes, workforce planning, performance management, employee training, benefit management and analytical data processing. This increases the efficiency of personnel processes and improves decision-making.

Cloud computing ensures the connection of individual systems and the sharing of information in real time. Social media supports employee recruitment, communication and performance evaluation. Chatbots streamline communication with applicants and employees. Virtual and augmented reality are used mainly in employee education, training and adaptation. Blockchain enables secure data processing and verification of applicant qualifications. Big Data supports the analysis of large volumes of data and predictions of future developments. Artificial intelligence is used in recruitment, performance evaluation, education and personalization of employee development. Business Intelligence provides aggregation, analysis and visualization of data needed for managerial decision-making.

The created model demonstrates how selected Industry 4.0 technologies can support individual HCM phases and improve organizational performance through more efficient processes, data-driven decision-making and enhanced human capital development.

The selected technologies were identified as the most frequently occurring and practically applicable Industry 4.0 elements in the reviewed literature related to human capital management. Technologies primarily associated with manufacturing processes, such as additive manufacturing, autonomous robotics or cyber-physical systems, were excluded because their direct application to HCM activities is limited.

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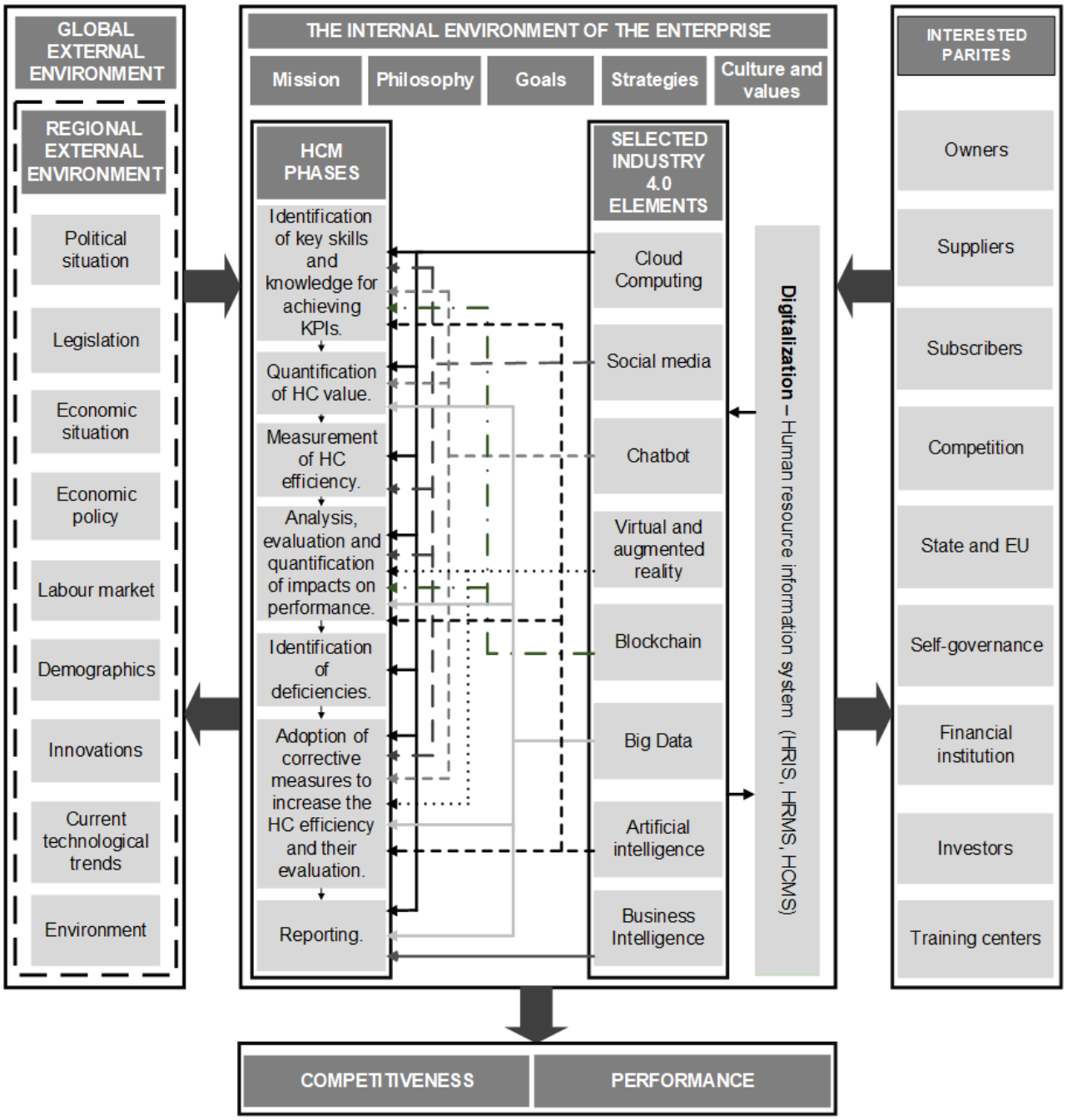


Figure 2. Conceptual model linking Industry 4.0 technologies with Human Capital Management phases
Source: own processing

The second block represents a company implementing Industry 4.0 technologies across human capital management processes. The basic prerequisite for successful implementation is a human capital management information system (HCMS), which ensures effective data management and supports the use of digital technologies. The second block is the external environment of the company, and the third block represents stakeholders who can significantly influence the course and results of the implementation.

The external environment includes factors operating at both regional and global levels. These include the political situation, legislation, economic situation, economic policy, the situation on the labor market, demographic development, technological trends, innovations and environmental requirements. These factors affect the ability of companies to introduce digital technologies, obtain financial resources, develop employees and respond to changing market conditions.

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Political stability and the legislative environment create the framework for the functioning of companies and determine the conditions for investments and digitalization of processes. The economic situation and economic policy affect the availability of financial resources and support for modernization projects. European Union initiatives that support digital transformation through grants, funds and other financial instruments also play a significant role.

An important factor is the situation on the labour market and demographic developments. Digitalization changes the requirements for employees and increases the importance of digital and social skills. At the same time, the aging of the population reduces the availability of the workforce, which increases the need for education, retraining and effective use of human capital.

Technological trends are moving towards the use of artificial intelligence, cloud solutions, virtual and augmented reality, blockchain, Big Data and social media. These technologies contribute to the automation of processes, higher labor productivity and more effective decision-making. At the same time, they support the principles of sustainability and environmental protection through resource savings, reduced paper consumption and process optimization.

The third block of the model consists of stakeholders. Internal stakeholders include business owners and employees. External stakeholders are customers, suppliers, competitors, the state, local governments, financial institutions, investors and educational organizations.

Business owners influence decisions on investments in digital technologies and create conditions for their implementation. Employees represent the bearers of human capital, the quality of which significantly affects the success of the transformation. Suppliers provide technological solutions and support for their implementation. Customers create pressure for innovation and higher-quality products and services. Competition motivates businesses to modernize and introduce new technologies. The state, the European Union and local governments create legislative and financial conditions for the development of digitalization. Financial institutions and investors provide the capital necessary for the implementation of transformation projects. Educational and training organizations ensure the development of employees' competencies in the field of digital technologies.

5. Discussion

The research results confirmed that the connection of the concept of human capital management (HCM) with the elements of Industry 4.0 represents a current and still insufficiently explored area of scientific research. An analysis of professional literature showed that digitalization significantly affects human capital management and gradually changes the way personnel processes are implemented. The importance of digitalization in business practice is also emphasized by Jankelová et al. (2021), who point to the acceleration of the implementation of digital technologies during the COVID-19 pandemic.

The main theoretical contribution of the article lies in the creation of a conceptual framework linking the individual phases of HCM with selected elements of Industry 4.0. Unlike most existing studies that focus on specific technologies or selected personnel processes, the proposed model provides a comprehensive view of the use of digital technologies in the entire human capital management process. The results thus extend the knowledge presented by the authors Pereira et al. (2021), Ghosh et al. (2024), Pandya and Wang (2024) or Podhorcová et al. (2023), who point out the growing importance of digital technologies in the field of human resource management and employee development.

The novelty of the proposed model lies in its comprehensive integration of Industry 4.0 technologies with all phases of human capital management. Unlike previous studies, which primarily address individual digital technologies or selected HR activities, the proposed framework systematically connects technologies, HCM phases, stakeholders and external environmental factors within a single conceptual model.

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A significant contribution to the proposed model is the use of the human capital management perspective instead of traditional human resource management. While HRM primarily focuses on personnel processes, HCM emphasizes the strategic value of human capital and its contribution to the performance and competitiveness of the enterprise. This approach is in line with the views of the authors Kianto et al. (2017), Debrah et al. (2018) and Zhang (2023), who consider human capital to be one of the decisive factors of the long-term performance of the organization.

The literature analysis also identified cloud computing, social networks, chatbots, virtual and augmented reality, blockchain, Big Data, artificial intelligence and Business Intelligence as the most important technologies usable in individual phases of HCM. Their application is most often associated with employee recruitment, training and development, performance appraisal, data management and management decision support. These findings correspond to the results of studies by Bilge et al. (2021), Chang (2023), Polat and Erkollar (2021), Flores et al. (2020) and Stachová et al. (2020), which point to the growing importance of digital tools in the development and effective use of human capital.

An important aspect of the proposed model is also the inclusion of stakeholders and external environmental factors. Many existing studies examine digitalization mainly from the perspective of internal company processes, however, the success of the implementation of Industry 4.0 technologies is significantly influenced by the legislative environment, economic situation, labour market developments, demographic changes, technological progress and availability of financial resources. The importance of external factors in the digital transformation of companies is also emphasized by Rodchenko et al. (2021), Cherenko et al. (2021), Kelchevskaya and Shirinkina (2019), Valiyev et al. (2022), Ranacher et al. (2023), Kosior (2022), Borchard et al. (2022), Shevtsova et al. (2020).

The results further indicate that the implementation of Industry 4.0 technologies is not only a technological challenge, but primarily a managerial and personnel challenge. The success of digital transformation depends on the level of digital competencies of employees, support from management, organizational culture and the willingness of companies to invest in human capital development. This conclusion is also supported by the authors Agolla (2018), Adams et al. (2018), Woerkom et al. (2023), Tuncdogan et al. (2021), Pirsoul et al. (2023) and Khalid and Syed (2024), who emphasize the importance of competencies, continuous learning and emotional skills of employees in a digital environment.

The practical contribution of the article lies in the creation of a framework that can help managers identify appropriate technologies for individual phases of HCM and plan the digital transformation process more effectively. The implementation of the proposed technologies can lead to increased labor productivity, more efficient use of human capital, improved decision-making processes and strengthened competitiveness of the enterprise, which is also confirmed by the results of research by the authors Vetráková and Smerek (2019), Field and Mkrtchan (2017), Bayram and İnce (2017), and Martincevic (2022).

Conclusion

Despite the above contributions, the research has several limitations. The proposed model was created based on a synthesis of knowledge from professional literature and has not been empirically verified in the conditions of specific enterprises. The results therefore primarily represent a theoretical basis for further research. A promising direction for future research is empirical testing of the model in companies of various sizes and sectors, as well as a more detailed examination of the impact of individual Industry 4.0 technologies on specific phases of human capital management. Future research may also compare the applicability of the model across different industries and organisational sizes and examine the contribution of individual Industry 4.0 technologies to specific HCM phases.

The aim of the article was to analyze the possibilities of integrating Industry 4.0 elements into the concept of human capital management and based on the synthesis of knowledge from professional literature, to create a conceptual framework illustrating their mutual connection. The analysis confirmed that digitalization and

Industry 4.0 technologies are gradually becoming an integral part of human capital management and significantly influence the way personnel processes are implemented.

The main contribution of the study is the development of a conceptual model linking Industry 4.0 technologies with all phases of human capital management while considering the role of HCMS, stakeholders and external environmental factors. The proposed framework provides managers with a structured overview of technologies applicable across HCM processes and serves as a basis for planning digital transformation initiatives.

The conceptual nature of the model and the absence of empirical validation represent the main limitations of this study. Future research should therefore focus on empirically testing the proposed model in organizations of different sizes and sectors and on assessing the contribution of individual Industry 4.0 technologies to specific phases of HCM.

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ALTERNATIVE TOURISM IN EUROPEAN UNION COUNTRIES: MARKET GROWTH, SEGMENT DIVERSIFICATION AND DEVELOPMENT PROSPECTS*

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Abstract. The diversification of contemporary tourism has transformed alternative tourism into an increasingly important component of the European tourism economy. However, it remains conceptually fragmented and lacks a unified framework integrating its diverse market segments. This study aims to conceptualize alternative tourism as an integrated system of interconnected tourism markets and to examine its development in the European Union through empirical evidence from multiple measurable tourism segments. The research adopts a mixed conceptual–empirical approach combining systems theory, literature analysis, and secondary data analysis. A conceptual framework is developed to explain the relationships among tourist motivations, destination resources, alternative tourism market segments, and sustainability outcomes. The empirical analysis draws on official statistics and institutional datasets from Eurostat, the Global Wellness Institute, ISTAT, Metsähallitus, and other authoritative sources. Six market segments are examined: wellness tourism, spa and thermal tourism, platform-based accommodation, agritourism, nature-based tourism, and pilgrimage tourism. The findings reveal consistent long-term growth across all analysed segments, driven by increasing demand for health, authenticity, sustainability, nature-based experiences, spirituality, and personal development. The study demonstrates that alternative tourism should be understood as an integrated and measurable tourism ecosystem rather than a collection of isolated tourism forms. The proposed framework contributes to tourism theory and provides a methodological basis for future empirical research on alternative tourism.

Keywords: alternative tourism; tourism diversification; wellness tourism; sustainable tourism; pilgrimage tourism; nature-based tourism; agritourism; European Union (EU).

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1. Introduction

In recent decades, the tourism industry in the European Union (EU) has been undergoing a gradual transformation from standardized mass tourism toward more individualized, experience-oriented and sustainable forms of travel (But, 2024; European Travel Commission, 2025; Karanikić et al., 2026). This transformation reflects broader changes in tourist motivations, including the growing demand for well-being, authenticity, contact with nature, cultural immersion, spiritual experience and personal development. In this

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context, non-traditional and alternative tourism has become an increasingly important direction of tourism market development, as it responds to the limitations of mass tourism and promotes a more balanced relationship between economic, environmental and socio-cultural dimensions of development (UN Tourism, n.d.; Weaver, 2006; Global Wellness Institute, 2026). From a theoretical perspective, alternative tourism can also be understood as a complex interdisciplinary system that includes tourists, destinations, host communities, infrastructure and socio-cultural interactions (Cohen, 1984; Smith, 1989; Jafari, 2001; Bertalanffy, 1968/2015).

At the same time, the market of alternative tourism is difficult to measure as a single statistical category. Eurostat does not distinguish "alternative tourism" as an independent market segment; therefore, its development should be assessed through a basket of measurable indicators, including wellness tourism, spa and thermal tourism, platform-based short-stay accommodation, rural tourism and agritourism, nature-based and ecological tourism, cycling and adventure tourism, pilgrimage and spiritual tourism, as well as emerging digital and virtual forms of tourism (European Parliamentary Research Service, 2023; CBI, 2024a, 2024b; Global Wellness Institute, 2025; Eurostat, 2026a, 2026b). This means that the expansion of alternative tourism in the EU cannot be captured by one official category, but can be demonstrated through several interconnected tourism segments.

The relevance of this topic is confirmed by the positive dynamics of several alternative tourism segments in EU countries. Platform-based short-stay accommodation represents one of the strongest measurable indicators: guest nights booked through major online platforms in the EU reached 951.6 million in 2025 and continued to grow in the first quarter of 2026 (Eurostat, 2026a, 2026b). Wellness tourism in Europe also exceeded its pre-pandemic level, while spa tourism and thermal/mineral spring tourism demonstrated growth in both revenues and infrastructure (Global Wellness Institute, 2025). Furthermore, rural tourism and agritourism show measurable development through the share of tourism nights in rural areas and the growth of agritourism farms in Italy (European Parliamentary Research Service, 2023; ISTAT, 2018, 2025). Nature-based and ecological tourism is supported by the growing importance of national parks and protected areas, as illustrated by visitation and local economic impact indicators in Finland (Metsähallitus, 2025a, 2025b).

The development of alternative tourism is also visible at the level of individual EU countries. Germany demonstrates growth in wellness, thermal, platform-based and adventure tourism; France combines wellness tourism, pilgrimage, sacred heritage and platform accommodation; Italy shows strong dynamics in wellness tourism, agritourism, thermal tourism and Jubilee-related pilgrimage; Spain combines wellness tourism, Camino routes, ecotourism, medical tourism and platform accommodation (Global Wellness Institute, 2025; ISTAT, 2025; Eurostat, 2026b; Cathedral of Santiago de Compostela, 2026; Vatican News, 2026). These country-level examples show that alternative tourism is not a marginal niche, but a diversified market formed by different national specializations and regional tourism resources.

Particular attention should also be paid to pilgrimage, spiritual and sacred tourism, since these forms increasingly intersect with cultural heritage, slow mobility, wellness practices and local economic development. The recovery and growth of major European pilgrimage destinations and routes, including Fátima, Lourdes, Camino de Santiago, Jasna Góra and the Rome Jubilee, indicate that spiritual and sacred tourism remains an important part of the alternative tourism market in Europe (Sanctuary of Lourdes, 2024; Dzieje.pl, 2026; Shrine of Fátima, 2026; Cathedral of Santiago de Compostela, 2026; Vatican News, 2026). These examples demonstrate the increasing hybridity of alternative tourism, where religious, cultural, restorative and experiential motives are often combined within one tourism product.

From a theoretical perspective, the study of alternative tourism remains conceptually important because its boundaries are not always clearly defined. Existing literature points to methodological difficulties in defining and classifying alternative tourism forms, especially where wellness, retreat, sacred, spiritual and transformational tourism overlap (Kelly, 2010; Korstanje, 2012; Smith & Puczkó, 2014; Buckley, 2023). This ambiguity creates a need for a clearer market-oriented analysis that does not reduce alternative tourism to one type of activity, but examines it as a diversified system of tourism practices connected with sustainability, well-being, nature, culture, spirituality and new consumption patterns.

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Therefore, the aim of this article is to analyse the market development of alternative forms of tourism in European Union countries and to identify the main measurable segments through which this market expansion can be assessed. The article focuses on evidence of market growth across wellness, spa and thermal, rural, nature-based, adventure, platform-based, pilgrimage and spiritual tourism. By combining conceptual analysis with statistical and country-level indicators, the study contributes to a more systematic understanding of alternative tourism as a diversified and economically significant component of the contemporary EU tourism industry.

2. Literature review

2.1. Theoretical foundations of alternative tourism

The concept of alternative tourism emerged as a response to the growing recognition that conventional mass tourism, while generating substantial economic benefits, also produces significant environmental, socio-cultural and spatial pressures. Rather than representing a single tourism product, alternative tourism has gradually evolved into a multidimensional concept encompassing diverse forms of travel that emphasize sustainability, authenticity, local participation, environmental responsibility and meaningful visitor experiences. Its theoretical foundations draw upon several academic traditions, including sociology, anthropology, systems theory, sustainability studies and tourism management. Collectively, these perspectives demonstrate that tourism should not be interpreted solely as an economic activity but as a complex socio-economic system characterized by interactions among tourists, host communities, destinations, institutions and natural environments (Cohen, 1984; Smith, 1989; Jafari, 2001; Panosso Netto, 2007).

One of the earliest systematic conceptualizations of tourism diversity was proposed by Cohen (1984), who argued that tourism should be understood as a multidimensional social phenomenon rather than simply a leisure industry. Reviewing the sociological foundations of tourism studies, Cohen demonstrated that tourism incorporates multiple tourist motivations, behavioural patterns and forms of interaction with host communities. His framework identified tourism simultaneously as commercialized hospitality, modern leisure, cultural exchange, pilgrimage, ethnic relations and an acculturative process, thereby illustrating the heterogeneity of tourism experiences. Importantly, Cohen's recognition that tourists differ fundamentally in their motivations and expectations provided an important theoretical basis for the later emergence of specialized tourism forms, including contemporary alternative tourism. However, because the study preceded the rapid expansion of wellness, retreat, spiritual and other experience-oriented tourism markets, it did not conceptualize these forms as distinct market segments, leaving important opportunities for further theoretical development (Cohen, 1984).

An equally influential anthropological perspective was introduced by Smith (1989), who shifted attention from tourism itself toward the relationships between hosts and guests. Rather than evaluating tourism primarily through its economic impacts, Smith conceptualized tourism as a process of cultural interaction in which visitors and local communities continuously influence one another. The volume proposed one of the earliest typologies of tourism by distinguishing historical, cultural, ethnic, environmental and recreational tourism, thereby demonstrating that different tourism forms generate different patterns of cultural exchange and socio-economic consequences. Furthermore, Smith emphasized that tourism should be interpreted as a dynamic process of negotiation between economic development and cultural preservation, an idea that remains highly relevant for contemporary discussions concerning authenticity, sustainability and responsible tourism. Nevertheless, the proposed typology predates the emergence of wellness tourism, retreat tourism, digital detox tourism and other modern forms of alternative tourism that have become increasingly important within contemporary tourism markets (Smith, 1989).

The theoretical maturation of tourism studies was further advanced by Jafari (2001), who explained tourism's evolution into an independent multidisciplinary scientific field. According to Jafari, tourism research progressed through four complementary knowledge platforms: the Advocacy Platform, emphasizing tourism's benefits; the Cautionary Platform, focusing on its negative impacts; the Adaptancy Platform, promoting sustainable and alternative forms of tourism; and the Knowledge-Based Platform, integrating previous perspectives into a comprehensive scientific framework. This final platform conceptualizes tourism as an interconnected socio-economic system requiring contributions from economics, sociology, anthropology, geography, psychology,

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ecology and management. Particularly significant for the present study is Jafari's Adaptancy Platform, which recognized the growing importance of alternative tourism as a response to the environmental and socio-cultural limitations of mass tourism. However, although the framework acknowledged ecotourism, rural tourism and sustainable tourism, it did not anticipate the subsequent emergence of wellness, retreat, mindfulness and transformational tourism, which have become increasingly prominent in the twenty-first century (Jafari, 2001).

Building upon systems thinking, Panosso Netto (2007) further contributed to the epistemological development of tourism by distinguishing between tourism as a phenomenon and tourism as an academic field of inquiry. Reviewing the historical evolution of tourism definitions, the author demonstrated that tourism has progressed through three principal theoretical stages: the pre-paradigmatic phase, focused on defining tourism; the tourism systems phase, conceptualizing tourism as an interconnected network of actors and institutions; and the new approaches phase, incorporating interdisciplinary, critical and post-positivist perspectives. This interpretation reinforces the idea that tourism should be understood as a complex system of interactions rather than as an isolated economic activity. Nevertheless, Panosso Netto's discussion remains primarily epistemological and does not examine the diversification of alternative tourism into specialized market segments or their contemporary significance within the EU (Panosso Netto, 2007).

Anthropological critiques have further enriched the theoretical understanding of alternative tourism by questioning the ethical implications of authenticity and cultural exchange. Korstanje (2012) argues that cultural and ethnic tourism should not be viewed exclusively as mechanisms for heritage preservation or intercultural understanding because they may also reproduce unequal power relations and commodify indigenous cultures. From this perspective, authenticity is interpreted as a socially constructed and negotiated phenomenon rather than an objective characteristic of destinations. Similarly, Smith's (1989) host–guest framework suggests that tourism inevitably transforms both visitors and local communities through continuous cultural interaction. Together, these perspectives emphasize that alternative tourism cannot be evaluated solely according to economic performance but must also consider issues of representation, identity, cultural ownership and social justice (Smith, 1989; Korstanje, 2012).

Collectively, these theoretical contributions demonstrate that tourism has evolved from a narrowly defined economic activity into a multidimensional socio-economic and cultural system characterized by diverse tourist motivations, destination characteristics and stakeholder relationships. At the same time, they reveal that most classical theories were developed before the rapid expansion of many contemporary forms of alternative tourism, including wellness tourism, retreat tourism, digital detox tourism, spiritual tourism and transformational tourism. Consequently, while existing theoretical frameworks successfully explain tourism as a complex social phenomenon, they provide only limited guidance for understanding the contemporary diversification of alternative tourism markets. The present study builds upon these foundational theories by conceptualizing alternative tourism as an integrated system of measurable and interconnected market segments, whose development reflects changing tourist motivations toward sustainability, authenticity, well-being, cultural immersion and personal transformation across EU countries.

2.2. Alternative tourism, sustainability and tourism diversification

The development of alternative tourism is closely associated with the broader paradigm of sustainable tourism development, which emerged as a response to the environmental, social and economic limitations of mass tourism. While conventional tourism has historically been evaluated primarily through visitor numbers, tourism receipts and employment generation, sustainable tourism emphasizes the balanced integration of economic prosperity, environmental conservation and socio-cultural well-being. Within this framework, alternative tourism represents not merely a collection of niche tourism products but a strategic approach to tourism development that promotes responsible resource use, local participation, cultural preservation and diversified destination economies. Consequently, sustainability and diversification have become two complementary principles underpinning the contemporary evolution of alternative tourism (Weaver, 2006; Hall, 2019).

One of the earliest systematic interpretations of this relationship was proposed by Weaver (2006), who argued that alternative tourism should be understood as a reaction against the environmental degradation, cultural commodification and spatial concentration associated with mass tourism. According to Weaver, sustainable

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tourism extends beyond environmental protection by incorporating long-term economic viability, social equity and destination resilience. Rather than replacing mass tourism entirely, alternative tourism should complement conventional tourism through the development of smaller-scale, locally embedded and environmentally responsible tourism products. This perspective established an important conceptual foundation by linking alternative tourism directly with sustainable development principles and by emphasizing the need to balance tourism growth with destination carrying capacity and community well-being (Weaver, 2006).

Subsequent research has further strengthened this relationship by emphasizing the strategic importance of tourism diversification. Hall (2019) argues that sustainable tourism requires destinations to diversify both their tourism products and visitor markets in order to reduce vulnerability to economic fluctuations, seasonality and external shocks. Diversification enables destinations to distribute tourism demand more evenly across geographical areas, seasons and tourism activities while simultaneously reducing dependence on highly standardized tourism products. In this context, alternative tourism contributes to destination resilience by expanding tourism opportunities beyond traditional coastal, urban or seasonal tourism and by encouraging the development of products that respond to increasingly heterogeneous visitor preferences (Hall, 2019).

The importance of diversification is examined empirically by Solarin, Ulucak and Erdogan (2024), who investigate the relationship between tourism diversification and economic growth. Their study demonstrates that tourism diversification should not be measured solely through the expansion of visitor source markets but also through the diversification of tourism activities themselves. While diversification of European tourism markets contributes positively to long-term economic growth, the diversification of tourism products exhibits even stronger and more consistent economic benefits by stimulating multiple sectors of the economy, including transport, hospitality, agriculture and health services. The authors therefore conclude that expanding the variety of tourism experiences represents a more sustainable development strategy than merely increasing tourist arrivals. These findings reinforce the argument that the growing diversity of alternative tourism products – including wellness, rural, adventure and nature-based tourism – constitutes an important mechanism for strengthening tourism competitiveness and economic resilience (Solarin et al., 2024).

A similar perspective is presented by Jovanović and Živković (2018), who argue that sustainable destination development depends upon the creation of diversified tourism portfolios rather than reliance on individual tourism products. Their analysis demonstrates that integrating complementary forms of tourism –including ecotourism, rural tourism, spa tourism, cultural tourism and adventure tourism – enables destinations to extend product life cycles, increase competitiveness and respond more effectively to changing tourist demand. Furthermore, diversification generates broader economic benefits by strengthening linkages between tourism, agriculture, environmental conservation and cultural heritage preservation. The authors therefore conceptualize tourism diversification as a multidimensional strategy simultaneously supporting economic development, environmental sustainability and regional resilience (Jovanović & Živković, 2018).

The relationship between diversification and sustainable regional development is examined further by Ursache (2015), who analyses niche tourism markets within the European Union's eastern periphery. The study argues that contemporary tourists increasingly seek authentic, personalized and experience-based travel, encouraging destinations to develop specialized tourism products based on their comparative advantages. Ursache conceptualizes niche tourism as a multidimensional framework incorporating cultural tourism, gastronomic tourism, wellness tourism and numerous other specialized tourism forms. Rather than treating these markets independently, the study demonstrates that diversification enables destinations to utilize local natural resources, cultural heritage and regional identity more effectively while simultaneously enhancing destination competitiveness and supporting sustainable rural development. This perspective reinforces the growing understanding that alternative tourism is not a single tourism segment but a portfolio of complementary tourism experiences responding to diverse consumer motivations (Ursache, 2015).

The importance of rural tourism as an instrument of economic diversification is examined comprehensively by Đorđević-Milošević et al. (2020). Their comparative analysis of South East European countries demonstrates that rural tourism has become an essential component of regional development policies, particularly in areas affected by depopulation, unemployment and declining agricultural incomes. The authors argue that rural

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tourism should not be viewed simply as a tourism activity but as a multifunctional development strategy integrating agriculture, local entrepreneurship, gastronomy, cultural heritage and environmental conservation. Successful rural tourism therefore depends upon coordinated institutional support, infrastructure investment and community participation rather than tourism development alone. Although the geographical focus extends beyond the European Union, the study illustrates how tourism diversification contributes simultaneously to economic resilience, social cohesion and environmental sustainability, principles that are equally relevant to contemporary EU tourism policy (Đorđević-Milošević et al., 2020).

The sustainability dimension of tourism diversification is further strengthened by Stoiljković et al. (2025), who evaluate tourism efficiency across European countries using a sustainability-oriented Data Envelopment Analysis (DEA) framework. Unlike conventional efficiency studies focused exclusively on economic outputs, the authors integrate tourism demand, employment, greenhouse gas intensity and tourism revenues into a comprehensive sustainability assessment. Their findings demonstrate considerable regional differences in tourism efficiency and indicate that sustainable tourism performance depends not only on visitor numbers but also on longer lengths of stay, lower environmental impacts and higher value creation. The study therefore highlights that future tourism competitiveness should be evaluated through integrated sustainability indicators rather than through tourism growth alone, reinforcing the broader shift toward quality-oriented and environmentally responsible tourism development (Stoiljković et al., 2025).

Recent studies have also demonstrated that diversification has become increasingly important in the context of global crises and structural transformations affecting tourism. Borutska et al. (2022) argue that the COVID-19 pandemic accelerated changes in tourist behaviour by increasing demand for safer, healthier and more environmentally responsible destinations. As a consequence, domestic tourism, nature-based tourism and environmentally sustainable destinations became increasingly attractive, while destinations dependent on mass international tourism experienced significant declines. The authors conclude that future tourism development will rely increasingly on digitalization, health protection, environmental quality and diversified tourism products rather than the previous model centred on maximizing tourist arrivals. Their findings therefore provide additional evidence that sustainability and diversification have become mutually reinforcing characteristics of contemporary tourism development (Borutska et al., 2022).

2.3. Wellness, health and retreat tourism as emerging alternative tourism segments

Among the numerous forms of contemporary alternative tourism, wellness, health and retreat tourism have become some of the fastest-growing and conceptually most dynamic segments. Their expansion reflects profound socio-economic changes, including population ageing, increasing prevalence of stress-related disorders, growing public interest in preventive healthcare, and changing consumer preferences toward experiences that promote physical, psychological and spiritual well-being. Unlike conventional leisure tourism, which primarily emphasizes recreation and entertainment, wellness-oriented tourism increasingly focuses on holistic health, self-development, mindfulness and lifestyle transformation. Consequently, these tourism forms have gradually evolved from niche products into strategically important components of the global tourism industry and represent one of the principal directions through which alternative tourism continues to diversify (Smith & Puczkó, 2014; Global Wellness Institute, 2025).

A significant milestone in the conceptual development of wellness tourism was the publication of Bushell and Sheldon (2009), which positioned wellness tourism within a holistic framework integrating mind, body, spirit and place. Rather than defining wellness exclusively through physical health or spa services, the contributors argue that tourism experiences can promote multiple dimensions of well-being, including emotional balance, spiritual fulfilment, social connectedness and interaction with natural environments. The volume demonstrates that wellness tourism should be understood as a multidimensional tourism philosophy rather than simply a specialized tourism product, thereby establishing one of the earliest comprehensive theoretical frameworks linking tourism with holistic well-being. Within this perspective, destinations, landscapes and local communities become active contributors to visitors' physical and psychological restoration rather than merely locations where tourism activities occur (Bushell & Sheldon, 2009).

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Expanding this holistic perspective, Kelly and Smith (2009) introduce the concept of holistic tourism, arguing that tourism experiences should simultaneously address the interconnected dimensions of body, mind and spirit. The authors contend that modern tourists increasingly seek experiences that provide not only relaxation but also opportunities for self-reflection, personal growth, emotional restoration and spiritual development. Consequently, wellness tourism extends beyond traditional spa facilities by incorporating mindfulness practices, meditation, healthy lifestyles, nature immersion and transformative experiences. Their work highlights the gradual convergence between wellness tourism, spiritual tourism and retreat tourism, suggesting that the boundaries separating these tourism forms have become increasingly fluid as tourists pursue more integrated approaches to health and well-being (Kelly & Smith, 2009).

The conceptual evolution of health tourism is examined comprehensively by Smith and Puczkó (2014), who distinguish clearly between medical tourism and wellness tourism. According to the authors, medical tourism is primarily motivated by diagnosis, treatment and rehabilitation, whereas wellness tourism focuses on prevention, lifestyle improvement and holistic well-being. They further demonstrate that wellness tourism has expanded considerably beyond traditional spa services to include complementary and alternative therapies, healthy nutrition, beauty and cosmetic treatments, longevity programmes, preventive healthcare and lifestyle-based wellness. The authors attribute this diversification to several long-term socio-economic trends, including population ageing, increased public attention to preventive medicine, growing acceptance of complementary therapies and changing consumer lifestyles. Consequently, wellness tourism has evolved into one of the most innovative and rapidly expanding sectors of contemporary tourism, encouraging destinations to diversify their tourism portfolios while integrating hospitality, healthcare and tourism services into comprehensive visitor experiences (Smith & Puczkó, 2014).

The relationship between tourism and psychological well-being has received increasing scholarly attention in recent years. Buckley (2023) argues that tourism should be recognized not only as a leisure activity but also as an important contributor to mental health. Reviewing evidence from multiple tourism sectors, the author demonstrates that nature tourism, cultural tourism and adventure tourism generate measurable psychological benefits through stress reduction, emotional restoration, self-confidence and personal transformation. Importantly, Buckley proposes that tourism products should be intentionally designed to maximize mental health outcomes and that tourism destinations should increasingly communicate these benefits within destination marketing and tourism policy. This perspective broadens the conceptual boundaries of wellness tourism by positioning psychological health as a central outcome of tourism participation rather than a secondary consequence of leisure travel (Buckley, 2023).

Empirical support for this broader conceptualization is provided by Dillette et al. (2020), who investigate the experiential foundations of holistic wellness tourism through the analysis of international wellness travellers' experiences. Building upon Dunn's holistic wellness theory, the authors identify four interrelated dimensions of wellness experiences–body, mind, spirit and environment. Their findings demonstrate that physical health programmes, psychological restoration, spiritual engagement and environmental quality jointly contribute to visitors' holistic well-being, while deficiencies in any of these dimensions may reduce the overall effectiveness of wellness tourism experiences. The study therefore confirms that wellness tourism should be interpreted as a multidimensional phenomenon extending well beyond physical health, reinforcing the conceptual integration proposed by Bushell and Sheldon (2009) and Kelly and Smith (2009) (Dillette et al., 2020).

Within the broader wellness tourism framework, retreat tourism has emerged as a particularly distinctive and rapidly developing market segment. Kelly (2010) provides one of the first comprehensive empirical investigations of retreat tourism by analysing more than 500 retreat centres worldwide and conducting detailed interviews with 50 retreat operators. The study demonstrates that retreat providers differ substantially from traditional wellness enterprises because they are predominantly lifestyle entrepreneurs motivated by personal philosophies, holistic values and quality-of-life aspirations rather than purely commercial objectives. Furthermore, retreat tourism is characterized by immersive programmes emphasizing mindfulness, meditation, spiritual reflection, self-development and holistic well-being rather than conventional spa or medical services. Kelly therefore argues that retreat tourism possesses sufficiently distinctive organizational, experiential and

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philosophical characteristics to justify its recognition as a separate category within the broader wellness tourism market (Kelly, 2010).

The growing significance of retreat tourism is further reinforced by research examining its psychological and behavioural outcomes. McClintock et al. (2019) conducted a meta-analysis of nineteen empirical studies evaluating the effects of mindfulness retreats on non-clinical adult populations. Their findings reveal significant improvements in mindfulness, psychological well-being and reductions in stress, anxiety and depression, with many benefits persisting after retreat participation. These results provide robust empirical evidence that retreat tourism contributes not only to temporary relaxation but also to lasting psychological development and behavioural change. Similarly, Quaye (2025) demonstrates that digital detox tourism, another rapidly emerging retreat-oriented tourism form, responds to increasing concerns regarding technological overload by combining mindfulness practices, nature-based activities and structured wellness programmes. Together, these studies indicate that contemporary retreat tourism increasingly addresses modern psychological challenges associated with stress, digital dependence and declining work-life balance (McClintock et al., 2019; Quaye, 2025).

The motivational foundations underlying these tourism experiences can be further explained through Self-Determination Theory developed by Deci and Ryan (2000). According to this framework, psychological well-being depends upon the satisfaction of three universal psychological needs: autonomy, competence and relatedness. Wellness and retreat tourism provide favourable environments for satisfying these needs by enabling voluntary withdrawal from everyday routines, encouraging personal development through mindfulness and wellness activities, and fostering meaningful relationships with other participants, local communities and natural environments. Consequently, Self-Determination Theory offers a robust psychological explanation for the increasing demand for wellness and retreat tourism by demonstrating how these tourism experiences contribute to long-term psychological flourishing rather than merely providing recreational benefits (Deci & Ryan, 2000).

2.4. Alternative tourism market development and EU trends

The expansion of alternative tourism over the past two decades reflects broader structural transformations occurring within the global and European tourism industries. Increasing environmental awareness, demographic change, digitalization, changing consumer lifestyles and the growing emphasis on health and well-being have collectively reshaped tourism demand, encouraging destinations to diversify beyond conventional mass tourism products. As a result, alternative tourism has evolved from a collection of niche activities into an increasingly significant market characterized by continuous product innovation, greater specialization and stronger integration with sustainability objectives. Contemporary tourism markets are therefore increasingly driven by demand for authentic, experience-based and value-oriented travel, creating favourable conditions for the expansion of wellness tourism, rural tourism, nature-based tourism, adventure tourism, pilgrimage tourism and other specialized tourism forms (OECD, 2026; European Travel Commission, 2025).

Recent market analyses indicate that alternative tourism represents one of the fastest-growing components of the global tourism economy. According to Market.us (2025), the global alternative tourism market was valued at USD 116.3 billion in 2024 and is projected to reach approximately USD 200.5 billion by 2034, corresponding to a compound annual growth rate of 5.6%. The report attributes this expansion to growing environmental consciousness, increasing demand for authentic cultural experiences and rising interest in sustainable travel practices. Rather than being confined to individual tourism niches, alternative tourism is presented as a diversified market incorporating ecotourism, adventure tourism, community-based tourism and other responsible travel experiences that increasingly differentiate themselves from standardized package tourism. This market evolution demonstrates that alternative tourism has become an economically significant component of the contemporary tourism industry rather than a marginal segment serving only specialized consumer groups (Market.us, 2025).

The rapid expansion of the wellness economy further illustrates this transformation. According to the Global Wellness Institute (2025), the global wellness economy reached USD 6.8 trillion in 2024, having doubled in size since 2013 and consistently outperformed global GDP growth over the same period. Europe is identified

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as one of the fastest-growing regional wellness economies, while all eleven wellness sectors have exceeded their pre-pandemic market levels. Particularly strong growth has been observed in wellness real estate, mental wellness and preventive health services, reflecting changing consumer priorities toward healthier lifestyles and psychological well-being. The Institute projects that the wellness economy will continue expanding at a rate substantially exceeding global economic growth, reinforcing the strategic importance of wellness-related tourism products within contemporary tourism markets (Global Wellness Institute, 2025). These trends are complemented by the broader analysis of the Global Wellness Institute (2026), which argues that wellness tourism increasingly represents one of the principal mechanisms through which tourism contributes simultaneously to economic development, public health and sustainable lifestyles.

The growing importance of alternative tourism is equally evident within the European Union. According to Future Market Insights (2025), the EU tourism industry is expected to expand from USD 722.9 billion in 2025 to approximately USD 1.49 trillion by 2035, representing a compound annual growth rate of 7.4%. The report identifies digital transformation, tourism analytics and online booking technologies as key drivers of future competitiveness, with online booking already accounting for more than two-thirds of tourism transactions. Simultaneously, the increasing prominence of operators specializing in adventure, nature-based and responsible tourism demonstrates that tourism growth is increasingly associated with diversified tourism products rather than standardized package holidays. These findings suggest that technological innovation and product diversification have become mutually reinforcing drivers of tourism market development across Europe (Future Market Insights, 2025).

The OECD Tourism Trends and Policies 2026 report similarly emphasizes that tourism has entered a period characterized by structural rather than cyclical change. The report argues that post-pandemic tourism recovery is increasingly shaped by sustainability, digitalization, resilience and visitor experience quality instead of maximizing tourism volumes alone. Governments are encouraged to diversify tourism products, strengthen regional tourism development, promote year-round tourism and reduce dependence on highly concentrated visitor flows. Furthermore, tourism policies increasingly recognize the importance of improving visitor well-being, environmental performance and destination resilience while supporting innovation and digital transformation. These policy directions closely align with the principles underlying alternative tourism and reinforce its growing strategic importance within European tourism development (OECD, 2026).

Evidence of market transformation is further supported by studies examining the changing structure of tourism demand. Borutska et al. (2022) demonstrate that the COVID-19 pandemic accelerated existing shifts toward healthier, safer and more sustainable tourism experiences. Domestic tourism, nature-based tourism and environmentally responsible destinations recovered more rapidly than destinations dependent upon international mass tourism, suggesting that changing consumer preferences have reinforced demand for alternative tourism products. Similarly, Badulescu et al. (2026) argue that contemporary tourism development is increasingly characterized by diversification, innovation and experiential consumption, with tourists placing greater value on authenticity, sustainability, local culture and personalized experiences than on traditional standardized tourism products. Together, these studies indicate that the evolution of tourism demand extends beyond temporary post-pandemic adjustments and reflects long-term structural changes within international tourism markets (Borutska et al., 2022; Badulescu et al., 2026).

Within the EU, these structural changes are observable across multiple alternative tourism segments. Wellness tourism has continued to expand through investments in spa infrastructure, preventive health services and lifestyle-oriented hospitality (Global Wellness Institute, 2025). Platform-based accommodation has become one of the most measurable indicators of tourism diversification, with Eurostat reporting record numbers of guest nights booked through online accommodation platforms (Eurostat, 2026a, 2026b). Rural tourism and agritourism continue to develop through diversification of agricultural activities, increased demand for authentic local experiences and stronger policy support for rural development (European Parliamentary Research Service, 2023; ISTAT, 2018, 2025). Meanwhile, nature-based tourism benefits from growing visitation to protected areas and national parks, supported by increasing public interest in biodiversity conservation and outdoor recreation (Metsähallitus, 2025a, 2025b). At the same time, pilgrimage and spiritual tourism have experienced renewed growth through the recovery of major European pilgrimage destinations,

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including Santiago de Compostela, Lourdes, Fátima and the Rome Jubilee, demonstrating that cultural heritage, spirituality and personal development have become increasingly integrated within contemporary tourism markets (Cathedral of Santiago de Compostela, 2026; Sanctuary of Lourdes, 2024; Shrine of Fátima, 2026; Vatican News, 2026).

2.5. Research gap

The literature demonstrates that alternative tourism has evolved into an increasingly important direction of contemporary tourism development**,** reflecting the growing demand for sustainable, authentic, experience-based and well-being-oriented travel. Classical tourism theories have established the conceptual foundations for understanding tourism as a multidimensional socio-economic and cultural phenomenon (Cohen, 1984; Smith, 1989; Jafari, 2001; Panosso Netto, 2007), while more recent studies have linked alternative tourism to sustainable development, destination resilience and tourism diversification (Weaver, 2006; Hall, 2019; Jovanović & Živković, 2018; Solarin et al., 2024). Simultaneously, the rapid expansion of wellness, retreat, rural, nature-based and spiritual tourism has demonstrated that tourism demand is increasingly driven by health, authenticity, personal development, environmental responsibility and meaningful experiences rather than traditional leisure consumption (Smith & Puczkó, 2014; Kelly, 2010; Buckley, 2023; Global Wellness Institute, 2025).

Despite these advances, the existing literature remains highly fragmented. Most studies **investigate individual forms of alternative tourism** independently, including wellness tourism (Smith & Puczkó, 2014), retreat tourism (Kelly, 2010), rural tourism (Đorđević-Milošević et al., 2020), ecotourism (Jovanović & Živković, 2018), mindfulness tourism (McClintock et al., 2019), digital detox tourism (Quaye, 2025), cultural tourism (Korstanje, 2012), or nature-based tourism (Buckley, 2023). Although these contributions substantially improve understanding of specific tourism segments, they rarely examine the conceptual and market interrelationships among these forms or explain how they collectively constitute the broader phenomenon of alternative tourism. As a result, alternative tourism is frequently treated as an umbrella concept without a sufficiently integrated analytical framework capable of explaining its internal structure and contemporary evolution.

A second limitation concerns the conceptual ambiguity surrounding the definition and boundaries of alternative tourism. While the literature generally agrees that alternative tourism differs from conventional mass tourism through its emphasis on sustainability, authenticity and individualized experiences, there is no consensus regarding which tourism forms should be included within this concept. Considerable overlap exists among wellness tourism, retreat tourism, spiritual tourism, sacred tourism, transformational tourism, nature-based tourism and health tourism (Bushell & Sheldon, 2009; Kelly & Smith, 2009; Kelly, 2010; Smith & Puczkó, 2014; Buckley, 2023). Consequently, existing classifications often employ inconsistent terminology or analyse these tourism forms separately without clarifying their conceptual relationships. This lack of conceptual integration limits comparative research and complicates the measurement of alternative tourism as a coherent market.

Another important limitation concerns the predominant focus on conceptual, psychological or destination-level analyses, while comparatively little attention has been devoted to market-oriented investigations of alternative tourism. Numerous studies examine tourist motivations, psychological outcomes, sustainability principles or destination management (Kelly, 2010; Jovanović & Živković, 2018; McClintock et al., 2019; Buckley, 2023), whereas market reports primarily estimate industry size and growth without providing an integrated conceptual interpretation of alternative tourism (Market.us, 2025; Future Market Insights, 2025). Consequently, relatively few studies combine conceptual tourism theory with statistical evidence capable of demonstrating how alternative tourism develops across different tourism segments and geographical contexts. This separation between theoretical and market-oriented research restricts a comprehensive understanding of alternative tourism as an evolving economic system.

A further limitation concerns the measurement of alternative tourism, particularly within the European Union. Official statistical systems, including Eurostat, do not classify alternative tourism as an independent tourism category. Instead, information is distributed across multiple statistical domains, including wellness tourism,

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platform-based accommodation, rural tourism, protected areas, pilgrimage destinations, cycling tourism and other specialized tourism activities (Eurostat, 2026a, 2026b; Global Wellness Institute, 2025; European Parliamentary Research Service, 2023). Consequently, the overall development of alternative tourism cannot be evaluated through a single statistical indicator but requires the integration of multiple measurable tourism segments. Despite the availability of these datasets, relatively few academic studies have attempted to combine them into a unified analytical framework capable of assessing the overall development of alternative tourism markets across European Union countries.

Moreover, although several studies investigate tourism diversification as a determinant of economic growth or destination competitiveness (Solarin et al., 2024; Ursache, 2015; Stoiljković et al., 2025), they generally focus on single destinations, individual countries or specific tourism products rather than undertaking comparative analyses across the European Union. Existing research therefore provides limited understanding of how EU member states differ in their specialization, comparative advantages and market structure with respect to alternative tourism. Comparative evidence remains fragmented across wellness tourism, agritourism, pilgrimage tourism, nature-based tourism and digital tourism, while relatively little attention has been devoted to analysing these segments collectively as components of one diversified tourism market.

Therefore, the present study seeks to address these gaps by conceptualizing alternative tourism as a diversified system of measurable and interconnected tourism segments rather than as a single tourism activity. Unlike previous studies that focus on individual tourism forms or isolated destination case studies, this research integrates conceptual tourism theory with official statistical indicators, market evidence and country-level examples to examine the development of alternative tourism across the EU. Particular attention is devoted to wellness, spa and thermal tourism, rural tourism and agritourism, nature-based tourism, adventure tourism, platform-based accommodation, pilgrimage and spiritual tourism, which collectively represent the principal measurable components of the contemporary alternative tourism market.

3. Conceptual framework for understanding alternative tourism and research methodology

The conceptual framework proposed in this study conceptualizes alternative tourism as a multidimensional tourism system that has emerged through the diversification of contemporary tourist demand and the transition from standardized mass tourism toward more personalized, sustainable, authentic, and transformative travel experiences (Jafari, 2001; Hall, 2019; OECD, 2026). Rather than representing a single tourism product, alternative tourism constitutes an umbrella concept encompassing multiple interconnected market segments that share common sustainability-oriented values while differing in their dominant motivations, tourism activities, and market characteristics (Ursache, 2015).

The framework is grounded in several complementary theoretical perspectives. General Systems Theory views tourism as an open system composed of interdependent elements whose interactions determine overall system performance (Bertalanffy, 1968/2015). This systems perspective is complemented by Leiper's Tourism System Model, which conceptualizes tourism through the relationships among tourist-generating regions, transit routes, destinations, tourists, and the tourism industry (Leiper, 1979). Jafari's knowledge-based platform further demonstrates the evolution of tourism scholarship from advocacy and cautionary approaches toward more balanced, scientific, and sustainability-oriented perspectives (Jafari, 2001). Similarly, Butler's Tourism Area Life Cycle (TALC) explains the dynamic evolution of destinations through successive stages of exploration, involvement, development, consolidation, stagnation, and potential rejuvenation or decline (Butler, 2006). Collectively, these theories explain tourism as a complex socio-economic system but provide only limited insight into the rapidly expanding diversification of alternative tourism markets.

Within this framework, alternative tourism represents the central analytical construct integrating multiple specialized tourism segments. These include wellness tourism, spiritual (sacral) tourism, retreat tourism, ecotourism, cultural tourism, rural tourism, adventure tourism, and other forms of niche tourism (Smith & Puczkó, 2014; Ursache, 2015; Hall, 2019; Market.us, 2025). Although these tourism forms differ in their products and experiences, they are connected by several common principles:
• sustainability and responsible resource management;

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• authenticity of tourism experiences;
• meaningful interaction with local communities and cultures;
• enhancement of physical, psychological, and emotional well-being;
• personal learning, self-development, and transformation.

The framework further proposes that the diversification of alternative tourism is primarily driven by changing tourist motivations. Contemporary travellers increasingly seek experiences extending beyond traditional recreation toward physical health, psychological restoration, mindfulness, cultural immersion, environmental responsibility, digital disconnection, spirituality, and self-realization (Bushell & Sheldon, 2009; Kelly & Smith, 2009; McClintock et al., 2019; Dillette et al., 2020). These evolving motivations stimulate demand for increasingly specialized tourism experiences and facilitate the emergence of new market segments, particularly wellness tourism, retreat tourism, transformational tourism, and spiritual tourism (Global Wellness Institute, 2025, 2026).

At the destination level, the development of alternative tourism depends on a combination of destination resources and enabling conditions, including natural and cultural assets, tourism infrastructure, accessibility, institutional support, governance quality, environmental sustainability, innovation, and digital technologies (Hall, 2019; European Travel Commission, 2025; OECD, 2026). These destination characteristics determine the ability of regions to develop competitive alternative tourism products while balancing economic development with environmental protection and community well-being.

The interaction between tourist motivations, destination capabilities, and tourism management practices generates multiple measurable outcomes across four interrelated dimensions. Economic outcomes include regional income generation, employment creation, tourism competitiveness, destination resilience, and diversification of tourism markets (OECD, 2026; European Travel Commission, 2025). Social outcomes encompass community participation, preservation of cultural heritage, social cohesion, and improvements in residents' quality of life (Hall, 2019). Environmental outcomes involve sustainable resource management, biodiversity conservation, reduced tourism pressure through spatial and seasonal dispersion, and support for sustainable regional development (Hall, 2019). Finally, individual outcomes include improvements in physical health, psychological well-being, life satisfaction, mindfulness, emotional recovery, and personal transformation (Bushell & Sheldon, 2009; McClintock et al., 2019; Dillette et al., 2020).

An important feature of the framework is the recognition that the individual segments of alternative tourism are highly interconnected rather than mutually exclusive. Wellness tourism increasingly incorporates mindfulness, spirituality, and nature-based experiences (Smith & Puczkó, 2014; Dillette et al., 2020). Retreat tourism frequently combines wellness, spiritual, cultural, and transformational elements within a single tourism product (Kelly & Smith, 2009). Similarly, cultural, rural, and ecotourism often integrate wellness-oriented activities and sustainable tourism practices, creating hybrid tourism experiences that respond to increasingly diverse visitor expectations (Hall, 2019; OECD, 2026).

Consequently, this study conceptualizes alternative tourism as an integrated, dynamic, and evolving tourism ecosystem composed of interconnected market segments whose development reflects the interaction between changing tourist motivations, destination resources, institutional support, and sustainability-oriented management practices (Figure 1).

To examine the proposed conceptual framework, the study adopts a mixed conceptual–empirical research design that integrates systems thinking with comparative market analysis. Given that alternative tourism is not recognized as a separate statistical category in official European tourism statistics, the empirical assessment is based on the analysis of multiple measurable tourism segments that collectively represent the contemporary alternative tourism market. This methodological approach reflects the multidimensional nature of alternative tourism and enables its development to be assessed through a combination of official statistical indicators, institutional market reports, and country-level evidence rather than through a single aggregate variable.

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The empirical analysis relies primarily on secondary data obtained from official statistical agencies and internationally recognized organizations, including Eurostat, the Global Wellness Institute, the European Travel Commission, the OECD, the European Parliamentary Research Service, ISTAT, Metsähallitus, and the official statistical services of major European pilgrimage destinations. These sources provide harmonized information on tourism expenditure, tourist flows, accommodation demand, infrastructure development, visitor numbers, and economic impacts across different tourism segments. Preference was given to official datasets with continuous annual observations covering the post-pandemic recovery period, thereby enabling the identification of medium-term market trends rather than short-term fluctuations.

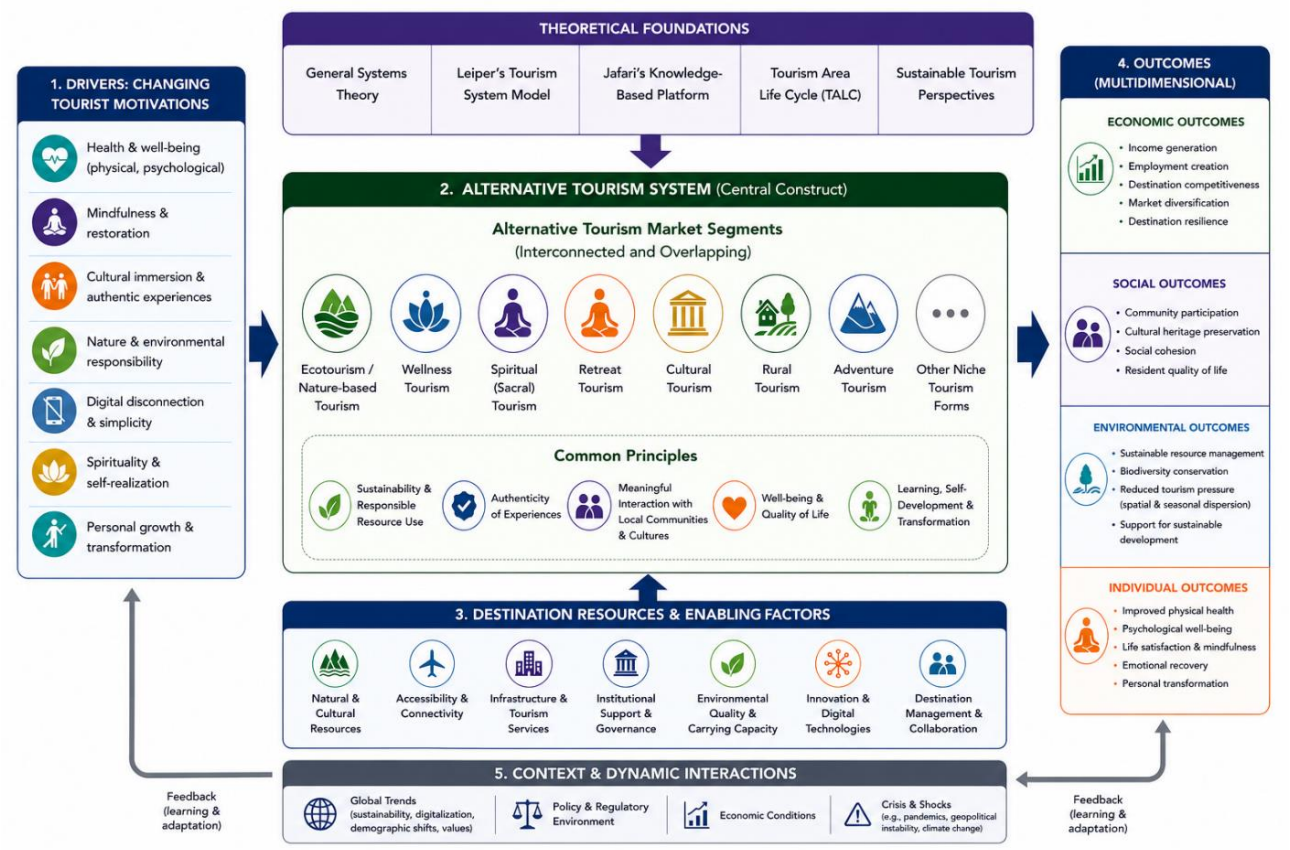


Figure 1. Conceptual framework for understanding alternative tourism: a multidimensional and interconnected tourism system
Source: elaborated by the authors based on Jafari (2001), Hall (2019) and OECD (2026).

Following the conceptual framework presented in Figure 1, the empirical analysis operationalizes alternative tourism through six principal market segments that represent the most measurable and economically significant manifestations of alternative tourism within the European Union: (1) wellness tourism; (2) spa and thermal tourism; (3) platform-based accommodation; (4) rural tourism and agritourism; (5) nature-based tourism; and (6) pilgrimage and spiritual tourism. For each segment, comparable quantitative indicators were analysed, including tourism expenditure, visitor numbers, overnight stays, infrastructure development, accommodation capacity, and selected measures of regional economic impact. Where appropriate, country-level comparisons were incorporated to illustrate differences in market specialization and development trajectories among EU countries.

Rather than attempting to estimate the overall size of the alternative tourism market directly, the study evaluates the consistency of development across its constituent segments. This approach is consistent with the systems perspective underlying the conceptual framework, according to which alternative tourism should be understood as an integrated ecosystem of interconnected market segments rather than as a homogeneous tourism product. Consequently, empirical validation focuses on identifying common patterns of market expansion,

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diversification, and structural transformation across multiple tourism segments. Particular attention is paid to the relationships between changing tourist motivations, destination resources, measurable market outcomes, and broader economic, social, and environmental implications.

The empirical findings presented in the following section therefore do not seek to test causal relationships through econometric modelling. Instead, they provide cumulative empirical evidence supporting the conceptual proposition that alternative tourism in the European Union has evolved into an interconnected system of measurable tourism markets characterized by sustained diversification and long-term growth. By integrating evidence from multiple independent datasets, the analysis enables a comprehensive assessment of how the principal segments of alternative tourism collectively contribute to the transformation of the contemporary European tourism industry.

4. Empirical evidence supporting the conceptual framework

The conceptual framework presented in Figure 1 proposes that alternative tourism develops through the interaction between changing tourist motivations, destination resources, market segmentation, and multidimensional sustainability outcomes. To provide empirical support for this conceptual model, official statistical sources and institutional datasets were analysed across the principal segments of alternative tourism in the European Union. Although no single statistical category exists for "alternative tourism", the combined evidence demonstrates consistent expansion across multiple tourism segments, confirming that alternative tourism represents an increasingly important component of the European tourism market rather than a collection of isolated niche activities.

4.1. Growth of wellness tourism

Among all alternative tourism segments, wellness tourism demonstrates one of the strongest and most stable growth trajectories. According to the Global Wellness Institute, wellness tourism expenditure in the EU increased from USD 202.5 billion in 2019 to USD 258.2 billion in 2024, representing an increase of 27.5%, while the number of wellness trips rose from 324.0 million to 348.4 million during the same period. Simultaneously, average expenditure per trip increased from USD 625 to USD 741, indicating not only increasing visitor numbers but also higher tourist spending. Furthermore, all five largest EU wellness markets exceeded their pre-pandemic levels by 2024, while approximately 79% of all wellness trips remained domestic, suggesting that market expansion reflects structural changes in travel behaviour rather than temporary recovery of international tourism (Table 1).

Table 1. Development of wellness tourism in the EU, 2019–2024

Year	Expenditure, USD billion	Wellness trips, million	Average expenditure per trip, USD
2019	202.5	324.0	625.0
2020	102.0	174.0	586.2
2021	139.7	222.5	627.9
2022	188.0	293.0	641.6
2023	232.7	327.1	711.4
2024	258.2	348.4	741.1

Source: compiled by the authors based on Global Wellness Institute (2025).

Following the aggregate EU trends, the Global Wellness Institute also provides comparable country-level expenditure data for the five largest wellness tourism markets within the European Union (Table 2). These data demonstrate that the expansion of wellness tourism is not concentrated in a single destination but represents a widespread phenomenon across the leading European tourism economies.

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Table 2. Wellness tourism expenditure in the largest EU markets, USD billion, 2019–2024

Country	2019	2020	2021	2022	2023	2024
France	35.3	22.2	28.8	34.5	41.5	45.6
Germany	36.3	16.3	23.9	28.9	37.3	40.6
Italy	14.6	7.2	10.5	13.0	18.5	20.0
Spain	11.1	3.5	6.1	11.5	14.6	16.7
Austria	15.7	9.7	9.1	13.5	16.4	18.3

Source: compiled by the authors based on Global Wellness Institute (2025).

The country-level evidence demonstrates that by 2024 all five largest EU wellness tourism markets had exceeded their pre-pandemic expenditure levels. Spain recorded the strongest recovery and expansion, with expenditure increasing by 50.5% compared with 2019, followed by Italy (+37.0%), France (+29.2%), Austria (+16.6%), and Germany (+11.8%). These findings indicate that the growth of wellness tourism is geographically widespread rather than concentrated within a limited number of destinations, thereby supporting the conceptualization of wellness tourism as one of the principal and mature segments of the alternative tourism market in the European Union. Furthermore, the European market remains predominantly domestic, with 273.6 million domestic wellness trips (79%) compared with 74.7 million international trips (21%) in 2024. This distribution suggests that the observed market expansion is driven primarily by structural changes in travel behaviour and increasing domestic demand for health- and well-being-oriented experiences, rather than solely by the recovery of international tourism.

Additional evidence highlighting the economic significance of wellness tourism is provided through a comparison with the overall tourism market (Table 3). At the global level, wellness tourism expenditure increased from USD 655.1 billion in 2019 to USD 893.9 billion in 2024, corresponding to an index of 136.4 (2019 = 100), whereas total tourism expenditure increased from USD 4,608.6 billion to USD 5,066.5 billion, corresponding to an index of only 109.9. Consequently, the compound annual growth rate (CAGR) of wellness tourism reached 6.4%, more than three times higher than the average annual growth rate of the overall tourism industry (1.9%). Moreover, average expenditure per wellness trip reached USD 721 in 2024, compared with only USD 340 for tourism overall.

Table 3. Global comparison of wellness tourism and the overall tourism market, 2019–2024

Indicator	Wellness tourism	Overall tourism
Expenditure in 2019, USD billion	655.1	4608.6
Expenditure in 2024, USD billion	893.9	5066.5
Index 2024/2019, %	136.4	109.9
CAGR 2019–2024, %	6.4	1.9
Average expenditure per trip in 2024, USD.	721	340

Source: compiled by the authors based on Global Wellness Institute (2025).

The comparative analysis confirms that wellness tourism is not merely expanding alongside the broader tourism industry but is developing substantially faster and generating considerably higher visitor expenditure. According to the Global Wellness Institute, wellness tourism grew more than three times faster than the global tourism market during 2019–2024, while average expenditure per trip was more than twice as high. In 2024, international wellness travellers spent on average 38% more than conventional international tourists, whereas domestic wellness travellers spent approximately 137% more than their counterparts travelling for general tourism purposes.

Collectively, these findings provide strong empirical support for the conceptual framework by demonstrating that wellness tourism constitutes a rapidly expanding, high-value segment of alternative tourism. The sustained growth in expenditure, tourist flows, and average spending per trip indicates that changing tourist motivations–particularly the increasing emphasis on health, well-being, self-care, and transformational experiences–are

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being translated into measurable market expansion. Consequently, wellness tourism represents one of the principal drivers of the contemporary diversification of alternative tourism within the EU.

4.2. Expansion of spa and thermal tourism

The empirical evidence further demonstrates the continuing development of spa and thermal tourism, representing one of the principal market manifestations of wellness-oriented travel. Between 2019 and 2024, European spa-sector revenue increased by 30.3%, while the number of spa establishments grew by 13.5%. Thermal and mineral spring tourism also exhibited positive dynamics, with total revenue increasing by 16.5%, despite the number of operating facilities remaining almost unchanged (Table 4). This indicates that market growth has been driven primarily by increasing visitor expenditure and improved economic performance rather than by simple expansion of physical infrastructure.

Table 4. Growth of spa and thermal tourism in Europe, 2019–2024

Indicator	2019	2024	Growth
Spa sector revenue, USD billion	43.61	56.83	+30.3%
Spa establishments	59,696	67,739	+13.5%
Thermal/mineral spring revenue, USD billion	25.20	29.35	+16.5%
Thermal facilities	6,482	6,536	+0.8%

Source: compiled by the authors based on Global Wellness Institute (2025).

Comparable annual data for the five largest European Union spa markets further demonstrate that the expansion of the spa sector has occurred across the major tourism economies rather than being limited to a few destinations (Table 5). Germany remained the largest spa market throughout the study period, with revenue increasing from USD 8.28 billion in 2019 to USD 10.02 billion in 2024. France recorded the strongest growth among the five largest markets (+41.4%), followed by Austria (+36.2%), while Italy and Spain also exceeded their pre-pandemic revenue levels by 2024. These findings indicate that spa tourism has become an increasingly important component of wellness-oriented travel across the European Union.

Table 5. Comparative annual spa sector revenue in the five largest EU markets, USD billion, 2019–2024

Country	2019	2020	2021	2022	2023	2024
Germany	8.28	6.10	5.85	7.90	8.79	10.02
France	5.27	3.41	3.92	5.19	6.38	7.45
Italy	4.09	2.11	2.27	3.35	4.62	4.82
Spain	3.31	1.73	1.98	2.92	3.36	3.78
Austria	2.32	1.30	1.28	2.15	2.73	3.16

Source: compiled by the authors based on Global Wellness Institute (2025).

Thermal and mineral spring tourism demonstrates a similar pattern of long-term expansion. Between 2019 and 2024, total European revenue increased from USD 25.2 billion to USD 29.35 billion, whereas the number of facilities remained virtually unchanged (6,482 and 6,536 establishments, respectively) (Global Wellness Institute, 2025). Consequently, the observed growth was driven primarily by higher revenues generated by existing facilities rather than by expansion of infrastructure, suggesting improvements in visitor expenditure, service quality, and operational efficiency.

Comparable country-level statistics further illustrate the differentiated development of thermal tourism across the European Union (Table 6). Germany remained by far the largest thermal tourism market, with revenue increasing from USD 7.78 billion to USD 8.51 billion between 2019 and 2024. Among the remaining leading markets, Hungary (+31.9%), Slovakia (+32.1%), and Romania (+23.6%) recorded the strongest overall growth, whereas Spain (-5.0%) and France (-1.5%) had not yet fully recovered to their pre-pandemic revenue levels by 2024. These differences suggest that although thermal tourism exhibits positive long-term development across

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Europe, national markets continue to recover at different rates depending on destination characteristics and market conditions.

Table 6. Comparative annual revenue of thermal and mineral springs in the ten largest EU markets, USD billion, 2019–2024

Country	2019	2020	2021	2022	2023	2024
Germany	7.78	4.86	5.17	6.63	7.34	8.51
Italy	1.79	1.01	1.33	1.49	1.71	1.95
Hungary	1.19	0.54	0.74	1.07	1.38	1.57
Austria	0.99	0.66	0.62	0.95	1.08	1.12
Czechia	0.75	0.42	0.39	0.60	0.88	0.91
Poland	0.71	0.47	0.57	0.70	0.83	0.79
Spain	0.80	0.41	0.49	0.67	0.79	0.76
Slovakia	0.53	0.35	0.36	0.46	0.57	0.70
Romania	0.55	0.28	0.31	0.43	0.64	0.68
France	0.68	0.22	0.43	0.52	0.63	0.67

Source: compiled by the authors based on Global Wellness Institute (2025).

The Global Wellness Institute also identifies several structural challenges affecting the future development of spa and thermal tourism in Europe, including rising energy prices, labour shortages, ageing infrastructure, and regulatory constraints. Nevertheless, global projections for 2024–2029 remain highly favourable, with compound annual growth rates of 7.7% for the spa sector and 10.0% for thermal and mineral spring tourism, indicating strong long-term market potential despite current operational challenges. It should be noted, however, that these forecasts refer to global markets rather than specifically to the European Union.

Collectively, these findings provide strong empirical support for the conceptual framework by demonstrating that spa and thermal tourism constitute economically significant and steadily expanding segments of alternative tourism. The observed growth patterns indicate that natural therapeutic resources, specialised infrastructure, and wellness-oriented services are increasingly transformed into high-value tourism products, contributing simultaneously to destination competitiveness, regional economic development, and the diversification of the European alternative tourism market.

4.3. Digital transformation through platform-based accommodation

Digital platforms have become an increasingly important component of contemporary alternative tourism by facilitating flexible, decentralized, and experience-oriented forms of accommodation. The rapid expansion of collaborative economy platforms has significantly increased the accessibility of rural, cultural, coastal, and niche tourism destinations, thereby supporting the diversification of tourism products throughout the EU.

Official Eurostat statistics demonstrate a remarkable increase in platform-based short-stay accommodation during the post-pandemic period. The number of overnight stays booked through collaborative economy platforms increased from 512 million in 2019 to 952 million in 2025, representing an overall growth of 85.9% (Table 7). Although demand declined substantially during the COVID-19 pandemic, falling to 272 million overnight stays in 2020, the sector recovered rapidly, exceeding pre-pandemic levels already in 2022. By 2025, platform-based accommodation had reached an index of 185.9 (2019 = 100), indicating that overnight stays were almost twice as high as before the pandemic. This pattern illustrates not only recovery but also a structural transformation in accommodation preferences among European travellers.

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Table 7. Platform-based short-stay accommodation in the EU, 2019–2025

Year	Overnight stays, million	Index, 2019=100
2019	512	100.0
2020	272	53.1
2021	364	71.1
2022	597	116.6
2023	719	140.4
2024	854	166.8
2025	952	185.9

Source: compiled by the authors based on Eurostat (2026b).

The country-level distribution further illustrates the unequal but widespread adoption of collaborative accommodation platforms across the European Union (Table 8). France remained the largest market in 2025 with 213 million overnight stays, followed by Spain (189 million) and Italy (139 million). Together, these three countries accounted for more than half of all overnight stays recorded among the largest national platform markets in the European Union, highlighting the dominant role of Southern and Western European tourism destinations within the collaborative accommodation economy. Germany ranked fourth with 68 million overnight stays, while Greece and Portugal also demonstrated substantial platform activity, reflecting the importance of digital accommodation services in Mediterranean tourism destinations.

Table 8. Overnight stays through collaborative accommodation platforms in the largest EU markets, million, 2025

Country	Overnight stays, million
France	213
Spain	189
Italy	139
Germany	68
Greece	52
Portugal	50
Poland	44
Croatia	42
Austria	25
Belgium	13
Hungary	13
Czechia	12
Netherlands	12
Romania	10

Source: compiled by the authors based on Eurostat (2026b).

The most recent annual statistics also indicate that the market continues to expand rapidly. In 2025, Poland recorded the highest annual growth among the leading markets (+13.8%), followed by Germany (+13.0%), Spain (+11.1%), and France (+10.5%). These results suggest that collaborative accommodation platforms continue to penetrate both mature tourism destinations and emerging regional markets, thereby contributing to the geographical diversification of tourism demand throughout the European Union.

Collectively, these findings provide empirical evidence that digital platforms have become an important enabling mechanism for the expansion of alternative tourism. Rather than simply increasing accommodation capacity, collaborative platforms facilitate access to authentic local experiences, rural destinations, cultural attractions, and niche tourism products that are frequently unavailable through traditional hotel infrastructure.

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Consequently, platform-based accommodation contributes to the diversification of tourism supply, enhances destination accessibility, and strengthens the competitiveness of regional tourism systems. Within the proposed conceptual framework, these findings demonstrate how digital innovation functions as an enabling factor connecting changing tourist preferences with the continued expansion of alternative tourism market segments across the EU.

4.4. Rural tourism and agritourism

Rural tourism and agritourism represent important components of alternative tourism by promoting authentic visitor experiences, supporting local communities, and contributing to sustainable regional development. Unlike mass tourism, these forms of tourism emphasize close interaction with rural environments, agricultural traditions, local culture, and regional food systems. Consequently, they play an important role in diversifying tourism products while simultaneously generating additional income opportunities for rural areas.

Official statistics from the Italian National Institute of Statistics (ISTAT) provide one of the most comprehensive longitudinal datasets on agritourism development within the European Union. Between 2014 and 2024, the number of officially registered agritourism farms increased from 21,744 to 26,360, representing an overall growth of 21.2% (Table 9). Despite temporary disruptions associated with the COVID-19 pandemic, the long-term trend demonstrates continuous expansion of the agritourism sector, indicating increasing demand for rural tourism experiences and successful adaptation of agricultural enterprises to tourism activities.

Table 9. Development of agritourism farms in Italy, 2014–2024

Year	Agritourism farms	Status
2014	21,744	Official
2015	22,238	Official
2017	23,406	Official
2020	25,060	Official
2022	25849	Official
2023	26,129	Official
2024	26,360	Official

Source: compiled by the authors based on ISTAT (2018, 2025).

The long-term perspective provided by ISTAT further illustrates the structural expansion of agritourism within Italy. The number of agritourism establishments increased from just over 14,000 in 2004 to approximately 26,000 by 2022, demonstrating that agritourism has evolved from a relatively niche activity into a well-established component of the national tourism economy. In 2024 alone, Italian agritourism establishments welcomed approximately 4.7 million visitors, representing a 4.3% increase compared with 2023, while the economic value generated by the sector increased by 3.3%. These indicators suggest that the sector continues to expand not only in terms of supply but also in visitor demand and economic performance.

Although Italy provides one of the most reliable official datasets on agritourism in Europe, caution is required when generalising these findings to rural tourism as a whole. According to Eurostat methodology, the most appropriate official proxy for rural tourism at the European level is the number of overnight stays in accommodation establishments located within rural areas according to the DEGURBA classification. However, rural tourism and agritourism are not identical concepts. Agritourism specifically refers to tourism activities directly associated with agricultural enterprises, whereas rural tourism encompasses a broader range of accommodation, recreation, cultural, and nature-based activities located in rural regions. Consequently, these two categories should be analysed separately in empirical research to avoid conceptual and statistical inconsistencies.

Collectively, these findings provide empirical support for the conceptual framework by demonstrating that agritourism constitutes a steadily expanding segment of alternative tourism that contributes simultaneously to tourism diversification, rural economic development, and sustainable destination management. The continuous

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increase in the number of agritourism enterprises, visitor arrivals, and economic value illustrates how rural resources and agricultural heritage are increasingly transformed into competitive tourism products responding to growing demand for authentic, locally embedded, and sustainability-oriented travel experiences. Moreover, the distinction between agritourism and rural tourism reinforces the conceptual framework by highlighting the multidimensional nature of alternative tourism, where related but distinct market segments coexist within a broader tourism ecosystem rather than forming a single homogeneous category.

4.5. Nature-based tourism

Nature-based tourism constitutes one of the fastest-growing segments of alternative tourism, reflecting the increasing importance of environmental sustainability, outdoor recreation, and authentic experiences in contemporary tourist behaviour. National parks and protected areas play a central role in this market by simultaneously supporting biodiversity conservation, regional development, and visitor well-being. Consequently, nature-based tourism represents an important intersection between environmental protection and sustainable tourism development.

Finland provides one of the most comprehensive official longitudinal datasets for analysing the development of nature-based tourism within Europe. According to Metsähallitus, annual visits to Finnish national parks increased from approximately 2.6 million in 2015 to more than 3.5 million in 2025, representing an overall increase of more than 35% during the study period (Table 10). Visitor numbers grew steadily until 2019, followed by a temporary peak of approxima tely 4 million visits in both 2020 and 2021. This exceptional increase was largely associated with the COVID-19 pandemic, when restrictions on international travel stimulated domestic demand for outdoor recreation and nature-oriented tourism. Although visitation declined slightly after the pandemic, the number of visitors remained substantially above the pre-pandemic level, indicating a lasting increase in interest in nature-based tourism rather than a temporary behavioural change.

Table 10. Visits to Finnish national parks, 2015–2025

Year	Visits, million	Note
2015	2.6	Official annual series (rounded)
2016	2.8	Official annual series (rounded)
2017	3.1	Official annual series (rounded)
2018	3.2	Official annual series (rounded)
2019	3.2	Official annual series (rounded)
2020	4.0	Official annual series (rounded)
2021	4.0	Official annual series (rounded)
2022	3.6	Official annual series (rounded)
2023	3.6	Official annual series (rounded)
2024	3.6	Official annual series (rounded)
2025	3.5	Official annual series (rounded)

Source: compiled by the authors based on Metsähallitus (2025a).

An even more important finding concerns the economic contribution of nature-based tourism. During the same period, the estimated local economic impact generated by Finnish national parks increased from €142 million in 2015 to €277.9 million in 2025, corresponding to an increase of approximately 96%. The economic impact therefore expanded almost three times faster than visitor numbers, suggesting that growth was driven not only by increasing visitation but also by higher visitor expenditure, greater consumption of local tourism services, and stronger regional economic multiplier effects. These findings indicate that protected natural areas generate increasing economic value while maintaining their primary environmental functions.

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Table 11. Nature-based tourism and local economic impact in Finnish national parks

Indicator	2015	2025	Change
National park visits, million	2.6	3.5	>35%
Local economic impact, € million	142.0	277.9	≈96%

Source: compiled by the authors based on Metsähallitus (2025b).

These results demonstrate that nature-based tourism contributes not only to increasing visitor numbers but also to improving regional economic performance. The substantially faster growth of economic impact relative to physical visitation indicates higher tourist spending and greater value creation for local communities, thereby illustrating the increasing economic efficiency of protected-area tourism. Such findings provide empirical evidence that investments in natural capital and sustainable destination management can simultaneously generate environmental, social, and economic benefits.

Collectively, these findings provide strong empirical support for the conceptual framework by demonstrating how natural resources are transformed into sustainable tourism products that generate measurable multidimensional outcomes. The continuous growth of visitor numbers, together with the disproportionately larger increase in regional economic benefits, illustrates the interaction between destination resources, changing tourist preferences for nature-oriented experiences, and sustainable regional development. Consequently, nature-based tourism represents one of the clearest examples of how alternative tourism contributes simultaneously to environmental conservation, economic resilience, and the long-term competitiveness of tourism destinations.

4.6. Pilgrimage and spiritual tourism

Pilgrimage and spiritual tourism represent one of the oldest yet continuously evolving segments of alternative tourism. While historically associated primarily with religious practice, contemporary pilgrimage increasingly combines spiritual reflection, cultural heritage, personal development, and experiential travel. Consequently, pilgrimage tourism occupies an important position within the broader system of alternative tourism by integrating spiritual motivations with cultural, wellness, and transformational travel experiences.

Among European pilgrimage destinations, the Camino de Santiago provides the most comprehensive official longitudinal dataset for analysing long-term development trends. According to the Pilgrim's Reception Office of the Cathedral of Santiago de Compostela, the number of pilgrims receiving the Compostela certificate increased from 183,366 in 2011 to 530,987 in 2025, representing almost a 2.9-fold increase over the study period (Table 12). Excluding the exceptional decline during the COVID-19 pandemic in 2020, the data reveal a remarkably stable long-term upward trend. Compared with the last pre-pandemic year (2019), the number of registered pilgrims increased by 52.8%, indicating that pilgrimage tourism has not only recovered but has substantially exceeded its previous level of development.

Table 12. Registered pilgrims receiving the Compostela certificate on the Camino de Santiago, 2010–2025

Year	Registered pilgrims	Index, 2010=100
2010	272,135	100.0
2011	183,366	67.4
2012	192,488	70.7
2013	215,880	79.3
2014	237,886	87.4
2015	262,516	96.5
2016	277,854	102.1
2017	301,036	110.6
2018	327,378	120.3
2019	347,578	127.7

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Year	Registered pilgrims	Index, 2010=100
2020	54,144	19.9
2021	178,912	65.7
2022	438,307	161.1
2023	446,035	163.9
2024	499,239	183.5
2025	530,987	195.1

Source: compiled by the authors based on Cathedral of Santiago de Compostela (2026).

The broader European context demonstrates that the expansion of pilgrimage tourism is not limited to the Camino de Santiago. Official statistics from several of Europe's largest pilgrimage destinations reveal consistently high visitor numbers across different countries (Table 13). The Sanctuary of Lourdes welcomed 3.2 million pilgrims in 2024, while the Shrine of Fátima received 6.5 million visitors in 2025, making it one of the world's largest pilgrimage destinations. Similarly, Poland's Jasna Góra sanctuary attracted 4.2 million pilgrims in 2025, following steady annual growth from 2.5 million visitors in 2022. These data demonstrate that large-scale pilgrimage flows are characteristic of multiple European destinations rather than representing an isolated phenomenon associated with a single pilgrimage route.

Table 13. Visitor numbers at selected European pilgrimage destinations

Pilgrimage centre	Year	Pilgrims/visitors, million
Lourdes (France)	2021	1.6
Lourdes (France)	2022	2.7
Lourdes (France)	2023	3.1
Lourdes (France)	2024	3.2
Fátima (Portugal)	2024	6.2
Fátima (Portugal)	2025	6.5
Jasna Góra (Poland)	2022	2.5
Jasna Góra (Poland)	2023	3.6
Jasna Góra (Poland)	2025	4.2

Source: compiled by the authors based on official statistics of Lourdes, Fátima and Jasna Góra sanctuaries.

The long-term expansion observed across these destinations suggests that pilgrimage tourism has become an increasingly significant component of the contemporary European tourism market. While religious motivations remain fundamental for many pilgrims, the sustained growth of pilgrimage routes and sacred destinations also reflects broader social trends, including the search for authenticity, personal meaning, cultural identity, mindfulness, and transformative travel experiences. These motivations increasingly overlap with those characterising wellness tourism, retreat tourism, and other forms of alternative tourism, thereby illustrating the growing interconnectedness of alternative tourism market segments.

Collectively, these findings provide strong empirical support for the conceptual framework by demonstrating that pilgrimage and spiritual tourism constitute dynamic and expanding segments of alternative tourism rather than static forms of traditional religious travel. The continuous increase in pilgrimage flows across multiple European destinations illustrates how changing tourist motivations are translated into measurable market growth while simultaneously contributing to cultural heritage preservation, regional economic development, and the diversification of tourism products. These results further support the conceptualisation of alternative tourism as an integrated system of interconnected market segments responding to evolving demands for meaningful, authentic, and transformative travel experiences.

The empirical evidence presented in this section provides strong support for the proposed conceptual framework of alternative tourism. Although the EU does not maintain a single official statistical category for alternative

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tourism, the consistent expansion observed across multiple independent market segments–including wellness tourism, spa and thermal tourism, platform-based accommodation, agritourism, nature-based tourism, and pilgrimage tourism–demonstrates that alternative tourism constitutes a measurable and rapidly developing component of the contemporary tourism economy. The analysed datasets reveal common development patterns despite differences in tourism products, destinations, and statistical indicators. In particular, the sustained growth in visitor numbers, tourism expenditure, accommodation demand, and regional economic impacts indicates that the diversification of alternative tourism is driven by changing tourist motivations, including increasing demand for health and well-being, authenticity, sustainability, nature-based experiences, spirituality, and personal transformation. At the same time, the empirical findings demonstrate that destination-specific natural, cultural, and digital resources are increasingly being transformed into competitive tourism products that generate measurable economic, social, and environmental outcomes. Consequently, the results confirm the central proposition of the conceptual framework that alternative tourism should be understood not as a collection of isolated niche activities but as an integrated and interconnected system of tourism market segments whose simultaneous development reflects the broader structural transformation of tourism across the EU.

Beyond the currently established market segments, the empirical evidence also suggests further diversification of alternative tourism through the emergence of digital and virtual tourism. Although this segment cannot yet be incorporated into the main empirical analysis because available market estimates are based on different product definitions and are therefore not directly comparable with official tourism statistics, existing industry forecasts indicate considerable future growth potential. Global Market Insights (n.d.) estimates the virtual tourism market at USD 0.729 billion in 2023 with a projected compound annual growth rate (CAGR) of 26.4% through 2032, while Grand View Research (2025) estimates the market at USD 8.05 billion in 2024 and forecasts expansion to USD 30.54 billion by 2030 (CAGR 24.9%). Despite substantial differences in market size resulting from alternative methodological approaches, both forecasts consistently indicate rapid expansion of digitally enabled tourism experiences. Consequently, virtual tourism should be regarded as an emerging component of alternative tourism that may complement rather than replace traditional travel, extending opportunities for destination interpretation, cultural experiences, education, and accessibility. From the perspective of the proposed conceptual framework, digital and virtual tourism represents a prospective market segment whose future development is likely to further increase the diversification, resilience, and innovation capacity of alternative tourism in the European Union, while requiring separate methodological approaches for empirical assessment due to the current lack of harmonised official statistics.

5. Conclusions

This study examined the development of alternative tourism in the EU by integrating conceptual analysis with empirical evidence from multiple measurable tourism segments. Building upon systems theory, sustainable tourism, and tourism diversification literature, the study proposed a conceptual framework that interprets alternative tourism as an integrated system of interconnected market segments driven by changing tourist motivations, destination resources, and sustainability-oriented tourism management. Unlike traditional approaches that examine individual tourism forms separately, the proposed framework conceptualizes alternative tourism as a dynamic tourism ecosystem in which wellness, spa and thermal, rural, nature-based, platform-based, pilgrimage, spiritual, and other specialized tourism forms interact and collectively contribute to the structural transformation of the contemporary tourism industry.

The empirical analysis provides consistent evidence supporting this conceptualization. Although alternative tourism is not recognised as an independent statistical category within official European tourism statistics, the analysis demonstrates sustained expansion across all principal measurable market segments. Wellness tourism exhibited strong growth in tourist expenditure and visitor spending; spa and thermal tourism continued to expand despite relatively stable infrastructure; collaborative accommodation platforms experienced rapid growth in overnight stays; agritourism and nature-based tourism demonstrated increasing economic importance for rural and protected areas; while pilgrimage tourism showed substantial long-term growth across major European pilgrimage destinations. Considered together, these independent datasets demonstrate that alternative tourism has evolved beyond a collection of isolated niche activities into a diversified and economically significant component of the European tourism market.

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The findings also confirm that the development of alternative tourism reflects broader structural changes in tourism demand. Across different market segments, tourists increasingly seek experiences associated with health and well-being, authenticity, environmental sustainability, cultural immersion, spirituality, personal development, and meaningful engagement with destinations. Simultaneously, destinations increasingly transform natural, cultural, agricultural, spiritual, and digital resources into specialized tourism products that generate measurable economic, social, environmental, and individual outcomes. These common development patterns observed across otherwise distinct tourism segments provide empirical support for the systems-based interpretation proposed in the conceptual framework.

Beyond documenting current market dynamics, the study also identifies important future development prospects. The continued expansion of wellness-related tourism, increasing digitalisation of tourism services, growth of collaborative accommodation platforms, and the emergence of virtual tourism indicate that the diversification of alternative tourism is likely to continue. Although digital and virtual tourism cannot yet be directly integrated into official tourism statistics because of inconsistent market definitions and measurement approaches, available industry forecasts suggest that these technologies may become increasingly important complements to physical travel through destination interpretation, education, cultural engagement, accessibility, and pre-visit experience design. Consequently, the future evolution of alternative tourism is expected to combine traditional place-based experiences with new digitally enabled forms of tourism consumption.

From a theoretical perspective, the principal contribution of this study lies in developing an integrated conceptual framework that bridges the fragmented literature on alternative tourism. Rather than analysing wellness tourism, rural tourism, pilgrimage tourism, or other specialized forms independently, the study demonstrates their conceptual interrelationships within a unified systems perspective. This contributes to a clearer understanding of alternative tourism as a multidimensional tourism ecosystem characterised by overlapping market segments, common sustainability principles, and interconnected development processes.

The study also makes an empirical contribution by demonstrating how alternative tourism can be analysed despite the absence of a single official statistical category. By combining official statistics, institutional datasets, and country-level evidence from multiple tourism segments, the proposed methodological approach provides a practical framework for assessing the development of alternative tourism at both European and national levels. This multidimensional measurement approach may also be applicable to comparative studies in other world regions where alternative tourism similarly lacks harmonised statistical classification.

Several limitations should be acknowledged. First, the empirical analysis relies primarily on secondary data compiled from multiple official and institutional sources that differ in statistical methodology, geographical coverage, and reporting practices. Second, some emerging tourism forms, particularly digital and virtual tourism, currently lack harmonised statistical indicators and therefore cannot be directly compared with traditional tourism measures such as visitor numbers or overnight stays. Third, the study adopts a descriptive and conceptual approach rather than econometric modelling and therefore does not attempt to establish causal relationships between tourist motivations, destination characteristics, and market outcomes.

Future research could extend the proposed framework by developing composite indicators capable of measuring alternative tourism as an integrated market, applying multivariate statistical techniques to analyse relationships among different tourism segments, and undertaking comparative analyses across European regions and other international destinations. Additional research may also examine the growing interactions between digital technologies, artificial intelligence, smart destinations, and alternative tourism, as well as investigate how hybrid tourism products combining wellness, nature-based, cultural, and spiritual experiences continue to reshape tourism development. Such studies would further improve understanding of alternative tourism as one of the principal directions of sustainable and resilient tourism development in the twenty-first century.

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PERSPECTIVE ON DIGITALIZATION IN TOURISM AND DIGITAL NOMADISM: EXAMINING THE GAP BETWEEN IDEAL CONCEPT AND OCCUPATIONAL REALITY*

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Abstract. This study explores the process of digital nomadism transitioning from an ideal concept to a real occupational experience, focusing on the gap between theoretical expectations and market reality. Through an analysis of quantitative data collected from 193 participants from the Slovak general public and workforce, this paper examines how professional specialization, demographic factors, and occupational status influence attitudes toward this lifestyle and its technological requirements. The data were collected anonymously from October 2024 to February 2025, primarily through the professional networking platform LinkedIn. Reflecting the specific dynamics of the Slovak socio-economic environment, the research sample largely comprises members of Generation Z and the millennial cohorts, with a dominant proportion of single female participants and students. To validate the four formulated hypotheses, non-parametric statistical tests (the Kruskal-Wallis and Mann-Whitney U tests) were employed, as the collected data deviated from a normal distribution. The results demonstrate that the perceived suitability for digital nomadism is strongly conditioned by the specific sector of operation; the IT and marketing sectors exhibit the highest levels of professional readiness, whereas administration and education record the lowest compatibility values. Furthermore, the study confirms a statistically significant relationship between the preferred duration of stay and professional status. Students exhibit a tendency to prefer significantly longer stays (an average of 68.4 days) compared to full-time employees (an average of 42.5 days), whose rigid work schedules and institutional constraints shape a transition toward a more stable form of "slowmadism". Additionally, the research reveals that respondents from collaboration-heavy industries (marketing and project management) display a strong preference for community-driven environments, rejecting the physical isolation of solo travel, and require a much more complex digital infrastructure. These professionals manage a more extensive portfolio of communication tools, which significantly increases demands on connection stability and bandwidth. These empirical findings defy the common stereotypes associated with digital nomads as a homogeneous group. Thus, the working reality of modern digital professionals requires specific technological infrastructure and tailored support structures. These insights are essential for the hospitality industry, destination management, and policymakers seeking to attract and retain this highly valuable, flexible, and location-independent global workforce in the era of ongoing digital transformation.

Keywords: digital tourism data; digital nomadism; work-life integration; occupational suitability; professional mobility

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1. Introduction

There is a progressive expansion in the adoption of remote and hybrid work models across various global sectors (Voll et al., 2022). In the post-pandemic period, several destinations responded to the decline in traditional travel by introducing specialized digital nomad visas, positioning this group as a strategic alternative to conventional mass tourism. This shift was largely accelerated by global digital transformation and the widespread normalization of location-independent work, as noted by Matušíková and Šambronská (2021), the pandemic significantly accelerated the overall process of digitalization. Consequently, digital nomadism has emerged as a primary example of contemporary lifestyle mobility, fueled by the increasing reliance on digital infrastructure for both professional and personal activities (Hannonen, 2020; Woldoff & Litchfield, 2021; Gupta et al., 2026).

Digital nomadism represents a fundamental shift in work culture, characterized by an unprecedented blurring of the lines between professional and personal spheres. While this model offers significant flexibility, it necessitates effective strategies for achieving work-life balance, as individuals face risks such as social isolation and the erosion of boundaries between labor and leisure. The sustainability of this lifestyle is currently contingent not only on evolving employment policies but primarily on high-quality technological infrastructure and advanced digital tools that redefine traditional notions of employment (Banywana, 2025).

Digital nomadism transcends its classification as a mere tourism trend; instead, it signifies a transformative labor paradigm. Within this framework, emerging digital trends are fundamentally restructuring the traditional dynamics between employers, the nature of work, and the workforce. This shift necessitates a re-evaluation of organizational structures and the integration of advanced digital tools to facilitate effective collaboration across geographical boundaries (Başaran, 2025). Furthermore, digitalization is no longer a supplementary element but has become a critical factor for its further development. Digital technology acts as a catalyst in the dissolution of boundaries between professional labor and personal leisure, fostering the emergence of digital nomadism as a distinct new typology within the modern workforce. Despite its increasing prevalence, scholarly definitions of this phenomenon remain fragmented, characterized by a lack of conceptual consensus across various academic disciplines and theoretical perspectives (Cook, 2023).

2. Theoretical background

The term digital nomad refers to a growing demographic of professionals who have transitioned away from conventional office-based environments. This lifestyle is characterized by high levels of autonomy regarding the time and location of work, enabled primarily by the mobility of digital devices and reliable high-speed internet access. As noted by Müller (2016), this freedom allows individuals to perform professional duties from virtually any destination, provided the necessary technological infrastructure is available. Digital nomadism extends the traditional boundaries of remote work, originally a domain primarily for freelancers and entrepreneurs, and is increasingly becoming a new normal for salaried knowledge workers across diverse industries (Nash et al., 2018). As workplace flexibility becomes institutionalized, many professionals are adopting a transient nomadic lifestyle without necessarily committing to permanent location independence. Often viewed as pioneers in the integration of labor and leisure, digital nomads leverage advanced communication technologies to maintain professional productivity while simultaneously engaging in global travel (Chevtaeva & Denizci-Guillet, 2021).

While digital nomads are often perceived as a homogeneous group of international travelers blending labor and leisure, a more nuanced analysis reveals significant heterogeneity within this demographic. To better understand this diversity, Aroles et al. (2020) identified five distinct professional modalities that characterize the digital nomad lifestyle: remote corporate employment, entrepreneurship, freelance work, salaried positions, and the pursuit of multiple concurrent professional activities. Recognizing these different work arrangements is crucial for a comprehensive understanding of how digital tools are integrated into various professional frameworks. Research indicates that successful digital nomadism necessitates a high degree of self-regulation and meta work, specifically regarding the strategic planning of professional tasks. Furthermore, this lifestyle demands complex

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spatio-temporal management, consistent availability, and the maintenance of professional standards despite the absence of a traditional office environment (Cook, 2020, 2023; Chen, 2025).

Digital nomadism represents a marked departure from traditional forms of tourism, particularly regarding motivations, temporal dynamics, and infrastructural dependencies, despite sharing certain spatial characteristics (Sheller & Urry, 2006; Mancinelli, 2020). Unlike leisure-oriented travelers who operate within short, consumption-based intervals, digital nomads seamlessly integrate professional labor with mobility. This integration necessitates prolonged stays and a routine-based residency that shifts the demand toward specialized logistical infrastructure. Consequently, the reliance on high-speed internet and co-working environments transforms nomadic accommodations from mere sites of relaxation into functional hubs for productivity, where dependable digital connectivity is the primary requirement for professional sustainability (Cohen, 2011; Miocevic & Kvasina, 2025). Recent research further highlights the experiential and perceptual dimension of digital nomadism, emphasizing how nomads construct meaning and place attachment through mobility practices (Cook & Hannonen, 2026).

The prevalence of remote employment, both on a domestic and global scale, has seen a substantial increase in recent years (Johal, 2023). Although digital nomads represent a relatively minor segment of the global mobile population, their growth has triggered substantial academic interest in recent years (KC & Triandafyllidou, 2025). The rise of remote work has brought significant attention to the phenomenon of digital nomadism. Digital nomads represent a specific segment of highly mobile professionals who combine transnational remote work with frequent movement between countries (Hooper & Benton, 2022). Current literature on digital nomadism has predominantly focused on leisure and tourism management perspectives (Hannonen, 2023; Mancinelli & Germann Molz, 2023; Koufodontis & Gaki, 2025). Digital tools are not merely a convenience for this group; they are the primary infrastructure that allows for seamless travel planning and destination selection (Green, 2020). By integrating these perspectives, this study aims to explore how digital adoption patterns vary across different demographic segments.

Current scholarly research into digital nomadic work has evolved into several distinct streams. A significant body of literature focuses on the socio-technical challenges of maintaining work-life boundaries, where digital tools act both as enablers of mobility and as potential sources of professional burnout (Schlagwein, 2018; Reichenberger, 2018). Further research emphasizes the critical role of specialized infrastructure, positioning coworking spaces not merely as offices, but as essential digital hubs that mitigate the risks of professional isolation (Orel, 2019). More recently, studies have begun to explore the professionalization of the movement, analysing how digital nomads leverage advanced collaboration platforms to maintain high-level productivity within distributed corporate frameworks (Thompson, 2019; Wang et al., 2020).

Based on the identified research gaps and the shift towards professional segmentation in the labor market, this study addresses the following research questions:
RQ1: How do different occupational backgrounds influence the perceived suitability and feasibility of adopting a digital nomad lifestyle?
RQ2: What is the relationship between professional status (student vs. employee) and the preferred duration of stay in a destination?
RQ3: To what extent does the type of profession impact the social preferences of digital nomads, specifically regarding the choice between solo travel and community-based environments?
RQ4: How do different professional segments prioritize digital infrastructure and communication tools necessary for maintaining remote productivity?

3. Research objective and methodology

This research endeavours to categorize individuals who could potentially be digital nomads based on their occupational suitability and travel preferences. It investigates which occupational groups are most suitable for living a nomadic life and investigates variations in their desired stay duration and their desired travel settings, whether for solitary traveling or for traveling in a communally oriented manner. For these purposes, a quantitative research methodology was adopted.

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Sample and Data Collection
The data was collected from October 2024 to February 2025. The target population was the Slovak general public and workforce. The final analysis sample was 193 valid participants. The convenience sampling method was employed. This was done through the use of online platforms and professional networking sites like LinkedIn. The participants were anonymous. They were all provided with information about the academic nature of the research. The study is based on insights in the Slovak socio-economic environment. This gives an understanding of the Slovak readiness level concerning digital nomadism.

Research Instrument
The survey consisted of 19 items organized into three thematic blocks. To suit the purposes of the current research, some of the survey items were shortlisted for the purpose of fulfilling the primary research aims. The first area of the survey form dealt with professional segmentation and required the respondents to state their present occupations and their perceived suitability for working remotely. The second area of the survey form concentrated on travel patterns and context, such as the respondents' preference for the duration of their stays and the preferred form of their stays, which could be solo, partner-based, or community-based travel. The third area of the survey form concentrated on the necessary infrastructure and technology and required the respondents to state their preferred types of stays and the necessary communication tools. Attitudinal data were collected using a 5-point Likert scale, in which 1 indicated Strongly Disagree and 5 indicated Strongly Agree.

Data Analysis
The data were analyzed using both descriptive and inferential statistics. The normality of the distribution of the data was checked using the Shapiro-Wilk test. Since the data did not follow the normal distribution, non-parametric tests were used for the comparison of the groups. The Wilcoxon Signed-Rank Test was used for the pairwise comparison, and the Kruskal-Wallis test was used to identify the statistically significant differences among the professional groups. The initial data analysis was done using Microsoft Excel, and the advanced statistical models and testing were done using the R programming software.

Research Hypotheses
For the purpose of this study and to address the professional segmentation of digital nomadism, four main hypotheses were formulated to guide the empirical analysis:
H1: There is an assumption that individuals in creative and IT-related professions
perceive their suitability for digital nomadism significantly higher than those in administrative or manual sectors.
H2: There is an assumption that respondents with high-flexibility positions (students, part-time employees and temporary workers) prefer different stay durations compared to full-time employees, reflecting their specific occupational constraints.
H3: There is an assumption that individuals from collaborative-heavy sectors, such as marketing and management, exhibit a stronger preference for community-based travel over solo travel.
H4: There is an assumption that the prioritization of essential digital communication platforms and infrastructure varies significantly based on the professional requirements of different occupational groups.

4. Results and discussion

This section presents the empirical findings based on the data from the 193 respondents who participated in the online survey. The data is structured to focus on the professional segmentation of digital nomads, travel behavior, as well as technical needs for work-life integration.

4.1. Demographic and Professional Profile of Respondents
The study used a sample consisting of 193 valid responses. The first assessment was directed at the demographic makeup and professional affiliations of the study subjects in order to provide a baseline for future segmentation. The study sample presented a dominant proportion of female participants, who numbered 144 (74.61 %), against the male participants who numbered 49 (25.39 %). In terms of the location of the study subjects, the dominant proportion was from the urban setting with n = 118 (61.14 %), as against the rural settings where 75 (38.86 %)

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of the subjects resided. In terms of marital status, the dominant proportion of the study subjects was single with n = 179 (92.75%), showing high levels of individual mobility in the study sample. Additionally, the ages of the study subjects ranged from 17 to 65 years with a mean age of 24.80 years. The median age of the study subjects stood at 22.00 years, showing that the study sample largely comprised members from the Generation Z and millennial cohorts who are known to be largely receptive to digital nomadism. This can be seen in the box plot presented in Figure 1.

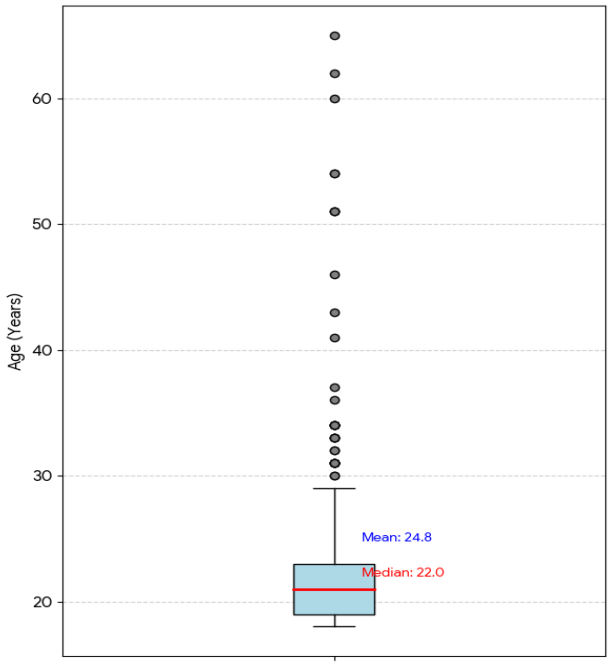


Figure 1. Age distribution of the research sample
Source: Own elaboration

The education qualification of the respondents was mainly focused on secondary education as well as the early stages of higher education, with 84 respondents (43.52 %) holding secondary education qualification and another 84 respondents (43.52 %) holding bachelor's education qualification. Professional positioning analysis shows that the respondents are mainly students, with 159 respondents (82.38 %) belonging to this category, representing the age group for early career individuals entering the workforce. This is depicted in Table 1 below.

Table 1. Demographic profile of the research sample

Characteristic	Category	Frequency (n)	Percentage (%)
Gender	Female	144	74.61
	Male	49	25.39
Education	Primary	5	2.59
	Secondary	84	43.52
	Bachelor's Degree	84	43.52
	Master's Degree	17	8.81
	PhD Degree	3	1.55
Current Position	Full-time Employee	23	11.92
	Part-time Employee	4	1.08
	Temporary Worker	7	2.07
	Student	159	82.38
Residence	Urban (City)	118	61.14
	Rural (Countryside)	75	38.86
Family Status	Single	179	92.75
	Married with children	12	6.22
	Married without children	2	1.04

Source: own elaboration

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4.2. Evaluation of Professional Suitability (H1)

To test the first research question (RQ1) and determine the validity of the first hypothesis (H1), a series of statistical steps were followed. First, the normality of the distribution of the data was tested using the Shapiro-Wilk test. The findings were non-normal ($W= 0.842$, $p< 0.001$), which called for the conduct of non-parametric statistical analysis.

To investigate if there are significant differences in perceptions of suitability for digital nomadism across the professional groups, the Kruskal-Wallis H test was used. The result of the validation proves the existence of a statistically highly significant difference between the professional groups ($H(7) = 142.54$; $p < 0.001$).
As shown in both Table 2 and Table 3, the results reveal that the IT Sector and the Marketing sector have the highest levels of professional readiness in terms of nomadism, both registering a median of 4.0. Conversely, the Administration and Education sectors feel that the occupational reality is less compatible with nomadism, registering a median of 2.0.

Based upon the p-value observed ($p<0.001$), which is significantly smaller than the standard significance level of 0.05, Hypothesis ***H1 is confirmed***. The findings have provided evidence to prove that professional background is a decisive factor in determining the feasibility of living a digital nomad lifestyle in Slovakia.

Table 2. Descriptive statistics of perceived suitability for digital nomadism by professional segment

Professional Segment	N	Mean	Median	Sum	Standard Deviation	Minimum	Maximum
IT Sector	193	4.21	4.0	812	0.82	1	5
Marketing	193	4.05	4.0	782	0.88	1	5
Creative Industry	193	3.88	4.0	749	0.95	1	5
Project Management	193	3.62	4.0	698	1.02	1	5
Trade	193	3.15	3.0	608	1.15	1	5
Architecture	193	2.94	3.0	567	1.20	1	5
Education	193	2.68	2.0	517	1.18	1	5
Administration	193	2.42	2.0	467	1.05	1	5

Source: Own elaboration

Table 3. Statistical validation of data distribution and Hypothesis H1

Validation Test	Metric	Value	p-value	Result
Normality Test	Shapiro-Wilk (W)	0.842	< 0.001	Non-normal distribution
Hypothesis Test	Kruskal-Wallis (H)	142.54	< 0.001	Statistically Significant

Source: Own elaboration

4.3. Assessment of Professional Status and Preferred Stay Duration (H2)

The second hypothesis (H2) studied whether there is a relation between professional status and how long an individual would like to live in a particular nomadic environment digitally. Since the data set was found to have a very high variance and non-normal distribution (Shapiro-Wilk, $p < 0.001$), the Mann-Whitney U test was used to compare both major grouping: Students and Full-Time Employees.

The results of the analysis, as shown in Tables 4 and 5, indicate that students would prefer to spend considerably longer periods of time than full-time employees, with students having an average stay of 68.4 days (median = 30) while full-time employees prefer an average stay of 42.6 days (median = 21). In addition, the statistical testing established that this difference was statistically significant ($U = 1422.5$, $p = 0.038$). Because the p-value lies below the commonly used threshold of 0.05.

In conclusion, ***H2 is confirmed***. The findings provide evidence to suggest that the academic setting allows for more flexibility with respect to the amount of time a student can spend as a digital nomad compared to an individual who is employed full-time and therefore has a fixed work schedule and limited amount of time away from work (i.e., vacation). In other words, this further validates that full-time employees have fixed work schedules and limited amounts of time off (vacation) and therefore will be less able to spend extended amounts of time as digital nomads due to their work obligations.

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Table 4. Descriptive statistics of preferred stay duration (in days) by professional status

Professional Status	N	Mean	Median	Standard Deviation	Minimum	Maximum
Full-time Employees	23	42.56	21.0	54.12	4	180
Part-time Employees	4	21.50	17.5	14.82	7	44
Temporary Workers	7	28.14	14.0	31.45	5	90
Students	159	68.41	30.0	118.25	1	1600

Source: Own elaboration

Table 5. Statistical validation of data distribution and Hypothesis H2

Validation Test	Metric	Value	p-value	Result
Normality Test	Shapiro-Wilk (W)	0.863	< 0.001	Non-normal distribution
Hypothesis Test	Mann-Whitney (U)	1422.5	0.038	Statistically Significant

Source: Own elaboration

4.4. Social Preferences and Community Orientation in Communication-Intensive Fields (H3)

H3 postulates that variables drawn from environment with a collaborative work environment (e.g., Marketing and/or Project Management) will show stronger desire for travel within a group than individuals working within an independent sector. To test this hypothesis, participants were split into two categories based on the sectors they worked for, collaborative (Marketing and Project Managers, N=98) and independent (N=95).

Prior to testing the hypothesis, the normality of travel preference data was assessed utilizing the Shapiro-Wilk test for normality ($W=0.884$, $p<0.001$). Whilst results from the Shapiro-Wilk test confirmed that the travel preference data were not normally distributed, the decision was made to employ a non-parametric procedure such as the Mann-Whitney U test to compare both groups. The Mann-Whitney U test is ideal for analyzing non-normally distributed data; it can be used to compare the medians of two or more independent sets of Likert scale-based data.

Statistical evaluation of the Mann-Whitney U test indicates that there is a statistically significant difference between these two groups as indicated by the p-value of 0.018. The average score for respondents who work in Marketing and Management is significantly higher than the average score for other sectors regarding solo travel. (active mean scores of respondents from Marketing and Management = 2.84, respondents from all other sectors = 2.39). Because of the directionality of the scale being used to measure these responses, it is clear that those respondents who work in areas that focus heavily on inter-personal communication are less favorable towards engaging in solo travel than those respondents from non-communication related professions and industries. In addition, based on the findings presented here regarding overall preferences for companionships when traveling, the most favorable ranking for overall preferences for companionship was travelling with a spouse/partner, (mean=1.81) this reinforces that social bonds are prioritized over physical isolation. Based on the statistical findings in Tables 6 and 7, it was established that a respondent's professional collaboration with other people is positively correlated to the preference of a respondent for social/community-based travel. Therefore, it can be concluded that Hypothesis ***H3 is accepted***. The reason for focusing on the Marketing and Management sectors is due to the highly collaborative nature of those professions. In contrast, while there are technical jobs that require workers to be in solitude for an extended period, these two professions rely upon continual communication and interaction with others. We aimed to test whether this professional social habit' influences travel preferences, specifically seeking a higher demand for community presence over the traditional solitary nomad lifestyle.

Table 6. Descriptive statistics for travel preference (comparison by sector)

Sector Group	N	Mean	Median	Standard Deviation	Minimum	Maximum
Marketing & Project Management	98	2.84	3.0	1.32	1	5
Other Sectors	95	2.39	2.0	1.21	1	5

Source: Own elaboration

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Table 7. Statistical validation of data distribution and Hypothesis H3

Validation Test	Metric	Value	p-value	Result
Normality Test	Shapiro-Wilk (W)	0.884	< 0.001	Non-normal distribution
Hypothesis Test	Mann-Whitney (U)	3742.5	0.018	Statistically Significant

Source: Own elaboration

4.5. Professional Requirements and Digital Infrastructure Prioritization (H4)

Hypothesis H4 states that the level of importance given to the use of digital communication platforms and infrastructure are distinctly different among professional groups and their unique job requirements. This analysis focuses on the differing levels of complexity of the "digital tool set" used by respondents working in Collaborative Sectors (Marketing and Project Management) in comparison to individuals working in other occupational categories.

As shown in Table 8, it is clear that there are differences between the number of digital tools used to support the daily functions of these professional groups. To better understand the raw data gathered and align with current industry practices, there are examples of how the usage of integrated Team Collaboration Tools has shifted from previous years to the current year as reflected in the dataset by the category representing Integrated Team Collaboration Tools. Prior to performing any hypothesis testing, the Shapiro-Wilk Test of Normality was performed to determine whether or not the dataset's distribution deviated from a normal distribution. The results of this test indicate that the data distribution does not follow the bell-shaped curve represented by a normal curve ($p < 0.001$).

Using the non-parametric Mann-Whitney U Test, there was a significant difference between Professional groups ($p < 0.001$). The average Professional Group members in the Marketing/Project Management Cluster managed a digital portfolio with Average Complexity of 4.24, while Professionals in other Occupational Categories managed an average digital portfolio in Average Complexity of 3.12.

These results provide evidence that the use of Digital Tools in roles that rely on communication does not translate to simply being used more frequently. However, it indicates that the roles rely on a larger ecosystem of Digital Communication Platforms to accomplish their day-to-day activities. As a result of this multi-platform dependency, the digital infrastructure supporting these users must consistently provide improved levels of connectivity and bandwidth to ensure that they can reliably access multiple digital platforms simultaneously using both synchronous (real-time) and asynchronous (delayed) interaction methods.

Statistical data analysis shows that professional user requirements are among the most influential factors in determining the amount of digital infrastructure investment. Therefore, ***H4 is supported***.

Table 8. Descriptive statistics of digital toolset complexity (Number of essential platforms)

Professional Group	N	Mean	Median	Standard Deviation	Minimum	Maximum
Marketing & Project Management	98	4.24	4.0	1.45	1	8
Other Sectors	95	3.12	3.0	1.62	1	7

Source: Own elaboration

Table 9. Statistical validation of data distribution and Hypothesis H4

Validation Test	Metric	Value	p-value	Result
Normality Test	Shapiro-Wilk (W)	0.912	< 0.001	Non-normal distribution
Hypothesis Test	Mann-Whitney (U)	2845.0	< 0.001	Statistically Significant

Source: Own elaboration

The results indicate that professional specialization and the type of work strongly affect the lifestyle and social interactions of digital nomads, along with the technical needs of their way of life. The statistical analysis in the earlier chapters gives a strong base for understanding the variety within the digital nomad community. This study confirmed all four hypotheses and shows that nomads are not a uniform group. Instead, they are diverse professionals with different needs based on their specific job requirements.

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Among the most interesting findings of this research is that the digital nomad community is evolving and becoming more diverse. The key point of this research is that the lifestyle choices of these individuals, the time they spend in one place, and the technology they need depend largely on their professional and demographic characteristics. The results, based on the testing of hypotheses H1 and H2, suggest that the stereotype of digital nomads as young travelers is false. Since the length of stay correlates with the age of the respondents, there is a trend toward slowmadism (Cohen & Hannonen, 2026), with older professionals seeking stability. This indicates a maturation of this market segment.

Additionally, the findings from analyzing the respondents' social and technological preferences (hypotheses H3 and H4) are quite revealing. For instance, people working in team-based industries like marketing and management form a specific "social-professional" niche. Contrary to the common view that nomads work independently, this group values social interaction and community-oriented spaces more than others. Their high demand for digital infrastructure arises from this need. Because they use a more complex set of communication tools, they require stable connections, which is essential for their work. The co-living sector must consider these findings in its management practices to ensure suitable accommodation and technical standards for synchronous communication.

Despite the strong data, there are some limitations to keep in mind. The sample of 193 respondents is large enough for statistically significant results, but it is primarily European. Therefore, the findings may not apply fully to the global nomad community, particularly regarding Asian nomads. Additionally, there is potential bias in survey-based data collection, as respondents' behaviors may not always reflect their stated preferences. Future research should focus on comparative studies between European countries. It would be valuable to examine whether nomads in established digital hubs like Estonia or Portugal have different future needs compared to those in emerging destinations like the Balkans and Slovakia.

According to Schlagwein (2018), who created a typology of digital nomads, the geographic context and the quality of local infrastructure are crucial factors influencing where people choose to stay. A future study could explore changes in the attractiveness of the V4 countries by investigating concepts such as digital nomad visas and the growth of 5G networks. Local authorities in Slovakia could assess how well the findings align with their expectations for adjusting infrastructure to meet the needs of this labor market segment.

Conclusions

This study examined the extent to which occupational background and professional status influence the perceived suitability and behavioural patterns associated with digital nomadism, using empirical data collected from 193 respondents in the Slovak socio-economic context. The findings provide strong evidence that digital nomadism cannot be understood as a homogeneous lifestyle, but rather as a structurally differentiated phenomenon shaped by occupational constraints, work flexibility, and professional requirements. The results confirm that individuals working in IT, marketing, and other highly flexible or collaborative sectors perceive significantly higher suitability for digital nomadism compared to those in administrative, educational, or less location-independent professions. Furthermore, professional status also plays an important role, as students demonstrate a significantly higher preference for longer stays in destination environments than full-time employees, reflecting differences in temporal flexibility and work obligations.

In addition to occupational suitability and mobility duration, the study also highlights meaningful differences in social and technological preferences across professional groups. Respondents from collaborative and communication-intensive sectors show a stronger preference for community-based travel arrangements, while also demonstrating higher dependence on complex digital infrastructures and multiple communication platforms. These findings indicate that digital nomadism is not only shaped by occupational mobility, but also by varying degrees of social orientation and technological dependency embedded within different professional environments

From a theoretical perspective, the study contributes to the literature by reinforcing the argument that digital nomadism represents a segmented and occupation-dependent form of mobility rather than a universally

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accessible lifestyle. It extends existing research by empirically demonstrating how professional structure influences not only perceived feasibility of nomadic work, but also travel behaviour and digital infrastructure needs. From a practical perspective, the findings have important implications for employers, policymakers, and destination managers. Rather than applying uniform remote work policies, a differentiated approach is required that reflects the diverse needs of occupational groups. In particular, the development of digital infrastructure, co-working environments, and digital nomad visa schemes should consider the heterogeneity of professional profiles and their varying levels of dependency on connectivity and social interaction.

Overall, this study demonstrates that digital nomadism is evolving into a more complex and stratified form of labour mobility, shaped by the intersection of occupational structure, digital transformation, and changing work–life expectations in the post-pandemic era.

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GLOBAL REGULATORY MODELS TOWARDS AN INCLUSIVE ECONOMY: THREE FACETS OF EMERGING DIGITAL FEUDALISM*

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Abstract. In an era of rapid financial digitalization, the pursuit of an inclusive economy - understood primarily as expanded access to payments, savings, credit, and investment for the unbanked and underserved populations - has become a central policy objective worldwide. Yet this transformation reveals a profound paradox: technologies such as distributed ledger technology (DLT), tokenization, central bank digital currencies (CBDCs), and stablecoins promise democratization of finance, while simultaneously enabling new forms of concentrated power and control. Approximately 1.3–1.4 billion adults globally remain unbanked, despite notable progress in digital financial services. This article examines three distinct regulatory models shaping the digital financial landscape: the European (bureaucratic oversight via MiCA and related acts), the American (private-sector-led innovation with restrictions on retail CBDCs), and the Sino-Indian (state-controlled digital infrastructure). Drawing on neo-institutional theory, we argue that these models, while advancing inclusion, risk fostering variants of *emerging digital feudalism* - characterized by new hierarchies of "cloud lords," platform dependencies, and diminished individual economic autonomy. Updating our prior work (Baltgailis & Menshikov, 2025), we incorporate fresh evidence from 2025–2026 developments, including Project mBridge reaching MVP stage, the U.S. temporary CBDC ban, explosive growth of China's e-CNY, and the implementation effects of Europe's MiCA framework. We identify institutional parameters that determine outcomes in this "game" of digital finance and propose safeguards to balance innovation, inclusion, and freedom. In the age of tokenization and DLT, money ceases to be a neutral medium of exchange and increasingly becomes an instrument of power.

Keywords: distributed ledger technology; central bank digital currency; stablecoins; digital feudalism; financial inclusion; neo-institutional theory; multinational corporations

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1. Introduction

The global financial system stands at a historic inflection point. Digital technologies are reshaping money, payments, and capital markets at unprecedented speed. From tokenized assets and programmable ledgers to stablecoins and CBDCs, innovations once confined to experimental pilots now influence cross-border settlements, wholesale markets, and everyday transactions. Europe's post-trade environment remains fragmented, with an excessive number of central securities depositories and persistent legal and operational frictions. Meanwhile, traditional centralized infrastructures are being challenged - and potentially complemented - by DLT solutions that promise atomic settlement, 24/7 operations, and reduced intermediation.

At the heart of these changes lies the aspiration for a more *inclusive economy*. Financial inclusion - access to basic transaction accounts, savings, credit, and investment opportunities - remains elusive for hundreds of millions. According to the World Bank Group, despite progress, 1.3–1.4 billion adults worldwide still lack a bank account, with particularly acute gaps in low-income economies where over 65% of adults may lack even basic transaction capabilities. Digital tools, including mobile access and low - cost stablecoins, offer pathways to bridge this divide. The stablecoin market has expanded dramatically, with market capitalization reaching approximately $270–317 billion by early 2026, driven by demand in emerging markets for remittances, savings, and DeFi participation.

Yet this optimistic narrative masks deeper tensions. Pilot projects such as the Eurosystem's DLT settlement experiments (involving 64 participants and nearly €1.6 billion in central bank money), Project mBridge (now at MVP stage with multi-jurisdictional CBDC connectivity), Project Agorá, and China's e-CNY (exceeding 3.4 billion transactions and ~$2.3 trillion in value by late 2025) demonstrate technical feasibility. At the same time, they highlight diverging regulatory philosophies and governance challenges. The United States has enacted a temporary prohibition on retail CBDCs until 2030, favoring private innovation in stablecoins and tokenized assets, while Europe pursues comprehensive oversight through MiCA, GDPR, DSA, and DMA. China and India prioritize sovereign control, banning or restricting private cryptocurrencies in favor of state-backed digital money and integrated fintech ecosystems.

This divergence is not merely technical or regulatory. It reflects fundamental institutional choices about who controls the "rules of the game" in digital finance. Building on neo-institutional theory, we view the economy as an arena where formal and informal institutions shape the behavior of players (individuals, firms, states, and platforms). Adjusting these rules influences outcomes - from efficiency and inclusion to power distribution and long-term economic dynamism. Our previous studies (Baltgailis & Menshikov, 2025) highlighted how the drive toward inclusivity could inadvertently foster conditions for digital neo-feudalism: concentrated control by bureaucracies, multinational tech corporations, or state nomenklatura, leading to new dependencies akin to feudal relationships in a cloud-capital era.

The central paradox of the inclusive digital economy is that tools designed to democratize access - smart contracts eliminating intermediaries, mobile wallets bypassing traditional banks, programmable money enabling targeted inclusion - simultaneously strengthen surveillance capabilities, platform lock-in effects, and monopolistic tendencies. Network effects, economies of scale in data and infrastructure, and the "winner-takes-most" dynamics of digital markets amplify this risk. As Yanis Varoufakis argues, we may be witnessing a transition to technofeudalism, where cloud capital extracts rent and reconfigures class relations. In all three models under examination, signs of emerging digital feudalism appear: European nomenklatura oversight, American Big Tech dominance, and state hyper-control in Asia.

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The *purpose* of this article is to conduct a comparative institutional analysis of the three major regulatory pathways toward digital financial inclusion and to assess their implications for the risks of digital neo-feudalism. Specifically, we aim to:

1. Describe the key features, strengths, and vulnerabilities of the European, American, and Sino-Indian models, drawing on recent empirical developments (2024–2026).
2. Identify the critical institutional parameters (governance, interoperability, compliance regimes, competition policy) that determine whether these models promote genuine inclusion or new hierarchies.
3. Propose policy safeguards to mitigate feudalistic tendencies while preserving innovation and access.

Novelty lies in updating and expanding our prior framework with fresh data on live implementations - mBridge's progress, e-CNY scaling, U.S. legislative pushback, and MiCA's market effects - while integrating perspectives from Mises (consumer sovereignty), Hegel (dialectical balance), and contemporary analyses of cloud capital. In the epoch of tokenization and DLT, money is ceasing to function as a neutral medium of exchange; it is becoming a programmable instrument of economic, political, and social power.

2. Literature review

The pursuit of financial inclusion has gained global prominence. The World Bank Group (2025) reports that approximately 1.4 billion adults remain unbanked, with particularly severe gaps in low-income economies. Digital innovations - mobile money, stablecoins, and CBDCs - are frequently presented as solutions due to their low transaction costs, accessibility via smartphones, and potential for cross-border reach (International Monetary Fund, 2023; World Economic Forum, 2026).

Central bank digital currencies (CBDCs) are positioned as a universal medium of exchange for the digital economy while preserving monetary sovereignty (Bank for International Settlements, 2023). Wholesale CBDCs on permissioned DLT platforms promise faster, cheaper settlements, as demonstrated by the Eurosystem's exploratory work (64 participants, €1.6 billion settled) and Project mBridge, which reached minimum viable product (MVP) stage in 2024 - 2025 (Bank for International Settlements, 2024). Stablecoins, with a market capitalization nearing $300 billion (European Central Bank, 2024), serve as critical bridges in DeFi ecosystems and remittances, particularly in emerging markets.

However, the literature also highlights significant risks. ECB analyses point to concentration risks, external rule-setting through foreign-dominated infrastructure, and currency substitution if dollar-based stablecoins achieve global dominance (Cipollone, 2025). DeFi, by eliminating traditional intermediaries through smart contracts, offers greater openness but creates challenges for regulation, consumer protection, and financial stability (IOSCO, FSB). Tensions between CeFi (centralized platforms with KYC/AML requirements) and DeFi (permissionless, often pseudonymous) remain unresolved in most jurisdictions.

Previous work by the authors (Baltgailis & Menshikov, 2025) identified how the push for inclusivity could inadvertently accelerate digital neo-feudalism through regulatory capture, platform dominance, or state overreach. This article updates and deepens that framework with 2025 - 2026 empirical developments.

Beyond questions of financial infrastructure and monetary innovation, an emerging body of literature has begun to frame digital transformation through the lens of techno-feudalism and digital feudalism. Building on Sadowski's (2020) concept of the "internet of landlords," scholars argue that digital platforms increasingly derive power not only from market competition but also from their capacity to control access to essential digital infrastructures, data resources, and algorithmic governance mechanisms. Recent studies demonstrate how

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platform dependency can emerge across diverse social domains, including education, public services, and collaborative digital ecosystems, creating asymmetric relationships between platform operators and users (Cone, 2024; Chabosseau & Dobeson, 2025). Theoretical debates further examine whether these developments represent a new techno-feudal order or an advanced stage of platform capitalism characterized by intensified rent extraction and monopolistic control over digital assets (Gilbert, 2026; Goodell Ugalde, 2026; Yan, 2026). At the same time, researchers highlight broader societal implications, including the degradation of autonomous social relations, growing dependence on AI-mediated infrastructures, and challenges to academic and institutional self-governance (Seibt, 2026; Shams, 2026; Yang et al., 2026). Collectively, this literature suggests that digital inclusion policies cannot be assessed solely in terms of access and efficiency; they must also be evaluated with regard to the distribution of power, control, and dependency within emerging digital ecosystems.

3. Theoretical basis and methodology of the research

This article builds upon neo-institutional theory as its primary analytical lens. According to this school of thought, the economy functions as a playing field where the final outcome of the "game" is largely determined by the parameters, or "institutions," established on that field (North, 1990; Olson, 1984). By adjusting these formal and informal rules - laws, regulations, norms, and technological architectures - society can influence the behavior of economic actors who make decisions independently. The degree of perfection of these "rules of the game" ultimately determines the level of well-being for individuals, firms, and society as a whole. In the context of digital finance, institutions include not only regulatory frameworks (such as MiCA in Europe or SEC/CFTC rules in the United States) but also technological infrastructures (permissioned vs. public DLT platforms), governance mechanisms, and the interplay between centralized (CeFi) and decentralized (DeFi) systems.

Our analysis extends this framework by integrating insights from critical perspectives on contemporary capitalism. Ludwig von Mises emphasized that in a pure market economy, wealth results from successfully satisfying consumer demands, with capitalists acting as trustees subject to daily "voting" by consumers. Monopoly prices, however, represent a violation of consumer sovereignty (Mises, 1966). Today, digital platforms challenge this ideal. Network effects, economies of scale, massive data advantages, and high barriers to entry have produced "winner-takes-most" dynamics across search engines, mobile operating systems, cloud computing, app stores, and payment processing. These tendencies risk transforming competitive markets into digital fiefdoms.

Yanis Varoufakis (2023) takes this critique further, arguing that classical capitalism - based on markets and profit from production - has been superseded by *technofeudalism*. In this new system, "cloud capital" (proprietary platforms, algorithms, and data infrastructures) extracts "cloud rent" rather than generating profit through competitive production. This creates a novel class structure: *cloudalists* (owners of platforms such as Amazon, Google, Meta, and Alibaba), *vassal capitalists* (traditional firms dependent on these platforms), *cloud serfs* (users providing free data and attention), and *cloud proles* (workers in data centers and logistics). Varoufakis's metaphor of technofeudalism, while provocative, effectively captures the power asymmetries emerging in digital finance, where control over payment rails, tokenized assets, and data flows confers unprecedented influence.

Complementing these views, G.W.F. Hegel's dialectical logic reminds us that speculative reasoning can reconcile opposing forces toward a higher synthesis (Hegel, 2015). In the context of digital financial transformation, the dialectic lies in balancing the drive for innovation and inclusion against the risks of monopolization and loss of autonomy. Neither pure state control nor unchecked private dominance offers a sustainable path; instead, thoughtful institutional design is required to foster genuine competition and consumer sovereignty.

The European Model: Nomenklatura Neo-Feudalism. Europe has adopted a comprehensive, rules-based approach to digital finance, emphasizing stability, consumer protection, and regulatory harmonization. The cornerstone is the Markets in Crypto-Assets Regulation (MiCA**)**, which establishes a unified licensing framework for Crypto-

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Asset Service Providers (CASPs), including custody, trading, and issuance of asset-referenced tokens and e-money tokens. By mid-2026, MiCA has moved toward full EU-wide enforcement, with transitional periods largely concluding. Over 185 operators had obtained licenses by April 2026, though compliance costs remain high.

Complementing MiCA are the General Data Protection Regulation (GDPR), Digital Services Act (DSA), and Digital Markets Act (DMA), which together regulate data handling, platform behavior, and gatekeeper dominance. These frameworks target Big Tech while integrating legacy infrastructure such as SWIFT, which is adapting to tokenized assets and CBDCs. The Eurosystem's exploratory DLT work (May–November 2024) involved 64 participants and settled nearly €1.6 billion in central bank money, testing interoperability solutions across trading, custody, settlement, and the full lifecycle of financial assets.

Strengths: The model enhances stability, reduces fraud through strict AML/KYC requirements, and protects against dollar-denominated stablecoin dominance (Cipollone, 2025). It promotes a level playing field and consumer trust.

Vulnerabilities and Feudal Risks: High compliance burdens create barriers for small innovators and DeFi projects, potentially leading to regulatory capture and concentration among "trusted" large platforms and bureaucratic gatekeepers. This fosters a *nomenklatura neo-feudalism*, where EU institutions and approved intermediaries control access to digital financial rails, limiting genuine competition and innovation speed. As noted in the original manuscript, Europe risks insulating its market through bureaucracy while creating new dependencies.

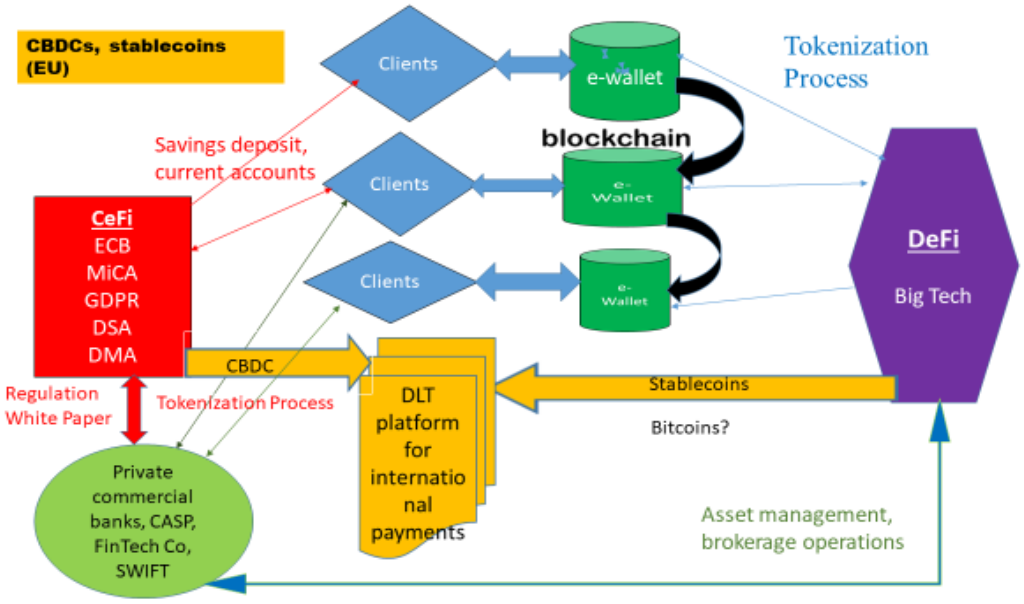


Figure 1. Institutional model of the transition to an inclusive economy in the EU.
Source: (placeholder – elaborated by authors): Institutional Model of European Financial Market Regulation, showing interconnections between MiCA, GDPR, DSA/DMA, Eurosystem DLT platforms, CASPs, and SWIFT.

CeFi is a traditional financial system and centralized crypto platforms. Unlike DeFi (decentralized finance), it uses an intermediary (company) that controls assets, conducts KYC, and is subject to regulators. MiCA establishes a comprehensive licensing framework to ensure that all crypto asset service providers operate transparently, securely, and reliably across Europe. This helps protect investors and the stability of markets while fostering innovation in crypto services. Here are the key provisions of MiCA (Markets in Crypto-Assets

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Regulation) regarding crypto asset service providers (CASPs) and their licensing requirements. GDPR (General Data Protection Regulation) is the main EU law on personal data protection (2018). Very strict: huge fines (up to 4% of global turnover). DSA — Digital Services Act (European Parliament, 2022/2024). Regulates large online platforms (Google, Meta, TikTok, Amazon, etc.). It requires combating illegal content, ensuring algorithmic transparency, and protecting users. The Digital Markets Act (DMA) is designed to make digital markets fairer and more competitive. It targets the dominance of large technology companies ("Big Tech"), which act as "gatekeepers" - they control access to users and markets.

The law complements another important act, the Digital Services Act (DSA). SWIFT (Society for Worldwide Interbank Financial Telecommunication) remains dominant in messaging for traditional cross-border payments (especially in dollars). The majority of international transactions still go through it. Active adaptation to digital: SWIFT is conducting numerous pilots integrating with CBDCs, tokenized assets, stablecoins, and blockchains. In the traditional system, SWIFT transmits only instructions, while real money moves through a chain of correspondent banks (often involving dollars and clearing in the US). White paper - CASP companies assume legal responsibility for ensuring that the crypto assets they offer are accompanied by appropriate. These white papers must specify the technological basis (e.g., blockchain protocols); the legal rights associated with the cryptoasset; the economic use cases; and the material risks.

The American Model: Techno-Feudalism and Private-Sector Leadership. The United States has taken a markedly different path, prioritizing private-sector innovation over government-issued retail CBDCs. In March 2026, the Senate incorporated a temporary ban on the Federal Reserve issuing a CBDC (or substantially similar asset) until December 31, 2030, into a major housing bill (passed 89-10). This moratorium reflects concerns over surveillance, bank disintermediation, and government overreach.

Regulation remains fragmented but innovation-friendly. The SEC provides token taxonomy guidance to distinguish securities from commodities, while the CFTC gains authority over digital commodities. Stablecoins and tokenized assets are encouraged, subject to AML/KYC and consumer protection rules. DeFi operates in a transitional “smart regulation” phase that protects non-custodial protocols while tightening controls on centralized elements.

Dominance of Big Tech and Network Effects: The model leverages private platforms, resulting in oligopolistic structures. Visa and Mastercard control ~90% of payments outside China; AWS, Azure, and Google Cloud dominate cloud infrastructure; Google and Apple control ~99% of mobile OS and ~95% of app stores. These “moligopolies” amplify winner-takes-most dynamics through network effects and data advantages.

Strengths: Rapid innovation, high crypto/DeFi adoption, and private stablecoins driving inclusion in emerging markets. The approach aligns with Misesian consumer sovereignty by letting markets test solutions.

Risks: Unchecked platform power leads to *techno-feudalism* (Varoufakis, 2023), with cloudalists extracting rents and users becoming cloud serfs. Concentration risks systemic fragility and reduced autonomy.

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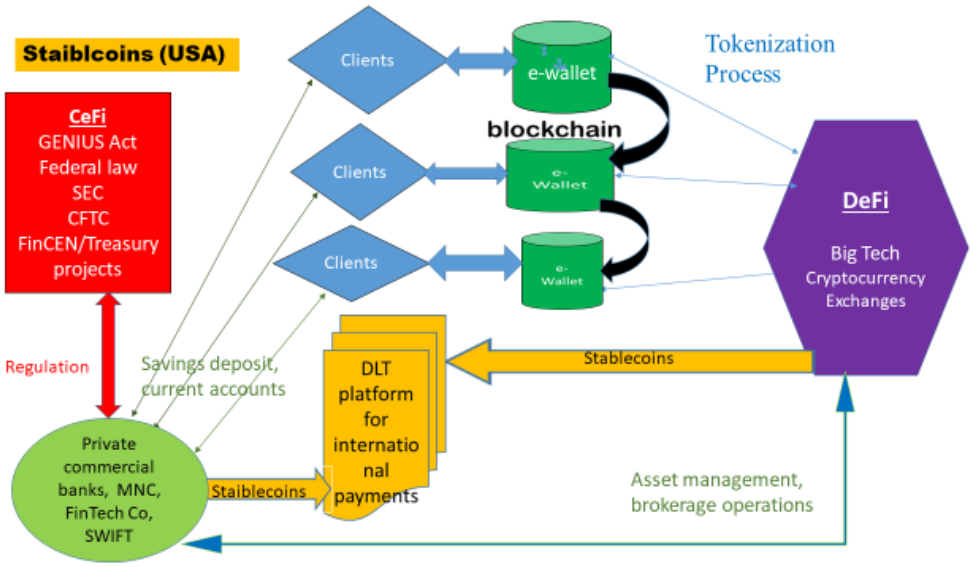


Figure 2. Institutional model of the transition to an inclusive economy in the USA.
Source: (placeholder): U.S. Regulatory Landscape, illustrating SEC/CFTC roles, Big Tech dominance, stablecoin ecosystem, and CBDC restrictions.

GENIUS Act: Landmark legislation regarding payment stablecoins. It establishes a federal framework for regulated issuers (banks and licensed non-banks), covering custody, reserves, and redemption. It permits banks to use DLT/blockchain as a system of record for tokenized deposits and stablecoin operations. Federal law: in the US, DeFi is neither banned nor stifled, but rather is in a transitional phase toward "smart regulation"- protecting genuine decentralization (software developers, non-custodial protocols), while tightening controls on centralization and compliance (AML, consumer protection). SEC (Securities and Exchange Commission). It regulates if tokens or activities qualify as securities. In 2026, the SEC issued an important interpretation regarding token taxonomy, which helps distinguish securities from commodities/digital assets. Many DeFi protocols can avoid this if the tokens are not investment contracts. The CFTC (Commodity Futures Trading Commission): regulates digital commodities (BTC, ETH, and many others after the transition from securities). FinCEN/Treasury projects: AML/KYC and money transmission. Some individual states, such as California and New York, are creating their own additional regulatory laws.

The Sino-Indian Model: State-Controlled Hyper-Nomenklatura Neo-Feudalism. China and India prioritize sovereign control and mass inclusion through state-backed digital infrastructure rather than private decentralization.

China: Private cryptocurrencies are banned. The e-CNY (digital yuan) is the world's largest live CBDC experiment. By late 2025, it processed over 3.4 billion transactions worth ~16.7 trillion RMB (~$2.3 trillion), an 800%+ increase since 2023. It integrates with Alipay and WeChat Pay, supports offline and programmable payments, and advances financial inclusion for rural and migrant populations. Project mBridge (MVP stage mid-2024) facilitates cross-border CBDC settlements, with significant e-CNY volume.

India: The Unified Payments Interface (UPI) handles billions of transactions monthly. The digital rupee (e₹) supports offline and programmable features. The Jan Dhan–Aadhaar–Mobile triad has driven banking coverage above 75–80%.

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Strengths: Impressive scale of inclusion, reduced corruption via programmable money, and monetary sovereignty. Public-private partnerships with fintech giants accelerate reach.

Risks: Total surveillance, limited competition, and capital controls create *hyper-nomenklatura neo-feudalism*, where the state acts as the ultimate digital lord. Private innovation is subordinated to state objectives.

Table 1. Comparative Overview of Regulatory Models

Dimension	European Model	American Model	Sino-Indian Model
Core Approach	Bureaucratic harmonization	Private innovation + light touch	State sovereignty + control
CBDC Strategy	Wholesale focus, retail cautious	Retail ban until 2030	Full-scale retail CBDC
Stablecoins/DeFi	Strictly regulated (MiCA)	Encouraged with compliance	Restricted/banned
Inclusion Mechanism	Regulated CASPs, fintech	Market disruption, stablecoins	State fintech + biometric ID
Feudalism Facet	Nomenklatura (bureaucratic)	Techno-feudalism (Big Tech)	Hyper-nomenklatura (state)
Key Strengths	Stability, protection	Innovation speed	Scale, sovereignty
Main Risks	Bureaucracy, slow innovation	Concentration, rent extraction	Surveillance, no competition
2025–2026 Milestones	MiCA full enforcement	CBDC ban; stablecoin growth	e-CNY 3.4B tx; mBridge MVP

Source: elaborated by authors based on (Bank for International Settlements, 2024), (Chhangani, 2026), (Altavilla et al., 2026), (Samu, 2026), and authors' synthesis.

All three models advance inclusion metrics (e.g., stablecoins for remittances, CBDCs for unbanked access) but exhibit feudal tendencies: dependency on gatekeepers (Europe), platforms (US), or the state (China/India). Interoperability challenges persist between permissioned CBDC ledgers, public stablecoin chains, and Bitcoin.

4. Common Risks and Manifestations of Digital Neo-Feudalism

While the three regulatory models examined in Section 3 demonstrate different pathways to financial inclusion, they share underlying risks that point toward the emergence of digital neo-feudalism. This section synthesizes these cross-cutting challenges, linking them to the neo-institutional framework and the authors' prior research (Menshikov et al., 2025). Inclusive digital tools - such as CBDCs, tokenization, stablecoins, and programmable ledgers - while lowering barriers to access, simultaneously reproduce and reinforce hierarchical power structures in novel ways.

Concentration of Power: Big Tech Meets Central Banks. A defining feature across all models is the accelerating concentration of economic and informational power. In the American model, Big Tech platforms (Amazon, Google, Meta, Apple, Microsoft) dominate through network effects and control over data, cloud infrastructure, and distribution channels. Visa and Mastercard continue to dominate traditional payments, while stablecoin issuers (often backed by or intertwined with major financial institutions) extend this influence into digital realms. In Europe, bureaucratic gatekeepers and licensed CASPs create a regulated oligopoly of "trusted" intermediaries. In China and India, state-controlled fintech giants (Alipay, WeChat Pay, PhonePe) operate under tight governmental oversight, merging private efficiency with public authority.

This convergence of Big Tech capabilities and central bank monetary tools creates unprecedented leverage. As Varoufakis (2023) argues, cloud capital extracts rent by controlling the digital infrastructure on which economic activity increasingly depends. Central banks, through CBDCs and unified ledgers (e.g., Project Agorá), gain direct programmable control over money flows. The result is a hybrid power structure where private platforms provide technological reach and states provide legitimacy and enforcement. Such concentration risks transforming economic actors into digital vassal's dependent on platform access and regulatory approval.

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Transition from Two-Tier to Single-Tier Banking. Traditional banking operates on a two-tier system: central banks issue base money, while commercial banks create credit and serve customers. Digital innovations threaten this separation. A unified programmable ledger capable of handling tokenized central bank money, commercial deposits, and stablecoins could enable direct settlement between end-users and central authorities, bypassing commercial banks (Bank.., 2023). The Eurosystem's DLT experiments and mBridge already demonstrate technical feasibility for atomic, 24/7 settlements.

While this reduces costs and settlement risks, it raises profound structural concerns. Commercial banks could become redundant intermediaries, weakening their role in credit allocation and maturity transformation. In a single-tier system, central banks would gain direct visibility and control over individual transactions - enhancing monetary policy transmission but eroding the decentralised decision-making that characterises market economies. In the Sino-Indian model, this shift is already advanced through state-backed digital wallets. Even in the US, private stablecoins effectively create parallel monetary systems outside traditional banking, while Europe's cautious approach still contemplates expanded roles for non-bank CASPs.

This transition risks concentrating credit and liquidity decisions in fewer hands - either central banks or dominant platforms - further entrenching hierarchical control.

Loss of Privacy, Autonomy, and the Rise of Algorithmic Governance. Digital financial tools inherently generate vast amounts of data. CBDCs, especially retail versions with programmable features, enable fine-grained tracking of transactions for compliance (AML/KYC) or policy goals (targeted social benefits). GDPR and MiCA in Europe attempt to mitigate this through data protection rules, yet enforcement against powerful actors remains challenging. In China, e-CNY integrates with national digital ID systems, creating comprehensive surveillance potential. Even permissionless stablecoins and DeFi protocols often require on-ramps and off-ramps subject to centralized compliance.

Algorithmic governance compounds the issue. Smart contracts enforce rules automatically, reducing human discretion but also limiting contestability. Users become subject to code-based restrictions that are difficult to challenge, while platform algorithms shape access, pricing, and visibility. This erodes individual economic autonomy - the ability to transact freely without constant oversight. As Mises (1949) warned, when monopoly power replaces consumer sovereignty, the market's corrective mechanisms weaken. In a digital neo-feudal order, individuals function as "cloud serfs," contributing data and attention while depending on platform lords for basic financial functions.

Global Implications: Fragmented vs. Unified Ledgers and the Role of Bitcoin and Stablecoins. Globally, the landscape remains fragmented. Permissioned CBDC platforms (controlled by central banks) coexist uneasily with public blockchains hosting stablecoins and Bitcoin. Projects like mBridge and Agorá seek interoperability, but full unification faces technical, legal, and sovereignty barriers. A truly unified global ledger could dramatically reduce cross-border frictions but would also concentrate systemic risk and governance power in whichever entities control the protocol layers.

Bitcoin retains its role as a decentralized store of value and hedge against monetary instability, yet its volatility limits payment utility. Stablecoins, particularly dollar-denominated ones, have become the de facto bridge for inclusion in emerging markets, offering low-cost remittances and DeFi access to the unbanked. However, their dominance risks "digital dollarization," amplifying US-centric dependencies even as other jurisdictions push back (Cipollone, 2025).

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This fragmentation creates a patchwork of digital fiefdoms rather than a seamless global commons. Smaller economies risk becoming peripheral to competing techno-blocs (US-led private ecosystems, EU-regulated zone, Sino-centric sphere), limiting true inclusivity.

Connection to Previous Works: How Inclusive Tools Reproduce Hierarchical Structures. This analysis builds directly on the authors' earlier studies (Baltgailis & Menshikov, 2025), which warned that the pursuit of an inclusive economy could accelerate digital neo-feudalism. Inclusive tools such as CBDCs and tokenization were intended to democratize access by reducing transaction costs and bypassing traditional gatekeepers. Instead, they often reproduce hierarchical structures in upgraded forms:

- Tokenization makes assets programmable and traceable, enhancing control rather than freedom.
- CBDCs shift power upward to issuers (states or approved entities).
- Stablecoins and DeFi, while innovative, gravitate toward centralized points of failure (issuers, bridges, major exchanges).

In all three models, the "rules of the game" favor scale, compliance infrastructure, and established players. Dialectically, as Hegel might observe, the thesis of technological democratization encounters the antithesis of power concentration, calling for a synthesis through institutional safeguards that preserve competition and individual sovereignty.

In summary, digital neo-feudalism manifests not as a return to medieval stasis but as a dynamic system of dependencies, rents, and algorithmic oversight. The inclusive potential of digital finance is real, yet without deliberate countermeasures, it risks subordinating individuals and smaller actors to new digital lords—whether bureaucratic, corporate, or state-based.

5. Research results and discussion

The comparative analysis of the European, American, and Sino-Indian regulatory models reveals that all three approaches have achieved measurable progress in expanding financial inclusion, yet they simultaneously generate new forms of institutional dependency. The findings support the central hypothesis of this study: the digital transformation of finance does not automatically produce greater economic freedom and may, under certain institutional conditions, foster the emergence of digital feudalism.

The European model demonstrates the strongest emphasis on legal certainty, consumer protection, and systemic stability. The implementation of MiCA, together with GDPR, DSA, and DMA, has established a highly regulated environment for digital finance. This framework reduces fraud, increases transparency, and strengthens trust in digital financial services. However, the analysis suggests that extensive compliance requirements create substantial barriers to entry for smaller firms and decentralized projects. As a result, market participation increasingly depends on access to legal expertise, regulatory resources, and institutional approval. Financial inclusion therefore expands through regulated channels, but at the cost of growing dependence on bureaucratic gatekeepers. This phenomenon can be characterized as a form of nomenklatura digital feudalism, where access to digital economic opportunities is mediated by regulatory structures rather than by open competition.

The American model produces a different outcome. By prioritizing private-sector innovation and limiting direct state involvement in retail digital currency issuance, the United States has created a dynamic environment for stablecoins, tokenized assets, and decentralized finance. The rapid growth of digital financial services has expanded access to alternative payment mechanisms and investment opportunities, particularly for underserved populations. Nevertheless, the concentration of cloud infrastructure, payment networks, operating systems, and

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digital marketplaces in the hands of a small number of technology corporations has generated significant power asymmetries. Network effects reinforce the dominance of established platforms, making it increasingly difficult for competitors to challenge incumbents. The result is a form of techno-feudalism in which economic participation depends not on state authorization but on access to privately controlled digital ecosystems.

The Sino-Indian model demonstrates the highest capacity for large-scale financial inclusion. Digital identity systems, mobile payment platforms, and CBDC initiatives have significantly expanded access to financial services among previously excluded populations. China's e-CNY and India's UPI ecosystem illustrate how state-supported digital infrastructures can rapidly increase participation in the formal economy. At the same time, the analysis identifies substantial risks associated with the concentration of informational and monetary power. Financial inclusion becomes embedded within highly centralized systems that enable extensive monitoring, programmability, and administrative control. In this model, economic participation increasingly depends on integration into state-managed digital infrastructures, producing what may be described as hyper-nomenklatura digital feudalism.

A key finding of this study is that financial inclusion and economic autonomy are not necessarily complementary objectives. While all three models successfully reduce barriers to access, they achieve this goal through mechanisms that simultaneously increase dependence on dominant institutions. In Europe, dependence emerges through regulation; in the United States, through platform concentration; and in China and India, through centralized state infrastructures. The institutional form differs, but the underlying dynamic remains similar: digital financial systems create new hierarchies of control over access to money, data, and economic participation.

The comparative assessment further demonstrates that digital feudalism manifests through three interconnected dimensions. The first is control over digital infrastructure, including payment rails, cloud services, digital identities, and settlement systems. The second is control over data, which increasingly functions as a strategic economic resource. The third is control over governance mechanisms, including algorithms, compliance systems, and programmable financial instruments. Actors that dominate these three dimensions acquire a privileged position within the digital economy, enabling them to extract rents, shape market behavior, and influence economic outcomes.

From a neo-institutional perspective, the findings confirm that technology itself remains neutral; it is the institutional framework governing technology that determines social and economic outcomes. CBDCs, stablecoins, tokenization, and distributed ledger technologies can either promote inclusive growth or reinforce digital hierarchies, depending on how incentives, governance structures, and competitive conditions are designed. Consequently, the principal challenge for policymakers is not merely to expand financial access but to ensure that digital inclusion does not evolve into new forms of dependency and concentrated power.

The evidence therefore supports the argument advanced in earlier research by Baltgailis and Menshikov (2025): the pursuit of an inclusive economy may unintentionally accelerate the formation of digital neo-feudal structures. The future trajectory of digital finance will depend on whether regulatory systems can preserve competition, interoperability, transparency, and consumer sovereignty while simultaneously maintaining financial stability and fostering innovation. The balance between these objectives will determine whether digital transformation strengthens economic freedom or creates a new generation of digital lords and digital vassals.

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Conclusions

The comparative analysis of the three regulatory models—European, American, and Sino-Indian—reveals that while each advances aspects of financial inclusion, all carry significant risks of emerging digital neo-feudalism. Whether through bureaucratic gatekeeping, Big Tech dominance, or state hyper-control, the institutional parameters shaping digital finance tend to concentrate power, erode autonomy, and create new dependencies. Updating our earlier work (Baltgailis & Menshikov, 2025), this article demonstrates that technologies promising democratization (DLT, tokenization, CBDCs, and stablecoins) often reproduce hierarchical structures in more sophisticated forms.

A hybrid approach emerges as the most promising path forward. It combines *clear, predictable rules* with sufficient space for private innovation, particularly in stablecoins and DeFi. Regulatory frameworks should focus on consumer protection, AML/KYC compliance, and systemic stability without imposing excessive barriers that stifle smaller players. Key safeguards include mandatory independent smart contract audits, formal verification protocols, ongoing reserve attestations for stablecoins, and robust interoperability standards between permissioned CBDC ledgers and public blockchains. Ethical frameworks - emphasizing transparency, data minimization, and contestability of algorithmic decisions - are equally vital to preserve individual autonomy.

Such a hybrid model would allow stablecoins to continue serving as practical tools for inclusion in emerging markets (remittances, savings, and basic DeFi services for the unbanked), while CBDCs focus primarily on wholesale efficiency and targeted public policy goals. Europe could relax some MiCA compliance burdens for innovative challengers, the United States could maintain its innovation-friendly stance while addressing systemic risks from dominant platforms, and China/India could gradually introduce controlled competition within sovereign frameworks.

Central to this hybrid vision is the *necessity of fostering competition through challenger firms*. Rather than pursuing aggressive breakups of existing monopolies (which often prove ineffective in digital markets due to network effects), policymakers should prioritize lowering entry barriers, ensuring fair access to infrastructure, and supporting open standards. Antitrust policy must evolve to address "moligopolies" by focusing on contestability, data portability, and interoperability. This aligns with Mises' emphasis on consumer sovereignty: true market discipline emerges when new entrants can challenge incumbents through superior service and innovation (Mises, 1966).

International coordination will play a decisive role. Organizations such as the Bank for International Settlements (BIS), International Organization of Securities Commissions (IOSCO), and Financial Stability Board (FSB) are well-positioned to develop global minimum standards for cross-border interoperability, stablecoin oversight, and DLT governance. Initiatives like Project mBridge and Project Agorá already demonstrate the value of collaborative experimentation. These bodies should prioritize public goods - such as standardized tokenization protocols and shared audit methodologies - while respecting monetary sovereignty and avoiding centralized global control.

Looking ahead, the dialectic of digital transformation (Hegel, 2015) demands a balanced synthesis: harnessing technological potential for inclusion without surrendering to new forms of feudal dependency. *An inclusive economy must not become digital feudalism.* The balance between advanced technologies, free markets, and individual freedom remains the key. As Ludwig von Mises consistently argued, only a system preserving genuine consumer sovereignty and open competition can sustainably allocate resources and maximize human well-being.

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THE IMPACT OF BIG DATA AND AI ON INNOVATION MANAGEMENT PROCESSES

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Abstract. In the era of digital transformation, innovation is becoming a key driver of enterprise competitiveness. This article analyses the impact of digitalisation on the management of innovation processes, focusing on the use of Big Data, artificial intelligence (AI), and advanced analytics as critical enablers of strategic decision-making. It examines how these technologies allow organisations to identify innovation opportunities more effectively, optimise product development and respond flexibly to rapidly changing market conditions. The article further discusses the main challenges associated with implementing digital solutions in the innovation process, including data quality issues, technical barriers, and organisational change. Finally, it offers practical recommendations for managers to support sustainable, agile, and data-driven innovation management.

Keywords: digital transformation; innovation; innovation management; data-driven innovation; Big Data; AI; data analytics; industrial laundry; circular economy

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JEL Classifications: M11, M15

1. Introduction

Under the influence of contemporary digital transformation, organisations are undergoing a fundamental shift in how they generate value for customers, establish relationships with them, and develop their products and services. The rapid advancement of technologies, including Big Data, artificial intelligence (AI), and sophisticated data analytics, brings substantial new opportunities to the field of innovation while simultaneously presenting considerable challenges. Innovation and associated processes no longer rely exclusively on managerial intuition or incremental improvement but increasingly leverage comprehensive, systematic data processing, automated methods, and digital solutions and platforms. This paradigm shift results in enhanced operational efficiency, new opportunities linked to digital innovation and its implementation, and the transformation of organisational structures.

The purpose of this article is to examine how digitalisation transforms innovation, innovation processes, and approaches to their management, with particular attention devoted to the roles of Big Data, artificial intelligence, and data analytics. The text is structured around three key thematic axes: the impact of digital transformation, opportunities to utilise data and AI to identify and evaluate innovation opportunities, and the influence of these changes on managerial decision-making and organisational structures within enterprises. In conclusion, the article presents a comprehensive set of concrete recommendations for managers seeking to effectively integrate contemporary technologies to enhance the performance and agility of their innovative activities.

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2. Research Methodology

Research Aim and Research Questions

The primary objective of this contribution is to analyse the impact of contemporary digital transformation and the associated management of innovation processes that leverage AI (artificial intelligence), Big Data, and data analytics. The following research questions were formulated to achieve the defined objectives:

- What impact does the approach to digital management of innovation have on enterprises?
- What role do modern technologies in the form of Big Data and AI play in identifying innovation opportunities?
- What are the primary barriers encountered in the implementation of data-driven innovation?
- How is digitalisation manifested in the industrial laundry sector?

Research Approach and Design

The research is grounded in a qualitative approach, within which theoretical-level analysis is combined with elements of a case study. The theoretical part of the contribution draws on a review of academic literature on digital transformation, the utilisation of contemporary data-oriented technologies, and innovation management in enterprises. The practical part of the contribution focuses on the analysis of a selected, specific sector of market services, namely the industrial laundry sector in the territory of the Slovak Republic. The chosen design enables a more detailed understanding of this contemporary phenomenon within its real-world context. It facilitates the identification of concrete relationships between technological tools and specific processes in innovation management.

Data Collection and Processing Methods

The following methods were applied in the development of this contribution:

- Analysis of secondary sources (scientific articles, academic literature, studies focused on the selected topic, and publications that collectively form the theoretical foundation of the subject matter).
- Comparative analysis (through which traditional and modern approaches to innovation management were compared)
- Case study (analysis of the implementation of innovative digital solutions in enterprises within the selected market services sector).
- Descriptive analysis (systematic processing of collected information and subsequent interpretation of findings).

Data on implemented innovations in industrial laundry enterprises (information systems, web portal, RFID) were obtained from secondary sources and from available information in business practice.

Selection of the Examined Market Services Segment

The industrial laundry sector was deliberately selected due to its highly specific nature as a market services area where traditional manufacturing processes are actively integrated with modern digital technologies to enhance operational efficiency and customer satisfaction. The chosen sector enables us to conduct a detailed analysis of:

- The utilisation of IoT sensors and production automation.
- The implementation of data analytics in enterprise operations.
- The impacts arising from digitalisation on operational efficiency and value creation for enterprise customers.

Research Limitations

The research is subject to several known limitations:

- Limited scope regarding the analysed enterprises within the given services sector.
- Reliance predominantly on secondary sources and information.
- Specificity of the selected services segment.

While these stated limitations do influence the research outcomes, the knowledge gained nonetheless provides significant insights into digital transformation and innovation management within the given market services sector.

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3. Theoretical Framework: Digital Transformation and Innovation

Digital Transformation

Digital transformation represents a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies (Vial, 2019). Digital transformation and the resulting business model innovation have fundamentally altered consumers'consumers' expectations and behaviours, pressured traditional firms, and disrupted numerous markets (Fitzgerald et al., 2013). The formulation and implementation of a digital transformation strategy (DTS) have become a key concern for many pre-digital organisations, given the transformative impacts of digital technologies on almost all aspects of an organisation's internal and external environments (Fitzgerald et al., 2013; Akis, 2015; Chanias et al., 2019). Despite growing acknowledge of the need for digital transformation, most companies struggle to get clear business benefits from new digital technologies. Digital technologies enable unprecedented replication at almost zero marginal cost once the required infrastructure is in place (Iansiti & Lakhani, 2014).

Digitalisation has emerged as one of the most significant global business trends over the past decade (Uršič & Čater, 2025; Andronikidis et al., 2025). Digital transformation represents a fundamental change that permeates the foundations of corporate strategy, internal business processes, and organisational culture through intensive and coordinated utilisation of modern, advanced digital technologies. This process transcends the scope of conventional software tool implementation or automation of individual tasks and activities – it signifies a fundamental restructuring and reformulation of the manner in which an enterprise operates. The principal components of digital transformation include the utilisation of cloud infrastructures, the Internet of Things (IoT), various mobile applications, diverse Big Data platforms and tools, as well as instruments based on artificial intelligence (AI), which collectively introduce a new level of interconnectedness, analytical capability, and automation. The digital revolution simultaneously creates significant pressure on enterprise agility, compelling organisations to substantially shorten innovation cycles and adapt more flexibly to continuously evolving customer requirements. Equally, pressure is created for more efficient collection, processing, and subsequent evaluation of vast quantities of data to enable informed and rapid decision-making on critical matters. As a result of digital transformation, the competitive landscape changes as barriers to entry for new competitors with digital and innovative business models are minimised, enabling them to operate with significantly lower initial investments and employ more flexible business strategies.

Innovation and Its Management in the Digital Age

Innovation is the process of creating new or significantly improved products, services, processes, or business models that generate value for organisations. Traditional innovation management models were typically based on a linear, step-by-step approach – from initial ideas through development to the market launch of products or services. Organisations increasingly apply open innovation principles, establish collaboration with start-ups, academic institutions, and technology partners, and make decisions based on extensive internal and external data.

Innovation management has become a fundamental component in building the success and sustainability of individual organisations in the contemporary era of digital transformation (Fernandez-Vidal et al., 2022; Fang & Liu, 2024). With the advent of digital technologies, the conceptual framework based on the strategic alignment of processes, tools, and rules that support innovative ideas and solutions has undergone a fundamental change. This era has opened new possibilities and opportunities for innovation, but has also increased the complexity and pace of subsequent management. Enterprises are therefore compelled to continuously innovate and adapt dynamically, as digital transformation increasingly affects sectors worldwide. Modern innovation management requires, above all, digital literacy, agile methodologies, and data-driven decision-making. Overall, innovation management is a dynamic field that continuously adapts to social, technological, and economic changes. Digital tools and technologies have fundamentally transformed the ways innovation is managed. They bring new possibilities for restructuring corporate structures and processes, while simultaneously supporting the emergence of innovative products and services as catalysts for change. Leading this change are technologies like the Internet of Things (IoT), Big Data Analytics, and Artificial Intelligence (AI). These technologies enable enterprises to acquire information, automate their processes and procedures,

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and, not least, to accelerate innovation cycles more efficiently. Successful innovation management in the digital age requires a combination of incremental improvements and fundamental changes, while it is essential to manage organisational resistance to transformation effectively.

The effectiveness of innovation management lies primarily in the regular examination of new opportunities, the continuous acquisition of contemporary knowledge, and the smoothest possible acceptance of change, which leads to sustained enterprise development and the formation of long-term benefits for all stakeholders. For an enterprise to achieve optimal innovation outcomes, it is essential to enhance its creative potential continuously and to actively utilise the opportunities offered by implementing digital innovations and solutions.

4. Transformation of Customer Value and Organisational Structures

New Forms of Customer Value

Companies that effectively manage digital technology can expect to gain in one or more of three areas: better customer operations, new lines of business, or new business models (Fitzgerald et al., 2013). Customer experiences reflect the clearest impact of digital transformation. The survey found that improving customer relationships was the area where companies were having the most success with digital technology. Most prominent was improving the overall customer experience, followed closely by enhancing products and services in customer-friendly ways (Fitzgerald et al, 2013). The implementation of digital technologies opens new pathways for creating innovative forms of value for consumers, whether through offerings "tailored to individual needs" or through digital service extensions that accompany existing physical products, subscription-based models, or interconnected service ecosystems. Innovation today does not focus exclusively on the product or service itself but on the overall consumer experience. This represents, from an innovation management perspective, the necessity for regular analysis of customer data, the collection and evaluation of the information obtained, monitoring of customer behaviour in the digital space, and, based on these indicators, the need to develop new approaches. Simultaneously, the relevance of methodologies such as design thinking and human-centred approaches is increasing, as they help enterprises better understand user needs. Digital innovations appear not only in the form of technological modifications but also in service-oriented approaches, where value is created through collaboration with engaged, actively participating customers who cooperate with enterprises. The analysis of big data and sophisticated forms of artificial intelligence enables the acquisition of extensive customer information, leading to innovations that are tailor-made and flexible in adapting to changing customer requirements in the market. Design thinking, conversely, helps empathise with customer needs and develop new solutions, thereby harmonising innovation with actual human needs, requirements, and problems, leading to greater success and customer satisfaction. Digital platforms, therefore, enable open innovation, which operates through the engagement of stakeholders, developers, and other partners in a shared creative process, leading to more diverse and user-focused solutions.

Organisational and Cultural Impacts

Broadly speaking, digital transformation extends beyond the mere implementation of new technologies and is primarily about a profound change in organisational structure and corporate culture, which increases responsiveness to change, fosters collaboration, and strengthens the enterprise's overall innovation performance. Digital transformation and the innovative methodologies associated with it represent fundamental driving forces that, by their nature, trigger bigger changes in organisational structure and corporate culture. Traditional enterprises, characterised by rigid, hierarchical structures, face significant challenges in adapting to the demands of the modern digital era. Such enterprises tend to operate on predetermined rules and procedures, which inhibit the flexibility required for rapid experimentation, continuous improvement, and interdisciplinary cooperation. A key factor in success is the ability to adapt flexibly to constantly changing requirements and to integrate new technologies and innovative solutions into enterprise operations actively. For this very reason, it is critical to build and continually support a corporate culture that helps overcome failure, encourages learning from mistakes, and facilitates knowledge sharing at all levels of the enterprise.

Culture should be directed toward encouraging and motivating all employees to remain open to voluntary experimentation with new, more modern methods, technologies, or procedures, thereby creating an environment that supports innovative thinking and creative problem-solving. In this way, space is opened for continuous

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process improvement, which is at the core of digital transformation. It is highly important that enterprise leadership continually focus on investing in the development of their employees, particularly in digitalisation, digital tools, and analysis of critical data, which enable enterprises to achieve higher levels of efficiency and more flexible responses to market challenges. Supporting employees through opportunities for further skills development increases engagement and motivation, and, consequently, they become active participants in various transformation processes, which is essential for building and maintaining lasting value derived from digital innovations.

5. Utilisation of big data, AI, and analytics in decision-making and implementation challenges

Big Data as a Source of Innovation Opportunities

Big Data refers to exceptionally large, complex, and diverse datasets that are generated and updated in real time and are characterised by exceptional velocity. All of this data is acquired from various sources, including intra-enterprise systems such as CRM and ERP, social media, IoT sensors, mobile applications, and external sources such as public repositories or specialised data solutions. The key characteristic of Big Data is not merely the volume of data itself, but rather its diversity (whether structured or unstructured) and, in particular, the velocity of its creation, which offers entirely new perspectives for enterprises across all sectors. In the field of innovation, Big Data holds tremendous value, as it provides comprehensive insights into various aspects of enterprise operations and market dynamics. Through Big Data, enterprises gain detailed information and knowledge about current trends, consumer behaviours, and specific preferences, product, or service functionality, and equally about the effectiveness of specific internal processes, enabling the enterprise to adapt its products and services more rapidly and thus dynamically optimise its offerings and significantly enhance customer satisfaction. Such an extensive data foundation enables enterprises not only to respond flexibly to unexpected changes but also to proactively identify new innovative solutions, opportunities, and strategic growth pathways. Given its extensive possibilities, Big Data is considered a source of energy for creating innovative solutions and decisions in modern enterprises. It provides a solid foundation for generating and managing innovative ideas, concepts, and projects. Big Data enables enterprises to transform raw data into highly valuable information and concrete findings, which in subsequent steps increase competitiveness and help maintain a strong position in a digitally oriented market.

Artificial Intelligence in Innovation Decision-Making

In the context of innovation, AI helps increase and optimise decision efficiency and quality by providing teams and managers with relevant, data-backed information, enabling them to make better-informed decisions. In the field of innovation, AI manifests in various critical applications, such as demand forecasting for the enterprise's new products or services, which facilitates production planning, important resource allocation, and the development of specific marketing strategies with maximum accuracy. Customer segmentation into distinct groups and tailored offerings enables more targeted engagement with different customer groups based on their specific preferences or behaviour, increasing the likelihood of success for innovative solutions. The evaluation of sentiment directly in customer reviews or comments, which are available on social media, provides valuable information about how customers perceive products, services, or the brand itself, bringing important insights in identifying weaknesses or areas where there is considerable room for improvement, or conversely reinforces assertions about the success of innovative elements. When product design is adapted based on feedback, it also signifies the rapid adaptation of products and services through an iterative process, ensuring the best possible alignment with consumer expectations and current market requirements.

Another highly significant application is the automated generation of solution variants, whether in product design or development. In this case, AI can generate multiple alternatives and simulate their potential before production begins and market launch occurs. This added value can save time, optimise costs, and particularly increase the quality and value of products or services. Through these applications, senior management and decision-makers obtain more comprehensive information to inform decision-making. Thanks to them, they gain a better overview of innovation projects in which they can invest, on which they can prioritise and determine how best to direct them.

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Artificial intelligence, through its capabilities, not only accelerates and improves the accuracy of critical decisions related to innovation but also creates space for new possibilities, testing, experimentation, and continuous learning amid a dynamically evolving digital transformation. Therefore, these technologies must be effectively implemented in enterprise operations, thereby significantly increasing competitive advantage not only in innovation but also in optimising processes and specific business models.

Data Analytics and Innovation Performance Metrics

Modern methods of advanced data analytics serve not only as a fundamental tool for identifying innovation opportunities but also provide the capability to track and evaluate innovation performance across the enterprise systematically and measurably. Through advanced and sophisticated analytics methods and additional tools, enterprises can precisely define and subsequently continually monitor all key performance indicators (KPIs), which provide them with noticeably clear insight into the extent to which their innovation processes are effective and the extent to which they help enterprises in building competitive positioning in the given market segment. The most important metrics enterprises monitor include the revenue share generated by new products or services. The aforementioned share reflects the true significance of innovation to the enterprise's financial results. An especially important factor that helps managers in evaluating innovation potential is the success rate of pilot projects or developed prototypes. They help evaluate the potential of ideas with the objective of further development or commercial implementation.

Data analytics plays a crucial role in all phases of the innovation process – from the selection and evaluation of proposals, through the efficient allocation of all necessary resources (human and financial), to the interim and final evaluation of the results achieved in the innovation process. In this manner, management can gain insight into which innovation activities and projects generate the greatest added value and, subsequently, which processes need further optimisation. A very important challenge, nonetheless, remains ensuring that data is reliable and of high quality, because on the basis thereof, necessary and authoritative analyses are performed. Very often, enterprises encounter barriers such as incomplete data, incorrect categorisation, and outdated or tainted information, which can lead to erroneous or inaccurate interpretations of the results (Agrawal et al., 2025). Moreover, it is necessary to ensure the correct interpretation of analytical data and, subsequently, its implementation into the specific strategic objectives of the enterprise, so that they appear not merely as dry numbers but rather serve as an effective tool supporting decision-making and the continuous improvement of affected processes. The main contribution of data analytics to innovation is that it can measure performance, identify weaknesses, and provide guidance for the strategic, purpose-driven management of innovation projects, thereby strengthening long-term enterprise growth and increasing the probability of success in a clear, impartial way.

Return on investment in research and development provides a perspective on economic efficiency and the long-term sustainability of innovation activities, which is critical for strategic decision-making and optimal resource allocation within the enterprise. This important indicator helps enterprises evaluate and visualise the extent to which their innovation initiatives contribute to growth and the maintenance of competitiveness, and, at the same time, enables the optimisation and efficient management of investments to maximise their market impact.

Implementation Challenges

The potential of data-driven innovation in the form of artificial intelligence, Big Data, and advanced data analytics is enormous, as these technologies offer new, simpler ways to improve the quality and efficiency of individual innovation processes. However, during implementation, various unexpected problems and challenges can emerge that enterprises must confront and overcome as effectively as possible. Among these challenges is, in particular, the lack of qualified specialists, such as data scientists. Thande specialists possess not only specific technical knowledge, but also a strong ability to connect developing modern technological solutions with the business needs of given enterprises. Another overly critical and troublesome obstacle is the fragmentation and incompatibility of available data sources, which create barriers for enterprises in systematic data acquisition, integration, and subsequent analysis. Necessary data may be stored and available in different formats, systems, or even platforms, representing a high degree of data heterogeneity and consequently requiring coordinated management and unified standards for the data environment. However, we must not overlook issues related to privacy protection, legislation, or data security, as they are equally capable of creating obstacles that an

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enterprise must by no means underestimate. Continuous protection and thorough safeguarding of all sensitive and personal data of employees, partners, and customers represent not only a legal obligation for all enterprises but also an important factor in credibility and the maintenance of the enterprise's reputation.

Enterprises often encounter the very natural resistance of employees and customers to change. Transformation from traditional, intuitive decision-making toward modern, data-driven processes places demands on changing mentality and ways of acting in practice at all levels of the business environment. Employees and managers must, above all, be open to adopting new methods of work, trust modern analyses, and be capable of re-evaluating established and customary work procedures. These very transformations in organisational structure and corporate culture are often neglected and underestimated, and yet they are a fundamental prerequisite for success. Management of data-oriented projects and innovations also requires an agile, iterative approach, which can entail something new, unfamiliar, and demanding to implement for some enterprises. Implementation challenges of digital technologies can also entail a high initial investment. These technologies, with their characteristics and the added value they offer, must convince enterprise leadership of their long-term return. They must see the significance of implementation and be able to predict returns over time. Generally, deploying data-driven innovation in enterprise operations is a complex process that demands not only technological resources but also a strategic approach, close cross-enterprise cooperation, and leadership support and motivation. Enterprises that, despite emerging barriers, successfully manage all challenges associated with implementing digital data-driven tools achieve a significant advantage over their competitors in the market and are particularly able to respond flexibly to constantly changing customer and market expectations and requirements.

6. Digital Transformation in the Industrial Laundry Sector

Industrial laundries play a significant role in the context of digital transformation, as they develop and implement important innovations in work organisation and service provision. Their growth is enabled by the efficient utilisation of digital and data-based tools and technologies in practice, thereby accelerating innovation processes and strengthening cooperation among various market actors.

Enterprises operating industrial laundries in the territory of the Slovak Republic represent a specific sector of market services, where digital transformation has enormous potential and scope for processes. By introducing modern digital technologies, these enterprises increase their efficiency, the quality of the products and services they offer, and even their energy sustainability. These are particularly manifested in IoT sensors, automated processes and procedures, advanced data analytics, and intelligent control devices in production. Digital transformation in this segment brings a substantial number of benefits and positive impacts, which are manifested in the form of better and more precise control over the entire laundry washing process from textile receipt, through main washing cycles, capacity planning, to predictive maintenance of technological equipment (Sardar et al., 2022; Sarkar et al., 2024). New technologies and innovations contribute to the continuous improvement of product and service quality, as their capabilities minimise downtime, prevent minor and serious malfunctions, and optimise operational costs (Taque et al., 2021). Beyond technological improvements, digitalisation brings positive progress also in the area of sustainability. Digital technologies help industrial laundries efficiently track and optimise resource consumption (water, energy, and chemicals), thereby significantly reducing negative environmental impact. Customers increasingly demand environmental innovations and improvements, and these are equally required by regulatory standards, underscoring the importance of sustainability in the examined market services segment. Thanks to technological capabilities and modern solutions, these enterprises are more competitive and can respond quickly and flexibly to constantly changing conditions and future challenges. Overall, digital transformation is not only reflected in innovation, improvement, and optimisation of operational performance, but forms the foundational pillars that shape the future of enterprises operating industrial laundries in the territory of the Slovak Republic and abroad, whose progress is directed toward "smart" and sustainable services. Innovations and their advantages are systemised in Table 1 below.

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Table 1. Innovations and their Advantages

Innovations	Advantages of Digital Innovation
Innovation 1: Integrated Information System	It consolidated various standalone systems into a single, flexible infrastructure, increasing transparency, clarity, and the speed of data access.
	It brought significant cost savings, particularly through the digitalisation of invoices and delivery notes and the reduction of postage expenses.
	It automates processes, thereby reducing manual work, errors, and accelerating document processing.
	It created specialised teams (Power Users) for system support and local customisation.
	Return on investment within a maximum of 5 years.
Innovation 2: Web Portal for Customers	It provides customers with online access to orders, invoices, shipment tracking, and complaint processes, thereby increasing customer satisfaction and efficiency.
	It reduces costs associated with customer support and administration.
	Integration with the internal system enables faster order processing and improves response time.
	Development of a mobile application is a further step toward improving accessibility and service convenience.
Innovation 3: RFID Technology	It enables contactless tracking of textiles through electronic chips embedded directly in the products.
	It increases the accuracy of record-keeping and reduces losses and errors in inventory management.
	It streamlines logistics, inventory management, and operational efficiency.
	The result is higher service quality and process transparency.

Source: own processing based on survey data

These digital innovations represent significant steps toward the modernisation of industrial laundries, which enable them not only to optimise internal processes and reduce costs, but especially to strengthen relationships with customers and build a firmer market position.

All the aforementioned digital innovations help companies fulfil their tasks and achieve increasingly better results (Schneider & Kokshagina, 2021; Verhoef et al., 2021; Tajpour & Dekamini, 2024; Uršič & Čater, 2025).

An enormous benefit of the integrated information system, which connects all departments from production through warehousing to administrative departments, is real-time data management, which is particularly helpful in optimising individual tasks, processes, and inventory management. Thanks to these capabilities, managers can acquire information more quickly and make decisions on important matters, thereby significantly reducing risks and increasing operational productivity. The customer web portal additionally streamlines communication with customers, offers them deeper insights, and provides timely information about their rented items and their record-keeping at every step. This innovation in this segment builds stronger loyalty and increases customer satisfaction by giving customers access to necessary information and data without delay. Thanks to RFID, the company and its customers gain a more precise overview of the movement of rented items, inventory status, submitted requests, and more. Together, these 3 innovations create a single, interconnected whole that, through its capabilities, helps companies not only reduce costs and make decisions more quickly but also respond more flexibly to changing market requirements. All these innovations help enterprises build strong competitiveness and long-term sustainability.

Despite the significant contributions of digitalisation and integrated solutions, complications can arise in practice in large-capacity laundries when implementing new technologies. The initial phase of introducing these tools brings not only high investment costs but also considerable organisational problems, which may be associated, for example, with inadequate employee preparation. Some teams' resistance to change may stem not only from fears of automation but also from insufficient training and subsequent support for new technologies.

As a result of the above, significant delays in daily operational processes can occur. It has been shown that without a clearly defined performance measurement strategy and a definition of key objectives, there is inconsistent use of systems, which can reduce the expected effect not only on efficiency but also on customer experience.

This example highlights that innovation alone is insufficient – success requires comprehensive preparation, timely training, cultural change, and strategic management of digitalisation. Otherwise, there is a risk that instead of growth and improvement, digitalisation will become a source of further complications and increased

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costs. When comparing traditional and model approaches to implementing digital innovations, we find considerable differences (see Table 2 below).

Table 2. Traditional Approach vs Model Approach for Successful Implementation

Criterion	Traditional Approach	Model Approach for Successful Transformation
Strategic Planning	Isolated projects, Innovations come ad hoc	Comprehensive digital strategy with clearly defined, concrete objectives
Investment in Technology	Investment in technology without a proper context	Technologies are an integral part of a coherent strategic and development process
Change Management	Weak Change Management, resistance without motivation	Proactive preparation and training of stakeholders.
Culture and Engagement	Resistance and concerns about digitalisation and automation	Support for an innovative culture, a circular economy, and the motivation of employees
Performance Metrics	Metrics are not concretely defined	Clearly established KPIs, proper monitoring and subsequent work with data
Flexibility	Rigid, inflexible systems and processes	Agile approaches, the capability of flexible adaptation to change
Source and Investment	Often ineffective or inefficient	Targeted investments with a focus on return on investment

Source: own processing based on survey data

Digital transformation in enterprises operating industrial laundries is an overly complex and so-called multi-level process that emphasises a systematic and thoughtful approach. Successful implementation of various modern digital technologies is conditional not only on investments in the technologies themselves, but also on the enterprise's competence to flexibly adapt its primary, managerial, and supporting processes, organisational culture, and employee capabilities.

A Holistic Approach to Digital Innovation: Big Data and AI as Catalysts for Enterprise Transformation Toward a Circular Business Model

As enterprises undergo strategic reorientation in the contemporary business environment, a comprehensive perspective on modenological transformation and innovative solutions is increasingly important, substantially transcending the narrowly focused optimisation of individual organisational operations (Nielsen et al., 2022; Ren et al., 2023; Ozen & Ozturk-Kose, 2024).

This perspective inherently recognises that today's enterprises face the imperative to simultaneously address multiple critical strategic dimensions: enhancing operational performance, fulfilling ecological and social requirements, and utilising insights from advanced data analytics to formulate significant business decisions. Within this framework, Big Data and Artificial Intelligence represent indispensable instruments that enable enterprises to accelerate their transition from linear business models toward regenerative and circular value creation models, particularly within specialised service sectors characterised by pronounced demands on human capital and intellectual resources, such as industrial maintenance and textile cleaning operations (Lv & Chen, 2024; Li et al., 2025).

The incorporation of advanced data analytics and AI-driven technologies into enterprise operations serves dual purposes in supporting the principles of the circular economy (Ciano et al., 2025). First and foremost, these technologies enable comprehensive, continuous collection of critical data at a massive scale and real-time monitoring across all phases of the value creation chain—from the initial inputs of individual resources and components, through product distribution, to final transformation, with the potential for reintroduction into the production process. Sophisticated data processing and interpretation tools are capable of monitoring critical performance indicators (KPIs) focused on resource-efficient effectiveness and optimal utilisation of natural resources (criteria R4: resource consumption optimisation, natural and renewable materials, partial or complete reuse, secondary raw material utilisation) and indicators of business model transformation processes (R10), thereby providing enterprises with precise information regarding where raw material losses occur, where energy losses can be minimised, and where circular economy linkages can be established (Dziallas & Blind, 2019; Chanias et al., 2019). Furthermore, computational systems and algorithms can more rapidly identify non-obvious patterns, complex, atypical regularities, and improvement perspectives within demanding operational

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ecosystems that might otherwise remain entirely invisible when applying conventional data analysis methodologies.

In the case of large-scale industrial laundry facilities, for example, predictive models based on automated analysis can anticipate expected fluctuations in service demand, adjust production schedules to reduce water and energy consumption optimally, alert to necessary equipment maintenance before failure occurs, and intelligently organise the movement and flow of textiles through individual equipment to eliminate redundant, unnecessary operations. Forecasting algorithms, derived from training on historical records, continuously refine recommendations for resource and material allocation and distribution, thereby assisting enterprises in achieving more agile transformation toward more sustainable and financially advantageous circular operational procedures (Dorrego-Viera et al., 2025).

Systems for data collection, further processing, and storage of massive volumes of data and information also enable enterprises to undertake continuous monitoring and evaluation of integrated approaches to business model transformation. Real-time interactive dashboards aggregate data from IoT sensors, enterprise production management systems, critical quality control modules, and customer feedback, providing comprehensive, transparent, and up-to-date information necessary for rapid hypothesis validation and agile directional course correction. Such a data- and information-oriented management approach aligns with contemporary change management and organisational development methodologies, which enable enterprises to continuously verify whether implemented circular economy initiatives achieve anticipated environmental and financial benefits and to facilitate adjustments to transformation plans based on empirical observations (Kuzma et al., 2020; Kim et al., 2021).

The synergistic interaction between holistic enterprise organisational design, circular economy principles, and sophisticated modern information technology tools thus creates a highly stable and effective foundation for sustained market positioning and competitive advantage (Hermundsdottir & Aspelund, 2021; Guo, Ali & Xu, 2023; Hamdouna & Khmelyarchuk, 2025).

Enterprises that effectively combine the discipline of individual process management with the capabilities of advanced data analytics of extensive data volumes and optimisation driven by Artificial Intelligence are capable of achieving significantly faster operational excellence, strengthen their commitment to environmental stewardship and organisational agility—thereby transforming what might initially appear as mutually exclusive business objectives into mutually reinforcing and supportive strategic outcomes (Hurtado-Palomino et al., 2022; Jiang et al., 2025). The integration of Big Data and AI into a Holistic Transformation Model Toward the Circular Economy is described in Table 3 below.

Table 3. Integration of Big Data and AI into a Holistic Transformation Model Toward Circular Economy

Model Component	**Function and Significance**	**Big Data and AI Application**
1. Process Management	Mapping, monitoring and optimisation of key processes within the service system (reception → washing → pressing → suspension → quality control → collection → balancing → delivery → processing). Identification of quality issues, minimisation of complaints and improvement of service efficiency.	IoT sensors monitor parameters in real time (temperature, humidity, weight); Big Data analytics identify patterns and anomalies in processes; AI algorithms optimise the sequence of operations based on historical data; predictive analytics provides critical feedback before process failures.
2. Transformation Toward Circular Economy Model	Integration of circular economy principles: minimisation of waste, optimal use of water and energy, environmental responsibility for materials, and logistics optimisation. R4 criteria (resource efficiency, renewable inputs, reuse, recycling) – principle of resource efficiency. R10 (process redesign, digitalisation) – metrics for transformation and circular process management.	Big Data captures the complete material and energy balances; AI models identify optimal opportunities for waste reduction and maximum recycling potential; machine learning predicts where to best apply circular principles; real-time dashboards visualise the circularity of processes.

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3. R4 and R10 Determinants	R4 (resource efficiency, renewable inputs, optimal utilisation, recycling) – principle of resource efficiency. R10 (process redesign, digitalisation) – metrics for transformation and circular process management.	Advanced analytics measure R4 and R10 metrics in real time; AI-driven benchmarking compares actual performance against best practices; predictive models simulate changes in R4/R10 before implementation.
4. Innovation Management	Active search for innovation opportunities, problem solving, implementation of new technologies and processes, effectiveness measurement, development of employees and organisational culture supporting innovation.	Big Data analytics identify innovation opportunities based on trends and customer needs; AI experiments validate hypotheses quickly; predictive analytics assess innovation potential and risk before implementation; intelligent knowledge management promotes sharing of innovation knowledge across the organisation.
5. Systematic Performance Monitoring and Optimisation	KPI monitoring (revenue, ROI, number of innovations, water/energy consumption, environmental indicators). Continuous process improvement, quality and environmental responsibility.	Real-time BI dashboards visualise KPI metrics in one place; predictive analytics provide trend forecasting and enable proactive adjustments; AI-powered optimisation provides specific recommendations for performance improvement; continuous learning systems automatically incorporate lessons from new data.

Source: own processing based on survey data

7. Description of Findings

Digital transformation and the development of data-oriented technologies fundamentally alter the primary role of innovation processes in contemporary enterprises. These technologies, on one hand, provide the means to achieve a substantially deeper and more precise understanding of customer expectations and requirements through comprehensive data source analysis, and on the other hand, help validate newly emerging ideas and test them in the shortest possible timeframe while most efficiently allocating often limited resources to projects demonstrating the greatest potential. This contribution addresses four fundamental research questions that guide the examination of digital transformation and innovation management in contemporary enterprises. Each question is accompanied by key points that outline the primary impacts, roles, barriers, and manifestations of digitalisation. Table 4 presents a comprehensive overview of these research dimensions, providing a structured framework for understanding how digital technologies reshape innovation processes, organisational structures, and competitive strategies in the industrial laundry sector and beyond.

Table 4. Research Questions and Key Findings

Research Question	Key Points
What impact does the approach to digital management of innovation have on enterprises?	Positive Impacts: More precise customer understanding, shortened time limits, resource optimisation
	Challenges: Investment costs, cultural change, employee training
What role do Big Data and AI play in identifying innovation opportunities?	Detection of hidden patterns and trends
	Predictive analysis
	Personalisation and segmentation
	Analysis of the competitive environment
	Optimisation of innovation processes
What are the primary barriers encountered in the implementation of data-driven innovation?	Technical and infrastructure barriers
	Data barriers
	Organisational and cultural barriers
	Management and strategic barriers
	External barriers
How is digitalisation manifested in the industrial laundry sector?	Modernisation of technological processes (ERP, RFID, web portals)
	Optimisation of operations
	Improvement of customer experience
	Data management and analytics
	Challenges and benefits

Source: own processing based on survey data

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Simultaneously, however, digitalisation and new data-oriented technologies create pressure for the continuous development of employees and their competencies, which represents additional investments in training and efforts toward organisational culture change. Cultural barriers, such as assistance to change, lack of employees' willingness to utilise modern data technologies, and concerns about automation, can significantly impede their implementation and practical application. For this very reason, it is critically important that enterprises actively invest effort in building a corporate environment that supports continuous learning and knowledge sharing, and that motivates further experimentation.

From the enterprise perspective, it is crucial to understand that the mere implementation of modern technologies such as AI, Big Data, and other advanced data analytics does not automatically guarantee success. Their genuine benefit and capacity to transform innovation processes lie in their strategic integration into the overall innovation strategy of the given enterprise. This implies that it is extremely important to define clear and measurable objectives, design and apply appropriate performance metrics, and ensure support for suitable processes, a corporate structure, and the competencies that facilitate the effective utilisation of these technologies. The absence of a strategic approach can introduce unexpected complications and increase organisational complexity in digital transformation, and may even result in chaos and reduced efficiency in innovation activities.

The implementation of digital innovations also depends on the industry and enterprise size, which influence both the capability and manner of its execution. When examining larger enterprises, we observe the availability of extensive resources for investment in advanced, modern solutions (AI, Big Data); however, their size and complexity often result in lower agility and significantly slower adaptation to new technologies and market changes. Conversely, small and medium-sized enterprises rely more substantially on their flexibility and speed of decision-making, yet typically face limited resources required for such innovations. This reality compels these enterprises to seek external partners, suppliers of specific technologies, or develop collaborations within ecosystems to best utilise the potential of modern tools.

This diversity of conditions and opportunities means that no single universal approach exists for managing digital innovation. Enterprises must adapt their strategies, processes, procedures, and necessary investments to the specificities of their size, industry, service segment, and market environment. To achieve successful implementation, it is necessary to analyse detailed challenges and concrete opportunities while simultaneously adapting flexibly to constantly changing conditions, thereby strengthening innovation capability and sustainable growth over the long term.

Digital transformation in the industrial laundry sector brings various benefits; however, simultaneously, it presents multiple challenges and risks that enterprises must critically evaluate. Through the implementation of modern digital technologies (ERP systems, RFID, web portals, and others), companies assume substantial investments in infrastructure, employee training, and organisational structure changes, which may be demanding and not easily accessible for some enterprises. Beyond the aforementioned financial burden, digitalisation brings significant risks associated with dependence on IT technologies, which, in the event of unexpected outages, can disrupt operations and the execution of necessary procedures to meet contractually established customer requirements. Another emerging problem is the protection of personal data and other sensitive information, as large volumes of data are processed, presenting potential security risks. Ultimately, the very dynamics of technological change may reflect the reality that certain solutions rapidly become obsolete, necessitating further investments and subsequent adaptation, which can slow the pace of transformation. For this reason, it is critically important that digitalisation in the laundry segment, which entails substantial investments in required technology, be executed with a thoroughly considered, sound strategy, clearly defined objectives, and a detailed, realistic implementation plan.

8. Conclusion and Recommendations

The era of digital transformation brings new opportunities for innovation and fundamentally influences how innovations are managed. Digitalisation tools provide enterprises with effective instruments for a better understanding of the market, customer expectations and requirements, greater precision in the decision-making

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process, and, in particular, the optimal utilisation of necessary resources. So that their potential is not left unutilised, it is extremely important to:

- Strategically integrate and anchor digitalisation and new data analytics technologies into the innovation strategy of the given enterprise, and subsequently determine their objective and expected benefits for the enterprise.
- Create and support an environment open to experimentation and continuous learning, which tolerates possible failures and unsuccessful attempts with the objective of learning from mistakes.
- Ensure the quality and integrity of necessary data, and secure and ethical further handling thereof, thereby creating credibility and relevance of analytical outputs.
- Link technological innovations to customer expectations and requirements, for example, by engaging customers in testing and developing new products or services.

Although digital transformation brings endless new possibilities, human potential remains a key element of success in work processes, whether in industrial laundries or in enterprises across other segments. Artificial intelligence and automation can efficiently process large volumes of data and perform repetitive tasks with very high precision; however, their effectiveness depends on clearly defined tasks, procedures, and objectives that must first be established and assigned by employees. Human creativity, the capability to resolve often unforeseen situations, critical thinking, and intuition are elements that remain irreplaceable, enabling adaptation to changing market conditions and technological environments.

The manner in which this phenomenon will continue to develop and how mutual cooperation between humans and, in this case, artificial intelligence will proceed remains largely unanswered to date. Currently, however, artificial intelligence cannot fully replace human potential; rather, it complements and extends human capabilities with its own. Therefore, it is extremely important to continually invest in the development of employees' capabilities, further training, and creativity, so that the potential of digitalisation can be utilised, particularly without loss of human value in the work process.

Future research on this topic may focus more on detailed examinations of specific case studies of other enterprises that actively implement and support digital transformation, as well as on the resulting benefits. It would be beneficial to monitor and evaluate approaches to digitalisation also by enterprise size, segment, and geographic region, to create a picture of best practices and strategic models tailored to the specific parameters of individual enterprises across various market conditions in the territory of the Slovak Republic.

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EUROPEAN UNION SECURITY AND DEFENCE TRANSFORMATION IN AN ERA OF GEOPOLITICAL CHANGE: STRATEGIC AUTONOMY, INNOVATION ECOSYSTEMS, AND SUSTAINABILITY

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Abstract. The European Union is undergoing a profound transformation of its security and defence policy in response to a changing geopolitical environment characterised by intensified strategic competition, geoeconomic fragmentation, technological rivalry, and the consequences of Russia's war against Ukraine. This article examines the principal drivers of this transformation and analyses the relationship between defence expenditure, defence-industrial development, strategic autonomy, and emerging mechanisms of collective defence governance. Employing a qualitative-quantitative analytical approach based on document analysis, comparative assessment, and secondary data analysis, the study argues that the current evolution of European defence reflects a broader adaptation to structural changes in the international system rather than a temporary response to a single crisis. The findings indicate that the effectiveness of rising defence expenditure depends on the ability of Member States to strengthen industrial capabilities, technological innovation, and collaborative procurement mechanisms. The analysis also highlights that security and defence influence the conditions for sustainable economic development, while defence investment contributes to innovation ecosystems, technological entrepreneurship, and the competitiveness of the European economy.

Keywords: European Union; security and defence; strategic autonomy; defence industrial base; innovation ecosystems; sustainable development

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Additional disciplines: Security, International Relations, Political Science

1. Introduction

The European security environment has undergone a profound transformation over the past decade (Ivančík & Andrassy, 2026a). Assumptions that shaped the post-Cold War order, including expectations of a relatively stable strategic environment, enduring transatlantic security guarantees, and the possibility of separating economic development from geopolitical competition, have come under growing strain (Biscop, 2021; Zwolski, 2025). Russia's full-scale invasion of Ukraine in 2022 accelerated trends that had already been reshaping the international system and exposed structural weaknesses in the European Union's approach to security and defence. As a result, debates once centred primarily on defence cooperation and military preparedness have expanded to encompass industrial capacity, technological competitiveness, economic resilience, and strategic autonomy (Ivančík & Andrassy, 2025; Guseinov, 2025; Ivančík & Dušek, 2026).

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This shift reflects broader changes in the international environment (Barakat, 2025). Strategic competition among major powers, geoeconomic fragmentation, technological rivalry, supply-chain vulnerabilities, and the growing use of economic instruments for geopolitical purposes have blurred the traditional distinction between security and economic policy (Georgio, 2024). Under these conditions, access to critical technologies, industrial capabilities, strategic resources, and resilient supply chains has become an important determinant of security (Ivančík & Andrassy, 2026b). For the European Union, these developments have raised fundamental questions regarding the sustainability of a security model that relied heavily on economic interdependence, limited defence investment, and extensive dependence on external security providers.

The war in Ukraine exposed the practical consequences of these vulnerabilities (Johansson-Nogués & Leso, 2025). European governments encountered difficulties in replenishing military stockpiles, expanding defence production, and coordinating procurement efforts at a scale required by a prolonged high-intensity conflict (Simón, 2023). These challenges reflected not merely temporary resource shortages, but deeper structural weaknesses associated with fragmented defence markets, insufficient production capacity, and limited coordination in capability development (Hackett & Schreer, 2025). At the same time, uncertainty surrounding the future trajectory of transatlantic relations has intensified discussions concerning Europe's ability to assume greater responsibility for its own security.

The growing prominence of defence within European policymaking therefore represents more than a reaction to a single geopolitical shock. It reflects a broader adaptation to an international environment in which security depends to a rising extent on the interaction between military capabilities, industrial competitiveness, technological innovation, and economic resilience (Ivančík & Majchút, 2026). The rapid growth of defence expenditure, the emergence of new defence-industrial instruments, and efforts to strengthen common procurement indicate that the Union is seeking not only to enhance military preparedness but also to reduce strategic dependencies and strengthen the foundations of long-term security (Bran & Bălăşoiu, 2025).

Beyond their security implications, these developments also have important consequences for sustainable economic development and innovation-driven entrepreneurship. The strengthening of defence-industrial capabilities increasingly supports broader innovation ecosystems and technological development while a stable and secure environment remains a fundamental precondition for long-term economic sustainability, investment, and industrial competitiveness (Ivančík & Majchút, 2026).

Against this background, the article examines how contemporary geopolitical developments are reshaping European Union security and defence policy and assesses whether current efforts in defence spending, defence-industrial development, and collective capability building can contribute to strengthening the Union's strategic autonomy. It argues that the ongoing transformation of European defence should be understood as an adaptation to structural changes in the international system rather than solely as a response to the war in Ukraine. While higher defence expenditure constitutes a necessary condition for strengthening European capabilities, its strategic impact depends on the Union's ability to reduce institutional fragmentation, expand defence-industrial capability, foster technological innovation, support innovation-driven industrial ecosystems, and improve mechanisms of defence governance and procurement.

The article employs a qualitative-quantitative analytical approach combining document analysis, comparative assessment, and secondary data analysis. Drawing on data from European institutions, defence agencies, and international organisations, it examines the relationship between geopolitical change, defence investment, industrial capacity, and strategic autonomy. The analysis proceeds in three stages. First, it identifies the principal geopolitical drivers of Europe's defence transformation. Second, it examines the relationship between defence spending, industrial capacity, and strategic autonomy. Third, it analyses the role of common procurement and emerging governance mechanisms in shaping the future trajectory of European defence integration.

The theoretical framework combines insights from realist approaches to international relations, geoeconomic perspectives, and the growing literature on strategic autonomy and resilience. Together, these approaches provide a basis for analysing how geopolitical pressures influence defence-industrial adaptation and institutional change within the European Union.

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2. Geopolitical Drivers of the EU Defence Transformation

The transformation of European Union security and defence policy is frequently interpreted as a direct consequence of Russia's full-scale invasion of Ukraine in 2022. Although the war accelerated political decision-making and heightened perceptions of insecurity across Europe, such an interpretation overlooks deeper structural forces that had already been reshaping the strategic environment. The current transformation of European defence reflects a broader adjustment to changes in the international system, while the war in Ukraine served primarily as a catalyst that exposed vulnerabilities accumulated over several decades (Ivančík & Andrassy, 2026a).

A central feature of this transformation has been the erosion of assumptions that underpinned the European security order after the Cold War. Reduced defence expenditure, expanding economic interdependence, and confidence in a relatively stable strategic environment encouraged European governments to prioritise economic integration over military preparedness (Biscop, 2021). Defence gradually lost political salience as large-scale interstate conflict appeared progressively less likely. This model delivered substantial economic benefits but also reduced incentives to maintain military readiness, defence-industrial capability, and long-term investment in collective defence capabilities.

The weakening of these assumptions reflects a broader shift in the distribution and exercise of power. Strategic competition among major powers has intensified, while technological leadership, control over critical resources, and resilience of supply chains have become major determinants of geopolitical influence (Georgio, 2024). Under these conditions, economic interdependence no longer functions solely as a source of stability; it may also generate strategic vulnerabilities. The growing overlap between economic security and national security has altered the strategic calculations of European governments and expanded the scope of defence policy beyond traditional military concerns (Ivančík & Andrassy, 2026b).

Russia's actions represent the most immediate manifestation of this changing environment. The annexation of Crimea in 2014 challenged the foundations of the European security order, while the invasion of Ukraine demonstrated that conventional interstate warfare remains a central instrument of power politics. The conflict not only exposed Europe's limited preparedness for prolonged high-intensity warfare but also revealed structural weaknesses within its defence-industrial base (Simón, 2023). Difficulties in replenishing ammunition stocks, replacing transferred equipment, and expanding production capacity highlighted a persistent gap between political ambitions and the material resources required to sustain them. The war revealed not merely a military threat but a broader problem of capability generation (Juncos & Pratt, 2025).

The strategic implications of these developments extend beyond Europe's eastern border. China's rise has accelerated the redistribution of economic and technological power at the global level, linking questions of competitiveness, innovation, industrial policy, and security more closely than at any point in recent decades. Although China does not constitute a direct military threat to the European Union comparable to Russia, its growing influence has reinforced concerns regarding technological dependence, access to critical raw materials, and the resilience of strategic sectors (Council of the European Union, 2022). Security policy can no longer be separated from the ability to sustain technological leadership and industrial competitiveness (European Defence Agency, 2021).

This geoeconomic dimension became particularly visible during the COVID-19 pandemic and the subsequent disruption caused by the war in Ukraine. Both crises exposed vulnerabilities associated with external dependencies and demonstrated how supply-chain disruptions can affect industrial production, economic stability, and security preparedness simultaneously (Tocci, 2022). As a consequence, resilience and strategic autonomy have moved from largely conceptual debates to practical policy objectives.

A further driver of European defence transformation stems from uncertainty regarding the future evolution of transatlantic relations. European security has long depended on a division of responsibilities in which the United States provided the majority of capabilities required for collective defence (Lippert & Mair, 2026; Maliutin & Perepelytsia, 2026). Yet changing strategic priorities in Washington and growing attention to the Indo-Pacific

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have raised questions about the long-term sustainability of this arrangement (Tatsumi, 2025). The challenge is not the disappearance of the transatlantic partnership but the possibility that Europe may need to assume greater responsibility for its own security under conditions of constrained American engagement (Council of the European Union, 2022).

Taken together, these developments have broadened the meaning of security within the European Union. Defence is no longer understood exclusively in terms of deterrence and territorial protection (Hackett & Schreer, 2025). It now encompasses industrial capability, technological innovation, economic resilience, supply-chain security, and the ability to sustain production during periods of prolonged geopolitical tension (Hellberg, 2026). This shift explains why contemporary European defence initiatives place growing emphasis on industrial policy, technological development, common procurement, and strategic autonomy alongside traditional military capabilities.

The ongoing transformation of European defence should be understood as an adaptation to a geopolitical environment in which military power, economic resilience, technological capacity, and industrial competitiveness have become deeply interconnected (Ivančík & Andrassy, 2026b). Its long-term success will depend on whether the current sense of strategic urgency can be translated into durable institutional, financial, and industrial reforms capable of strengthening Europe's capacity to act under conditions of sustained geopolitical competition (Marek & Baun, 2026).

Table 1 summarises the principal geopolitical drivers behind the ongoing transformation of European Union defence policy and identifies their corresponding strategic implications. The table illustrates that the current transformation is shaped by the interaction of geopolitical, technological, economic, and security-related pressures rather than by any single event. Understanding these drivers is essential for explaining why defence spending, defence-industrial base, and Europe's capacity for independent action have become interconnected dimensions of European security policy.

Table 1. Geopolitical Drivers and Strategic Implications of the EU Defence Transformation.

Driver	Main Impact on EU Defence
Russian aggression	Military preparedness and deterrence
Rise of China	Technological competition and economic security
Geoeconomic fragmentation	Supply-chain resilience
Transatlantic uncertainty	Strategic autonomy and burden-sharing
Technological rivalry	Defence innovation and industrial modernisation

Source: Author's own elaboration based on the analysed literature and policy documents

3. Defence Spending, Industrial Capacity, and Strategic Autonomy

The transformation of the European security environment has been accompanied by an unprecedented increase in defence expenditure across the European Union. After decades during which defence budgets were constrained by competing fiscal priorities and relatively low threat perceptions, European governments have substantially revised their spending priorities (Ostanina, 2025). Yet the significance of this shift cannot be assessed solely through the volume of resources allocated to defence. A more important question concerns whether higher expenditure contributes to the development of sustainable military capabilities, technological competitiveness, and strategic autonomy (Vroege, 2023).

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According to the European Defence Agency, total defence expenditure among the twenty-seven Member States reached approximately €343 billion in 2024 and is projected to rise to around €381 billion in 2025, compared with approximately €218 billion in 2021 (European Defence Agency, 2026). The scale of this increase reflects a profound reassessment of Europe's security environment and the growing recognition that military preparedness has once again become a central requirement of state security.

The evolution of European defence expenditure between 2021 and 2025, presented in Figure 1, provides quantitative evidence of this strategic reassessment. More importantly, it illustrates a broader shift in political priorities in which defence has re-emerged as a component of economic robustness, industrial preparedness, and long-term security planning.

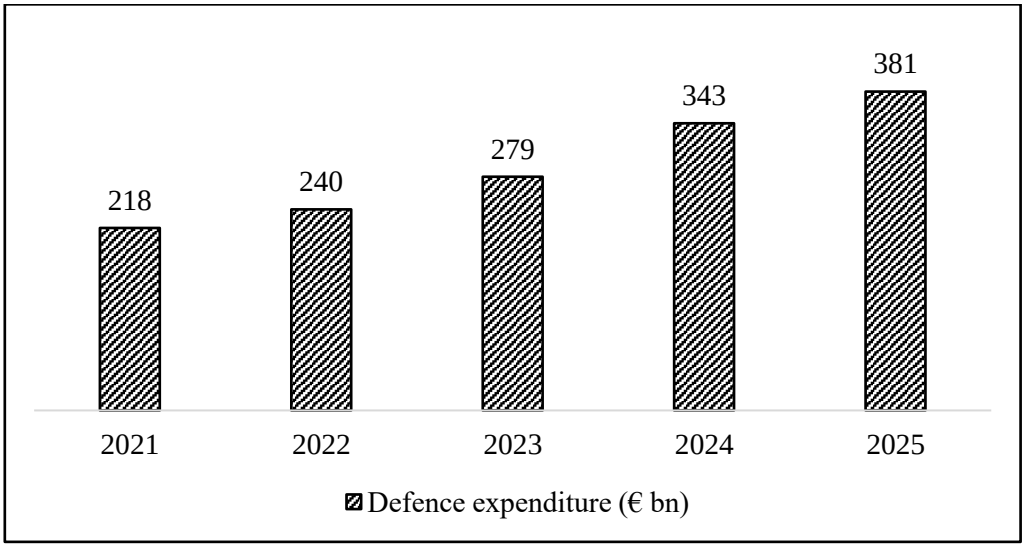


Figure 1. Growth of EU Defence Expenditure (2021–2025)
Source: Author's own elaboration based on EDA, 2026

Rising expenditure alone, however, does not guarantee stronger defence capabilities. The principal challenge facing the European Union is not the availability of financial resources but the dispersion of defence investment across twenty-seven national systems characterised by different procurement cycles, industrial priorities, force structures, and strategic cultures (Vroege, 2023). Although Member States collectively spend more on defence than Russia and allocate resources comparable to other major military actors, fragmentation continues to limit the Union's ability to convert expenditure into coherent military capabilities (Ivančík & Andrassy, 2025). This challenge is reflected in procurement and capability development. Collaborative spending remains limited, while European armed forces continue to operate a wide range of platforms and weapons systems (Clapp, 2026). Such dispersed procurement structures increase acquisition and maintenance costs, reduces interoperability, and constrains economies of scale. The strategic consequence is a persistent gap between aggregate expenditure and collective capability generation.

Defence investment has emerged as a key instrument for addressing these shortcomings. In 2024, defence investment exceeded €106 billion and accounted for approximately 31 percent of total defence expenditure, the highest share recorded by the European Defence Agency (European Defence Agency, 2026). Expenditure on equipment procurement reached approximately €88 billion, while defence research and development spending rose to around €13 billion. These figures indicate that Member States are directing a growing share of resources towards long-term capability development, technological innovation, and military modernisation rather than solely increasing operational expenditure.

Table 2 summarises the principal investment, research, and innovation indicators associated with the current transformation of European defence. Beyond the growth of overall defence expenditure, the data highlight the increasing importance of defence investment, equipment procurement, and research and development activities.

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These indicators are particularly relevant because they capture the extent to which additional financial resources are being directed towards capability development, technological innovation, and the strengthening of the European Defence Technological and Industrial Base.

Indicator	Value
Total defence expenditure	€343 bn
Defence investment	€106 bn
Equipment procurement	€88 bn
Defence Research and Development	€13 bn
Defence Research and Technology	€5 bn

Table 2. EU Defence Investment, Research and Innovation Indicators
Source: Author's own elaboration based on EDA, 2026

While aggregate expenditure figures demonstrate the scale of Europe's financial commitment to defence, investment trends provide a more accurate indication of the long-term transformation taking place within the European security and defence sector. Figure 2 therefore illustrates the evolution of defence investment between 2021 and 2025. The rapid growth in investment expenditure is particularly significant because it suggests that Member States are directing a rising share of resources towards military modernisation, technological development, research and innovation, and the expansion of manufacturing capability. In the context of strategic autonomy, these developments are arguably more important than rising expenditure alone, as they strengthen the technological and industrial foundations upon which future European defence capabilities will depend.

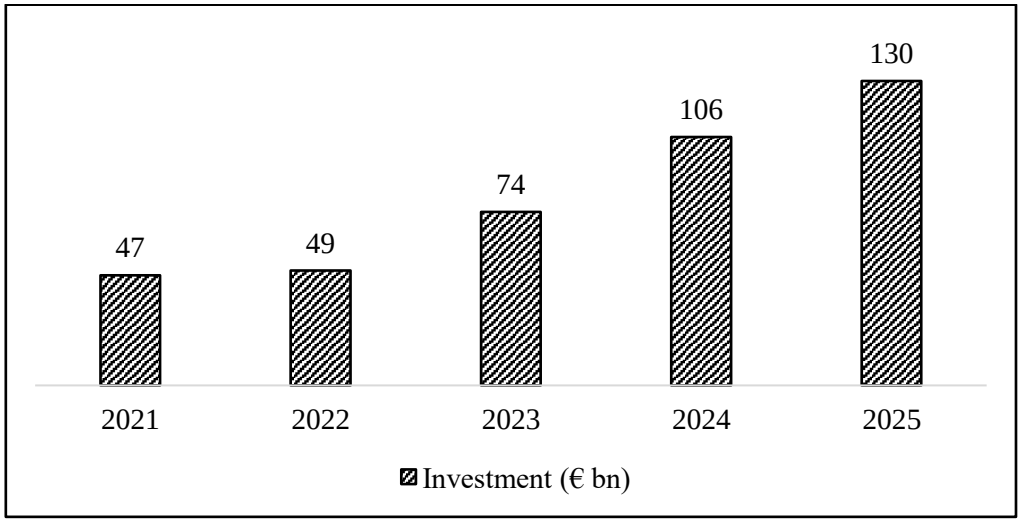


Figure 2. Growth of EU Defence Investment (2021–2025)
Source: Author's own elaboration based on EDA, 2026

The trends presented in Figure 2 suggest that the quality and structure of defence spending may be more consequential for Europe's future strategic capacity than expenditure levels alone. Strategic autonomy is often discussed in political terms, yet its foundations are fundamentally economic and technological. States cannot sustain meaningful strategic autonomy without the industrial capacity required to produce critical equipment, the technological base necessary to support innovation, and supply chains capable of withstanding disruption during periods of crisis.

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The war in Ukraine exposed the strategic implications of these dependencies. Replenishing ammunition stocks, replacing transferred equipment, and expanding production capacity proved far more difficult than anticipated (Marrone, 2024). In several sectors, industrial output was unable to keep pace with rapidly growing demand, revealing a gap between financial commitments and production capabilities (Hellberg & Lundmark, 2025). The conflict therefore demonstrated that the defence-industrial base constitutes a strategic asset rather than merely an economic sector.

This insight has broader implications. Contemporary military power depends not only on the quantity of available equipment but also on the capacity to sustain production, integrate emerging technologies, and adapt to changing operational requirements (Zagorodnyuk, 2026). Artificial intelligence, cyber capabilities, autonomous systems, advanced semiconductors, space technologies, and critical raw materials now shape both military effectiveness and economic competitiveness (Hellberg & Lundmark, 2025). Defence-industrial policy has consequently become inseparable from debates concerning technological sovereignty, industrial adaptability, and long-term competitiveness (European Commission, 2024).

Beyond its military significance, the strengthening of the European defence-industrial base also carries important implications for long-term economic sustainability. Sustainable development depends not only on environmental performance and social cohesion but also on the existence of secure institutional, economic, and technological foundations (Genini, 2025). Prolonged geopolitical instability, disrupted supply chains, and external strategic dependencies can undermine economic growth, investment certainty, and industrial development (Popov, 2025). From this perspective, security and defence should be viewed not as competing with sustainability, but as enabling conditions that support the resilience and continuity of sustainable economic development within increasingly uncertain geopolitical environments (Tocci, 2022; Batusaru & Sbârcea, 2023). The ongoing expansion of defence investment is also creating new opportunities for innovation-driven entrepreneurship. Emerging technologies increasingly shaping contemporary security—including artificial intelligence, cyber security solutions, autonomous systems, advanced sensors, and space applications—are frequently developed by specialised technology firms, start-ups, and dual-use innovators operating at the intersection of civilian and defence markets (Besch, 2023). Consequently, defence-industrial policy is becoming closely linked to broader innovation ecosystems that connect public investment, private entrepreneurship, research institutions, and technological commercialisation (Genini, 2025). In this regard, instruments supporting collaborative defence investment may generate effects extending beyond military capability development by stimulating technological innovation, industrial upgrading, and the emergence of new high-value entrepreneurial activities (European Defence Agency, 2021).

The pursuit of strategic flexibility nevertheless involves significant trade-offs. Immediate security requirements following the outbreak of war in Ukraine encouraged many European governments to prioritise rapid procurement over industrial-policy objectives (Genini, 2025). A substantial share of recent acquisitions has therefore been directed towards suppliers outside the European Union. While such decisions often reflect practical considerations related to availability and delivery speed, they also risk reinforcing external dependencies and slowing the development of the European Defence Technological and Industrial Base (Perotto, 2023).

This tension helps explain why recent European initiatives increasingly combine defence spending with industrial and technological policy instruments. Their objective is not simply to increase expenditure but to strengthen production capacity, stimulate innovation, support collaborative development programmes, and reduce critical dependencies (Popov, 2025). The capacity for independent action extends beyond military preparedness; it encompasses the industrial, technological, and economic foundations required to sustain European security under conditions of prolonged geopolitical competition.

Europe has entered a new phase of defence transformation characterise d by sustained growth in both expenditure and investment. The strategic consequences of this shift will depend less on the absolute volume of resources available than on the effectiveness with which those resources are converted into technological innovation, industrial capacity, and operational capability. The opportunity created by higher defence spending is significant, but its long-term impact will depend on whether Member States can overcome persistent

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coordination deficits and strengthen the foundations of a more resilient and autonomous European security architecture.

4. Common Procurement, Defence Governance, and the Limits of European Defence Integration

The rapid increase in defence expenditure across the European Union has intensified a longstanding question: how can national defence investments be transformed into collective military capabilities? The effectiveness of defence spending depends not only on the resources invested but also on the institutional mechanisms through which those resources are coordinated and translated into operational outcomes (European Council, 2025a). Fragmented procurement, overlapping capability-development programmes, and limited industrial integration have historically reduced the strategic return on European defence expenditure (European Commission, 2025). The current debate concerns not simply how much Europe spends on defence, but how effectively those resources are organised.

This challenge is rooted in the historical structure of the European defence market. Defence procurement has traditionally remained one of the most protected domains of national policymaking, reflecting concerns related to sovereignty, industrial development, employment, and technological control (Perotto, 2023; Mueller, 2025). While this approach helped preserve national defence-industrial capabilities, it also generated duplication, reduced interoperability, and limited economies of scale. As Europe's security environment deteriorated, the costs of market fragmentation became more visible (Johansson-Nogués & Leso, 2025).

The war in Ukraine exposed these limitations with particular clarity. European governments were required simultaneously to support Ukraine, replenish depleted stockpiles, modernise armed forces, and strengthen deterrence (Brezula, 2026). These demands revealed that fragmented procurement and production structures were poorly suited to addressing security challenges that exceeded national manufacturing capabilities. Cooperation in procurement consequently evolved from a desirable objective into a strategic necessity (European Council, 2025a).

The significance of recent European initiatives such as EDIRPA and SAFE lies less in their immediate financial value than in the logic that underpins them. Both initiatives reflect recognition that defence integration requires mechanisms capable of reducing capability fragmentation, encouraging collaborative procurement, and strengthening the European Defence Technological and Industrial Base (European Parliament and Council of the European Union, 2023). Their broader purpose is to address structural inefficiencies that have long limited the effectiveness of European defence spending and capability development.

This logic extends beyond procurement itself. European policymakers now regard industrial fragmentation as a strategic vulnerability because it constrains production capacity, weakens competitiveness, and limits the ability of industry to respond rapidly to changing security requirements. Common procurement is not merely a defence instrument; it also serves as a mechanism for industrial consolidation, technological development, and the creation of more robust production networks (European Commission, 2024; Andersson & Britz, 2025).

The growing importance of common financing reflects a similar shift in thinking. Defence integration cannot be achieved solely through political declarations or voluntary coordination if the costs of capability development exceed the financial capacity of individual states. Instruments such as SAFE, which provides access to large-scale financing for defence investment and procurement, indicate a gradual movement towards collective approaches to security financing (European External Action Service, 2026). More broadly, they reflect the growing recognition that security constitutes a collective European public good whose provision may require forms of collective financial responsibility.

These developments point towards the gradual emergence of new forms of defence governance within the European Union (Brøgger, 2025; European Council, 2025b). Security challenges associated with military coercion, cyber threats, technological competition, critical infrastructure vulnerabilities, and supply-chain disruptions frequently transcend national borders. As a result, pressures for greater coordination arise not

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primarily from political ambitions for deeper integration but from the practical requirements of managing shared security risks (European External Action Service, 2026).

The development of common governance mechanisms nevertheless faces significant constraints. Defence remains closely associated with national sovereignty, and governments remain reluctant to relinquish control over procurement decisions, industrial priorities, and force-development strategies (Council of the European Union, 2022). Divergent strategic cultures and differing threat perceptions further complicate efforts to establish more integrated approaches. These factors help explain why institutional adaptation continues to progress more slowly than the changing security environment might require.

A further limitation arises from the tension between long-term autonomous capability generation and operational urgency. The need to strengthen military capabilities rapidly has often encouraged procurement from non-European suppliers capable of delivering equipment within shorter timeframes. Although such decisions may be justified by immediate security requirements, they may also reinforce external dependencies and slow the development of the European defence-industrial base (Bran & Bălăşoiu, 2025). The result is a persistent dilemma: measures that strengthen military readiness in the short term may complicate efforts to strengthen Europe's capability for independent action in the longer term.

The broader significance of contemporary European defence initiatives lies in their potential to reshape the institutional foundations of European security. Common procurement, collective financing, and defence-industrial cooperation represent attempts to reconcile national sovereignty with the practical necessity of collective action (Nemeth et al., 2025). Their success will depend not only on the availability of financial resources but also on the willingness of Member States to address the structural sources of institutional and industrial disunity that continue to limit Europe’s capacity to generate collective capabilities.

European defence governance remains a work in progress. Nevertheless, recent developments suggest that defence integration is driven more by strategic necessity rather than political symbolism. The central question is no longer whether greater cooperation is desirable, but whether emerging governance and financing mechanisms can generate the level of industrial integration, technological innovation, and capability development required to sustain European security in an increasingly competitive international environment.

Conclusion

The transformation of European Union security and defence policy represents one of the most significant strategic adjustments in the history of European integration. Although Russia’s full-scale invasion of Ukraine accelerated political decision-making and exposed critical weaknesses in European military preparedness, the analysis presented in this article demonstrates that the origins of this transformation lie in broader structural changes within the international system. Intensifying geopolitical competition, technological rivalry, geoeconomic fragmentation, and uncertainty surrounding the future of transatlantic burden-sharing have collectively altered the conditions under which security is pursued and sustained. In alignment with the first phase of our analytical framework, these overarching geopolitical drivers demonstrate that the ongoing evolution of European defence is not a temporary response to a single isolated crisis, but a fundamental, long-term structural adaptation to a permanently altered global order.

The findings suggest that the current evolution of European defence should be understood not as a temporary response to a single crisis but as an adaptation to an environment in which military power, industrial capability, technological innovation, and economic security have become closely interconnected. Security is no longer determined solely by the size of armed forces or defence budgets. It also depends on the capacity to sustain production, secure critical technologies, maintain supply chains capable of withstanding disruption, and mobilize industrial resources during periods of prolonged geopolitical tension. Addressing the second phase of the analysis regarding the relationship between spending and autonomy, the study underscores that a quantitative increase in defence budgets is insufficient on its own. The strategic impact of these financial resources inherently depends on expanding the production capacity of the European Defence Technological and

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Industrial Base, embedding defence policy within broader innovation ecosystems, and recognizing security as an enabling condition for sustainable economic development.

This challenge explains the growing importance of common procurement, defence-industrial cooperation, and collective financing mechanisms. Initiatives such as EDIRPA and SAFE indicate a gradual recognition that many of Europe's security challenges cannot be addressed effectively through purely national approaches. Their broader significance lies in their potential to improve the efficiency of defence investment, strengthen the European Defence Technological and Industrial Base, and reduce vulnerabilities arising from external dependencies. Focusing on the third phase of our framework, these emerging collective governance and common procurement mechanisms represent a shift toward structural, transnational risk management driven by strategic necessity rather than mere political symbolism. At the same time, significant obstacles continue to limit deeper integration. National sovereignty concerns, divergent strategic priorities, and the tension between short-term capability requirements and long-term industrial objectives remain important constraints. The pursuit of rapid military modernization has frequently encouraged procurement from non-European suppliers, illustrating the continuing difficulty of balancing immediate security needs with the objective of strengthening Europe's own technological and industrial foundations.

The future of European defence will depend less on the continued expansion of defence budgets than on the Union's ability to translate financial resources into industrial strength, technological advancement, innovation capacity, and operational effectiveness. Strategic autonomy should therefore be understood not as self-sufficiency or a substitute for transatlantic cooperation, but as the capacity to act, adapt, and sustain security under conditions of growing geopolitical uncertainty. The current period represents a critical juncture. The strategic pressures that emerged after 2022 have created a unique opportunity to address long-standing structural weaknesses within European defence. Whether this opportunity results in a more integrated and effective security architecture will depend on the willingness of Member States to overcome persistent coordination gaps, deepen cooperation, and align investment, industrial policy, innovation ecosystems, and capability development with the strategic realities of a rapidly changing international environment while supporting the long-term sustainability and competitiveness of the European economy.

The scientific novelty of these findings manifests in several interconnected dimensions that enrich the contemporary academic discourse. First, this study offers a holistic tri-sectoral integration by breaking down traditional academic silos, effectively demonstrating how industrial defence policy serves as a direct catalyst for dual-use technological entrepreneurship and economic resilience within modern innovation ecosystems. Second, the analysis reveals a critical structural paradox: the immediate operational urgency to secure external procurement directly undermines the long-term industrial foundations required for genuine strategic autonomy. Finally, the article advances the conceptualization of European defence integration by proving that the transition toward collective financing and common procurement is no longer an expression of normative or symbolic ambitions, but a functional, hybrid adaptation to transnational geoeconomic and geopolitical pressures.

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SIX LEVELS OF ROBOTIC SUBSTITUTION OF HUMAN LABOUR: A STAGED FRAMEWORK FOR IMPROVING PERFORMANCE IN ENGINEERING ENTERPRISES*

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Abstract. Engineering enterprises face increasing pressure to improve productivity, quality, competitiveness and long-term sustainability under conditions of labour shortages, rising complexity and accelerating digital transformation. Robotic systems are often presented as a response to these pressures, yet the relationship between robotisation and enterprise performance is neither automatic nor uniform. Existing automation and autonomy frameworks classify system capability, while Industry 4.0 maturity models assess organisational readiness; however, they do not sufficiently explain how the progressive substitution of human labour by robotic systems can be linked to concrete performance outcomes. This paper addresses this gap by proposing a six-level framework of robotic substitution of human labour in engineering enterprises. The framework adopts work substitution as its central unit of analysis and distinguishes six stages: Assisted Work, Robot as a Helper, Human–Robot Tandem, Teleoperated Robotic Work, Semi-Autonomous Robotic Work and Full Robotic Autonomy. Each level is connected to specific performance mechanisms and indicators, including ergonomic load, safety, quality, overall equipment effectiveness (OEE), labour productivity, value added per employee and capital productivity. The framework is developed as a conceptual design artefact grounded in socio-technical systems thinking and illustrated through typical engineering operations such as welding, material handling, assembly, quality inspection and internal logistics. The paper argues that higher autonomy is not automatically superior; progression between levels should be governed by safety as a gatekeeper and operational data as an enabler. The framework provides managers with a structured language for performance-oriented, safe and evidence-based robotisation decisions.

Keywords: robotic substitution of human labour; engineering enterprises; manufacturing performance; productivity; competitiveness; Industry 4.0; human–robot collaboration; socio-technical systems; sustainable manufacturing

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JEL Classifications: O31, O32, O33

1. Introduction

Engineering and manufacturing enterprises face increasing pressure to improve productivity, quality, competitiveness and long-term sustainability. In Europe, these pressures are intensified by labour and skills shortages: around four out of five small and medium-sized enterprises report difficulty finding workers with the required skills, while advanced-manufacturing sectors face ageing workforces and widening capability gaps (European Commission, 2024; CECIMO, 2025). At the same time, adoption is accelerating: average robot density in Western European manufacturing reached a record 267 units per 10,000 employees in 2024 (IFR,

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2025). Robotic systems are therefore increasingly viewed not only as technological innovations, but as strategic instruments for improving enterprise performance and reducing dependence on scarce manual labour.

However, robotisation does not automatically improve performance. Empirical research shows that the effects of advanced automation and Industry 4.0 technologies depend on implementation approach, production context, organisational capabilities and human capital rather than on technology alone (Krulický et al., 2024; Čižo et al., 2025; Bureš & Bartoš, 2025). A robot may improve repeatability but reduce flexibility; a collaborative robot may improve ergonomics but increase cycle time; a semi-autonomous system may improve throughput but require new supervision, maintenance and data capabilities. Robotisation should therefore be evaluated as a multidimensional performance intervention, not as a linear path toward higher autonomy. This contingency is consistent with recent competitiveness research showing that the effects of digital transformation vary with firms' underlying competitive capacity and organisational characteristics, rather than emerging uniformly from technology adoption itself (Pan et al., 2025).

Existing research provides valuable but partial perspectives. Levels-of-automation models explain how control is distributed between humans and machines (Endsley & Kaber, 1999; Parasuraman et al., 2000). Autonomy taxonomies such as SAE J3016 and ALFUS classify system capability (SAE International, 2018; Huang, 2008). Industry 4.0 maturity models assess organisational readiness, while safety and human–robot collaboration standards define interaction limits and protective requirements. However, these streams do not sufficiently explain how specific human tasks are progressively substituted or transformed by robotic systems, nor how such substitution translates into enterprise performance.

This creates a practical gap for managers of engineering enterprises. They must decide whether a unit of work should remain manual, be supported by an assistive device, be performed in cooperation with a robot, be teleoperated, be semi-autonomous or be fully autonomous. Each option implies different performance outcomes, safety requirements, data needs, human roles and governance responsibilities.

This paper addresses this gap by proposing a six-level framework of robotic substitution of human labour in engineering enterprises. The framework adopts work substitution as its unit of analysis and links each level to performance indicators such as ergonomic load, occupational safety, quality, overall equipment effectiveness (OEE), labour productivity, value added per employee and capital productivity. It is governed by two principles: safety acts as a gatekeeper of progression, and operational data act as an enabler of informed transition between levels. The framework does not assume that full autonomy is always desirable; remaining at a lower level may be rational when it provides a better balance between productivity, flexibility, quality, safety, cost and human capability.

The paper is guided by two research questions:

- *RQ1*: How can the stages of robotic substitution of human labour be structured so that each stage is linked to specific performance outcomes of an engineering enterprise?
- *RQ2*: What role do safety and the accumulation of operational data play as conditions governing progression between stages?

The remainder of the paper is organised as follows. Section 2 reviews the relevant literature. Section 3 defines the research gap and conceptual approach. Section 4 presents the six-level framework. Section 5 develops the performance logic and governing conditions. Section 6 illustrates the framework for typical engineering operations. Section 7 discusses managerial implications. Section 8 concludes with contributions, limitations and a research agenda

2. Literature Review

2.1 Digital transformation, Industry 4.0 and enterprise performance

Digital transformation and Industry 4.0 are widely associated with improved productivity, flexibility, quality and competitiveness in manufacturing enterprises. Their technological basis includes cyber-physical systems, industrial Internet of Things, sensors, simulation, cloud computing, advanced analytics, artificial intelligence

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and robotics. In management-oriented research, these technologies are not only technical artefacts, but resources that can reshape value creation, business models, performance management and, at the network level, more sustainable and flexible production architectures.

However, empirical evidence shows that performance effects are contingent rather than automatic. Smart manufacturing maturity can improve financial performance and operational efficiency, but its effects depend on industry type and workforce structure (Jang et al., 2022). Industry 4.0 technologies can strengthen the relationship between servitisation and performance, but mainly when aligned with broader strategic transformation (Bortoluzzi et al., 2022). Human factors also matter: implementation is shaped by skills, fear, resistance and organisational readiness, not only by technological capability (Obermayer et al., 2022). Beyond technology adoption itself, organisational performance is shaped by the joint configuration of technology, leadership and human-resource practices.

Recent research on Industry 4.0, digital transformation and labour productivity similarly suggests that digital technologies support productivity, competitiveness and sustainability only when mediated by organisational conditions, data capabilities and human capital (Krulický et al., 2024; Čižo et al., 2025; Bureš & Bartoš, 2025). This literature establishes the first premise of the paper: digital and robotic technologies can contribute to enterprise performance, but only under specific contextual and organisational conditions. A complementary competitiveness perspective also identifies future readiness, knowledge, adaptive attitudes and regulatory frameworks as interdependent drivers of digital performance, supporting a holistic rather than isolated view of technological upgrading (Qazi, 2025).

Recent cross-sectoral studies further reinforce the view that the business value of digital technologies depends on organisational readiness and systematic evaluation rather than on technology adoption alone. Skare et al. (2026) developed a three-stage information-analytical system that evaluates the feasibility of artificial intelligence adoption, managers' understanding of its implementation and its potential contribution to sustainable business outcomes, based on data from 1,000 Slovak enterprises. From complementary sectoral perspectives, Gavurova et al. (2025) proposed a hybrid decision-support model combining stakeholder assessments and expert knowledge to evaluate the socio-economic effects of digital transformation, while Smolanka et al. (2024) developed an expert model for measuring and managing the level of information-technology implementation in healthcare institutions. Although these studies focus on different economic sectors, they collectively demonstrate that technological transformation requires context-sensitive, multidimensional and evidence-based evaluation frameworks – a principle that is directly relevant to performance-oriented robotic substitution in engineering enterprises.

2.2 Robotisation of manufacturing work

Robotisation is a specific form of digital transformation because robots physically intervene in the execution of work. Unlike many digital technologies, they alter not only information flows but also physical tasks, work organisation, safety conditions, skill requirements and the relationship between humans and machines on the shop floor.

Stingl et al. (2024) conceptualise robotised manufacturing work as a complex system of entangled changes involving work, organisation of labour, workers' experiences and the firm's environment. This systemic view is important because robotisation cannot be reduced to a linear cause-effect relationship between robot adoption and performance improvement. Anzolin and Andreoni (2023) further show that firms robotise in heterogeneous ways depending on production modularity, technology flexibility and product-design stability. Even within the same sector, robotisation differs according to how technology is integrated into the production system. Evidence from robotic process automation similarly indicates that successful deployment is determined less by the technology itself than by implementation approach, organisational readiness and clearly defined success factors.

These findings support the paper's focus on work substitution. Robotisation should not be understood as simple replacement of a worker by a machine. When a robot takes over part of a task, surrounding human roles, coordination mechanisms, data flows, safety requirements and managerial responsibilities also change. In many cases, workers are not removed from the system but repositioned toward preparation, supervision, exception

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handling, maintenance, quality control or process improvement. This staged perspective is also consistent with evidence from production enterprises showing that successful corporate change depends on clearly defined objectives, regular monitoring, implementation data and systematic tracking of incremental progress (Vrtana et al., 2025).

2.3 Contingent performance effects of robotisation

The performance effects of robotisation are multidimensional and contingent. Robots may improve repeatability, precision, safety or throughput, but they may also reduce flexibility, increase capital intensity, require new skills or introduce new coordination and safety risks. Therefore, robotisation should not be evaluated as a general move toward higher autonomy, but as a performance intervention whose value depends on task characteristics and organisational conditions.

This contingency is consistent with evidence from smart manufacturing and Industry 4.0 adoption (Jang et al., 2022; Bortoluzzi et al., 2022). It is also visible in lean production contexts, where Industry 4.0 technologies may generate tensions between managerial expectations, worker roles and established improvement routines (Margherita & Braccini, 2024). Such tensions show that technology adoption is also an organisational change process.

For engineering enterprises, this implies that performance must be assessed across several dimensions: productivity, quality, OEE, lead time, unit cost, safety, ergonomic load, flexibility, value added per employee, reliability, energy use and human-capital development. A higher level of robotic substitution should be considered better only if it improves the performance dimensions that matter for the specific enterprise without creating unacceptable safety, organisational or economic costs. More broadly, recent European evidence links the prevalence of high-growth firms in digitally transforming environments to labour-market efficiency, business sophistication, market size and access to finance, underscoring that technology-related performance is embedded in a wider competitiveness configuration (del Olmo-García et al., 2025).

2.4 Automation, autonomy and maturity frameworks

Existing automation, autonomy and maturity frameworks provide useful foundations but do not fully address the managerial problem studied here. Levels-of-automation models describe how control and decision-making are distributed between humans and machines (Parasuraman et al., 2000; Endsley & Kaber, 1999). They show that automation is not binary and that human-machine responsibility can be distributed in different ways. However, they do not link levels of work substitution to enterprise performance outcomes.

Autonomy taxonomies such as SAE J3016 and ALFUS demonstrate the communicative value of staged models (SAE International, 2018; Huang, 2008). Yet they classify system capability rather than the transformation of concrete human work. Industry 4.0 maturity models, in turn, assess organisational readiness, connectivity and data infrastructure, but usually operate at the level of the firm or production system as a whole. They do not specify how individual tasks are progressively substituted or transformed.

The limitation is therefore one of unit of analysis. Existing frameworks ask how control is distributed, what a system can do, or how digitally mature an organisation is. This paper asks a different question: how can progressive robotic substitution of human labour be structured so that each stage is linked to enterprise performance and governed by safety and data conditions?

2.5 Safety, human–robot collaboration and socio-technical governance

Safety and human factors are central to robotic substitution. Standards such as ISO 10218 and ISO/TS 15066 define interaction modes, separation requirements, speed and force limits, and protective measures for industrial and collaborative robots. These standards are essential, but in a staged framework safety should be treated not only as compliance, but as a transition condition.

Human–robot collaboration (HRC) illustrates this point. Collaborative robots can combine human flexibility with robotic precision and repeatability, but their performance effects are not straightforward. They may improve ergonomics and quality while also introducing coordination costs, cycle-time penalties, cognitive load

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or resistance. Worker adaptation is therefore critical. Employees working with robots face technical issues, skill gaps and changing responsibilities, and their roles often shift from direct execution toward supervision and exception handling (Salcedo-Gil et al., 2025). Regional and organisational perceptions also matter, especially in Central and Eastern Europe, where robotics is associated with workflow automation, safety, profitability and workforce retention (Stor et al., 2025).

Robotisation may generate concerns about job substitution, but its social meaning is not always negative. Technological innovation can also signal firm health and long-term competitiveness, reducing perceived job insecurity among remaining workers under certain conditions (Caselli et al., 2024). Overall, safety, adaptation and governance determine whether robotic substitution becomes a sustainable performance improvement or a premature technological intervention.

2.6 Literature synthesis

The reviewed literature provides five building blocks. Industry 4.0 research shows that digital technologies can support performance, but their effects depend on organisational and human conditions. Robotisation research shows that manufacturing work is transformed as a socio-technical system. Performance studies show that automation effects are contingent and involve trade-offs. Autonomy and maturity frameworks provide staged thinking, but focus on system capability or organisational readiness. Safety and HRC research shows that progression toward higher robotic involvement must be governed by safety, adaptation and responsibility.
What remains missing is an integrated framework that treats robotic substitution of human labour as the central unit of analysis and links different stages of substitution to specific enterprise performance outcomes. This gap is practically important because managers do not decide about autonomy in the abstract. They decide whether a concrete task should remain manual, be assisted, be shared with a robot, be teleoperated, be semi-autonomous or be fully autonomous. The present study addresses this gap by proposing a six-level framework that connects each stage to performance outcomes and defines safety and operational data as governing conditions for progression.

3. Research Gap and Conceptual Approach

The literature shows that robotisation, Industry 4.0 and automation are well-established research themes, but they remain insufficiently integrated from the perspective of managerial decision-making. Automation frameworks classify control allocation, autonomy taxonomies classify system capability, maturity models assess organisational readiness, and safety standards define interaction constraints. None of these approaches adopts progressive work substitution as its central unit of analysis.

This creates a practical and conceptual gap. Managers of engineering enterprises do not decide about autonomy in the abstract. They decide whether specific tasks or task segments should remain manual, be supported by robots, be performed collaboratively, be teleoperated, be conditionally automated or be fully substituted. Each option implies different performance outcomes, safety requirements, data needs, human roles and governance responsibilities. A technically feasible robotic solution may still be economically unjustified, unsafe, too rigid for customer-specific production or dependent on capabilities that the firm does not yet possess.

To address this gap, the paper adopts work substitution as the central unit of analysis. Work substitution is understood as the progressive transfer, transformation or reallocation of responsibility for task execution, physical action, monitoring, decision support or exception handling from humans to robotic systems. This perspective differs from system autonomy because it starts not with what the robot can do technically, but with which elements of human work are being changed and what this means for enterprise performance.

The conceptual approach is grounded in socio-technical systems thinking, which emphasises the joint configuration of technical artefacts, human roles and organisational processes (Trist & Bamforth, 1951; Checkland, 1985). From this perspective, each level of robotic substitution represents a socio-technical configuration in which robotic capability, human responsibility, safety assumptions, operational data and performance indicators must be aligned.

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The framework is developed as a conceptual design artefact following the logic of design science research, where artefacts are created to address relevant organisational problems and support structured problem-solving (Hevner et al., 2004; Peffers et al., 2007). Its purpose is not to predict performance outcomes statistically, but to provide a structured language for analysing and managing staged robotic substitution in engineering enterprises.

Three assumptions shape the proposed framework. First, robotic substitution is staged rather than binary: human labour is progressively supported, shared, supervised, transferred or transformed across different configurations. Second, performance is multidimensional and contingent: the value of a substitution level depends on the indicators that matter in the given enterprise context and on whether benefits outweigh safety, organisational and economic costs. Third, progression is conditional: a higher level of substitution is justified only when safety requirements are met, operational data reduce uncertainty, and governance responsibilities are clearly defined. This staged and conditional view is consistent with conceptual accounts of digital transformation that describe enterprise development as a path punctuated by qualitative transition points rather than continuous change.

The contribution of this paper is therefore to reframe robotisation as a staged, safety-governed and data-enabled transformation of work. Whereas existing automation frameworks classify levels of control and maturity models classify organisational readiness, this study classifies levels of work substitution and links them to enterprise performance. The following section presents the proposed six-level framework.

4. Conceptual Framework: Six Levels of Robotic Substitution

This section presents the proposed six-level framework of robotic substitution of human labour in engineering enterprises. The framework classifies how human-performed work can be progressively supported, shared, transferred or substituted by robotic systems. Its central unit of analysis is not the robot as a technical system, but the unit of work being transformed. A unit of work may refer to a task, task segment, workstation activity, production operation or recurring role, such as material handling, welding preparation, machine loading, assembly support, quality inspection or internal logistics.

The framework distinguishes six levels of robotic substitution. Its staged logic builds on levels-of-automation and autonomy frameworks, but shifts the unit of analysis from system capability to work substitution and enterprise performance (Parasuraman et al., 2000; SAE International, 2018). Each level represents a relatively stable socio-technical configuration in which robot role, human role, safety paradigm, data requirements and performance logic are aligned. Progression between levels is conditional rather than automatic. Higher levels require stronger safety assurance, richer operational data, clearer governance and a stronger business case. Therefore, Level 6 is not treated as a universal target; in many engineering enterprises, an intermediate level may provide the best performance fit.

At **Level 1 — Assisted Work**, the human worker remains the primary executor and decision-maker, while robotic, mechatronic or wearable systems provide passive or semi-passive assistance. Examples include passive exoskeletons, lifting assistance, ergonomic supports, positioning aids or wearable guidance systems. The performance contribution is mainly improvement of human work conditions rather than labour substitution. Key indicators include ergonomic load, fatigue, injury risk, absenteeism, worker acceptance and stability of manual performance.

At **Level 2 — Robot as a Helper**, the robot performs simple auxiliary tasks, usually separated from the human in space, time or responsibility. The human continues to perform the core value-adding task, while the robot supports transport, feeding, positioning, sorting, preparation or repetitive movement. The performance contribution is reduction of non-value-adding work, such as walking, waiting, handling or internal transport. Safety is typically ensured through separation, predefined routes, restricted movement and procedural controls.

At **Level 3 — Human–Robot Tandem**, humans and robots operate in the same process or workspace and jointly contribute to task execution. The robot actively participates in production work, while the human remains responsible for judgement, correction, quality and exceptions. Examples include collaborative assembly, robotic positioning, cobot-assisted manipulation or collaborative inspection. The performance logic is complementarity: human flexibility and judgement are combined with robotic precision, repeatability or strength. This level corresponds to HRC; the terms Human–Robot Tandem and HRC are used interchangeably

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in this paper. Performance at this level depends on task allocation, interaction design and controlled physical interaction (ISO/TS 15066; Onnasch et al., 2014).

At **Level 4 — Teleoperated Robotic Work**, the robot performs the physical task remotely under continuous or on-demand human control. The human is no longer co-located with the work process but retains decision-making authority. This level is relevant where human judgement remains necessary but direct human presence is undesirable, dangerous or inefficient, such as remote inspection, hazardous handling or maintenance in restricted spaces. The performance contribution lies in separating human expertise from physical exposure.

At **Level 5 — Semi-Autonomous Robotic Work**, the robot performs the task autonomously under predefined normal conditions, while humans supervise and intervene only in exceptions. The robot is expected to execute the task, monitor its own state, detect anomalies and request human support when uncertainty exceeds acceptable limits. Examples include robotic machine loading, autonomous internal transport with exception escalation, robotic welding of standardised parts or automated inspection with human review of uncertain cases. This level can generate substantial productivity gains, but requires reliable perception, decision logging, exception management and governance.

At **Level 6 — Full Robotic Autonomy**, the robot fully substitutes human labour for a defined task, role or process within a defined operating envelope, i.e. the specified range of conditions under which safe and reliable operation is assured. Human involvement is limited to strategic oversight, system maintenance, periodic auditing and long-term governance. Examples include fully autonomous production cells, lights-out (fully unmanned) machining, autonomous quality-control loops or automated storage and retrieval systems. Level 6 should be defined only for a specific task or operational domain, not for the enterprise as a whole. Its performance logic is based on high repeatability, scalability, labour independence, uptime and long-term reliability. OEE is particularly relevant where robotic substitution affects availability, performance rate and quality losses in production equipment (Nakajima, 1988). Table 1 summarises the six-level framework.

Table 1. Six levels of robotic substitution of human labour in engineering enterprises

Level	Name	Robot's role	Human role	Typical performance contribution	Key performance indicators
1	Assisted Work	Passive or semi-passive support	Full execution and decision-making	Reduced physical or cognitive burden	Ergonomic load, fatigue, injury risk, absenteeism, acceptance
2	Robot as a Helper	Execution of simple auxiliary tasks	Core task execution and coordination	Reduction of non-value-adding work	Walking distance, waiting time, handling effort, task reliability, labour utilisation
3	Human–Robot Tandem	Active participation in shared task execution	Collaboration, judgement, correction and responsibility	Complementarity of human flexibility and robotic repeatability	Defect rate, rework, ergonomic load, cycle-time stability, human interventions
4	Teleoperated Robotic Work	Remote physical execution under human control	Remote decision-making and control	Separation of human judgement from hazardous or distant physical work	Hazard exposure, downtime, response time, latency tolerance, intervention logs
5	Semi-Autonomous Robotic Work	Conditional autonomous execution under normal conditions	Supervision and exception handling	Scalable execution with human oversight	OEE, throughput, intervention frequency, exception rate, quality stability, mean time between failures (MTBF), value added per employee
6	Full Robotic Autonomy	Full execution within defined operating envelope	Strategic oversight, maintenance and audit	High repeatability, labour independence and system-level performance	OEE, unit cost, capital productivity, uptime, rare-event frequency, long-term reliability, value added per employee

The framework can be used both analytically and managerially. Analytically, it classifies the current state of robotisation for a given task or process. Managerially, it supports decisions about whether progression to a higher level is desirable, feasible and justified.

Progression between levels is governed by four transition gates: capability, safety, data and organisational governance. The capability gate asks whether the robotic system can reliably perform the target function. The safety gate asks whether the configuration can be deployed without unacceptable risk. The data gate asks

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whether sufficient operational evidence exists to support the transition. The governance gate asks whether roles, responsibilities, escalation procedures and accountability mechanisms are defined. This transition-gate logic extends capability-oriented autonomy frameworks by adding safety, data and governance conditions as prerequisites for progression (Huang, 2008; ISO 10218; ISO/TS 15066). Table 2 summarises the transition logic.

Table 2. Transition gates between levels of robotic substitution

Transition	Capability gate	Safety gate	Data gate	Governance gate
Level 1 → Level 2	Assistance is stable and task segments suitable for robotic support are identified	No new active hazards are introduced	Evidence of load reduction and task variability	Task ownership, basic risk assessment and operator training are defined
Level 2 → Level 3	Robot behaviour is predictable near humans and can be integrated into shared workflow	Shared-space operation is validated through speed, force, collision and stop controls	Incident-free operation, stable task boundaries and intervention records are available	HRC procedures, responsibility model and safety validation are defined
Level 3 → Level 4	Task can be executed without co-located human presence	Communication loss, latency and fail-safe behaviour are addressed	Human interventions, corrections and latency tolerance are documented	Remote operation roles, authority and monitoring infrastructure are defined
Level 4 → Level 5	Routine decisions can be delegated to the system under normal conditions	Robot behaves conservatively under uncertainty and requests help in exceptions	Decision logs, intervention patterns and exception taxonomy are available	Supervision model, escalation protocols and AI risk management are defined
Level 5 → Level 6	System can handle expected scenarios within the defined operating envelope	Intrinsic safety is assured without real-time human fallback	Long-term stability, rare-event analysis and auditable decision traces are available	Liability, audit, maintenance and continuous review mechanisms are defined

The transition gates prevent the framework from becoming a purely technological ladder. A firm should not progress to a higher level simply because the technology exists. Progression is justified only when capability, safety, data and governance are aligned with the enterprise's performance objectives.

5. Performance Logic and Governing Conditions

The six-level framework becomes managerially useful only when levels of substitution are connected to enterprise performance. The central argument is that robotic substitution should not be evaluated by autonomy alone. Higher autonomy may increase throughput, reduce labour dependency and improve repeatability, but it may also increase capital intensity, maintenance complexity, safety requirements, coordination costs and organisational risk. The performance value of a given level therefore depends on the task, production context, strategic priorities and readiness of the socio-technical system.

5.1 Multidimensional performance

In engineering enterprises, performance is multidimensional. A robotic system may reduce manual labour while increasing downtime, improve throughput while reducing flexibility, or reduce ergonomic strain without improving cycle time. For this reason, robotic substitution should be assessed through a balanced set of indicators.

The main dimensions are operational performance, quality performance, labour and human-capital performance, safety and risk performance, economic and strategic performance, and sustainability performance. Operational performance includes cycle time, throughput, OEE, lead time, downtime and process reliability. Quality performance includes repeatability, defect rate, rework, first-pass yield and inspection consistency. Labour and human-capital performance includes labour productivity, value added per employee, skill utilisation, ergonomic load, fatigue, absenteeism and retention. Safety and risk performance includes accident risk, near-misses, hazardous exposure and clarity of responsibility. Economic and strategic performance includes unit cost, return

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on investment (ROI), capital productivity, scalability and customer responsiveness. Sustainability performance includes resource efficiency, workplace safety, waste reduction and long-term workforce sustainability.

This multidimensional perspective is essential because each substitution level creates value differently. Lower levels often improve ergonomics, safety and workforce sustainability. Intermediate levels reduce non-value-adding work, combine human judgement with robotic repeatability, or separate human expertise from hazardous exposure. Higher levels may improve throughput, OEE, labour productivity, quality stability, unit cost and capital productivity. A higher level is therefore not automatically better; it simply changes the performance profile. Higher levels of robotisation have also been linked, albeit non-linearly, to corporate environmental performance and to a shift of workers toward higher value-added activities, connecting substitution to environmental and social sustainability (Zhu et al., 2024; Luan et al., 2025).

5.2 Trade-offs in robotic substitution

A core principle of the framework is that higher autonomy is not automatically superior. The optimal level of robotic substitution is the level that creates the best balance between performance benefits and transition costs under specific enterprise conditions.

Several trade-offs are particularly important. The productivity–flexibility trade-off arises because highly automated systems can be efficient in repetitive and stable processes, but may be too rigid for customer-specific or low-volume engineering production. The speed–quality–safety trade-off appears when increasing robotic speed improves throughput but creates additional safety constraints or makes recovery from errors more difficult. The labour-saving–capability-building trade-off means that reducing direct manual labour often creates new requirements for programming, maintenance, supervision, data analysis and process engineering. The standardisation–learning trade-off is relevant because higher autonomy requires stable operating envelopes, while many engineering processes contain variability that is still understood mainly through human experience. Finally, the capital-productivity trade-off arises when high fixed investment improves performance only under sufficient utilisation and process stability.

These trade-offs explain why remaining at a lower or intermediate level may be rational. A Level 3 human–robot tandem may outperform Level 5 conditional autonomy when the task requires frequent judgement and adaptation. A Level 1 assistive solution may be more valuable than a complex robot if the main performance problem is fatigue, injury risk or workforce retention. A Level 2 helper robot may generate strong benefits by removing non-value-adding work without redesigning the core process. The framework therefore does not prescribe a universal path toward full autonomy; it supports selection of the substitution level that best fits the enterprise's performance logic.

5.3 Safety, data and governance as progression conditions

Progression between levels should be governed by three conditions: safety, data and governance.
Safety acts as a gatekeeper. A higher level of substitution is permissible only if the target configuration can be deployed without unacceptable risk. At lower levels, safety is mainly associated with ergonomic design, mechanical constraints and separation. At collaborative levels, it becomes part of shared work design, including speed and force limits, collision detection, safe-stop behaviour and clear responsibility. At semi-autonomous and autonomous levels, safety depends increasingly on robustness, perception, uncertainty management, exception handling and intrinsic safe behaviour within the defined operating envelope. The absence of a sufficient safety case is therefore a legitimate reason to remain at a lower level. Empirical risk analysis in custom-manufacturing engineering settings confirms that automation does not automatically reduce operational risk, which reinforces the role of safety as an explicit gate rather than an assumed by-product of robotisation.

Operational data act as an enabler. Each level should generate evidence that reduces uncertainty and supports informed progression. Assisted work generates ergonomic and human-factor data. Helper robots generate reliability and task-standardisation data. Human–robot tandem work generates interaction data, corrections, near-misses and contextual cues. Teleoperated work generates intervention and failure-mode data. Semi-autonomous systems generate decision logs, exception patterns and uncertainty estimates. Full autonomy requires long-term monitoring, audit trails and rare-event analysis. Lower levels are therefore not only

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operational states; they are learning environments. Treating accumulated operational data as a strategic asset is consistent with evidence that big-data-supported decision-making contributes to the economic sustainability of enterprises. Governance ensures that capability, safety and data are translated into responsible action. Progression requires ownership of the process, clear responsibilities, escalation procedures, training, maintenance capability, vendor management, cybersecurity, data governance and continuous review. This is especially important at higher levels, where humans no longer directly execute the task. Responsibility does not disappear when work is delegated to a robot; it shifts to system design, supervision, maintenance, monitoring and organisational accountability.

5.4 Summary

The performance logic of the framework can be summarised in three propositions. First, each level of robotic substitution creates value through a different mechanism and must be evaluated through different performance indicators. Second, higher autonomy is not automatically better; the optimal level depends on the balance between performance benefits, safety requirements, data maturity and organisational costs. Third, progression between levels must be governed by safety, operational data and organisational readiness.

This turns the six-level framework from a classification tool into a managerial decision model. It helps engineering enterprises ask not only what level of robotisation is technically possible, but which level is performance-relevant, safe, evidence-based and governable in their specific context.

6. Illustrative Mapping for Engineering Enterprises

The framework can be applied to different types of engineering work, but its managerial value becomes clearer when it is mapped onto concrete operations. This section illustrates its use in five typical engineering-enterprise contexts: welding, material handling, assembly, quality inspection and internal logistics. The purpose is not empirical validation, but demonstration of how the framework supports structured reasoning about appropriate substitution levels for specific units of work.

Engineering enterprises combine repetitive operations, skilled manual work, product variability, customer-specific requirements and safety-critical tasks. This diversity makes one-step automation unrealistic in many cases. Some operations may justify high levels of substitution because they are repetitive, standardised and data-rich. Others may remain at lower levels because human judgement, flexibility or safety constraints remain central. Table 3 summarises this mapping.

Table 3. Illustrative mapping of engineering operations to likely substitution levels

Operation	Lower-level substitution logic	Intermediate-level substitution logic	Higher-level substitution logic	Main constraints
Welding	Positioning aids, lifting devices, fume extraction or ergonomic supports reduce physical strain and exposure	Human–robot tandem welding, robotic positioning or selected robotic weld paths while human judgement and quality decisions remain central	Semi-autonomous or autonomous welding of standardised product families with stable fixtures and validated parameters	Part variability, fixture quality, weld-path repeatability, inspection requirements, safety
Material handling	Lifting aids, manipulators, balancers or exoskeletons reduce physical load while human control remains dominant	Robot-as-helper or collaborative handling reduces walking, waiting, transport and repetitive manipulation	Autonomous handling, palletising, machine loading or robotic transfer in structured environments	Object variability, gripping reliability, route stability, identification accuracy
Assembly	Guided work, ergonomic fixtures, visual instructions and part presentation support manual assembly	Human–robot tandem assembly, robotic fastening, holding or positioning while humans manage alignment and sequencing	Semi-autonomous assembly of stable product families with controlled tolerances and reliable sensing	Product variety, tolerances, dexterity, sequencing, tacit knowledge
Quality inspection	Digital checklists, measurement aids and visual guidance support human inspection	Robotic measurement or scanning combined with human interpretation of borderline cases	Automated inspection, AI-supported defect classification and closed-loop quality feedback	False positives/negatives, customer requirements, traceability, auditability

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Internal logistics	Ergonomic picking aids, wearable scanners, visual guidance or lifting devices support operators	Transport assisted by autonomous mobile robots (AMR), shared logistics workflows and robot-as-helper material delivery	Semi-autonomous or autonomous material flow integrated with enterprise resource planning (ERP), manufacturing execution (MES) or warehouse management (WMS) systems	Layout stability, load standardisation, localisation, system integration

The mapping shows that different engineering operations naturally align with different substitution levels. Material handling and internal logistics often progress more easily toward higher levels because tasks can be standardised, routes can be controlled and performance indicators are measurable. Welding and quality inspection may reach high levels in stable product families, but often require human judgement for variation, interpretation and exception handling. Assembly is frequently the most sensitive to product variability and tacit skill, making Levels 2 and 3 particularly relevant in many customer-specific engineering environments.

The key implication is that the appropriate level is operation-specific. A single enterprise may simultaneously operate Level 6 in selected logistics loops, Level 5 in machine loading, Level 3 in assembly, Level 2 in material preparation and Level 1 in specialised manual work. The framework should therefore not be used to classify the digital maturity of the firm as a whole. It should be used to classify and manage substitution levels for specific units of work.

Illustrative mapping also helps managers decide where progression is valuable, premature or unnecessary. It shows that full autonomy should not be treated as the universal objective: a collaborative assembly cell may be more valuable than a rigid automated cell if product variety is high, while an assistive welding device may be more rational than a robotic welding cell if volumes are low and variability is high. In addition, each level guides data collection: assisted work generates ergonomic data, helper tasks generate reliability data, collaborative work generates interaction data, teleoperation generates intervention data, semi-autonomous work generates decision logs and full autonomy requires audit data.

In this sense, the framework functions as a practical diagnostic tool. It helps engineering enterprises identify where robotic substitution is feasible, where it is valuable, where it is unsafe or premature, and where lower levels of substitution may remain strategically appropriate.

7. Managerial Implications

The proposed framework reframes robotisation from a technology-acquisition problem into a performance-oriented work-design decision. Instead of asking whether the firm should “automate more”, managers can ask which units of work should be supported, shared, remotely controlled, semi-autonomously executed or fully substituted, and under what performance, safety, data and governance conditions.

First, robotisation should be assessed at the level of concrete work units, not at the level of the enterprise as a whole. Engineering enterprises rarely become automated uniformly. A single firm may operate autonomous internal logistics in one area, collaborative assembly in another, assisted manual welding elsewhere, and semi-autonomous inspection for selected product families. The framework therefore functions as a task-level diagnostic tool: each relevant task, workstation or operation can be mapped to one of the six levels. This helps managers identify where the firm is under-automated, over-automated or prematurely automated.

Second, managers should start from the performance problem rather than from the robot. If the problem is ergonomic strain or workforce sustainability, Level 1 or Level 3 may be sufficient. If the problem is waiting time, walking distance or material availability, Level 2 may provide the most efficient improvement. If the problem is hazardous exposure, Level 4 may be appropriate. If the problem is throughput and repeatability in a stable process, Level 5 or Level 6 may become relevant. This performance-first logic helps prevent technology-driven overinvestment.

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Third, lower levels of substitution should be treated as legitimate strategic choices. Remaining at Level 1, 2 or 3 is not necessarily a failure of innovation. Assisted work may be optimal when human skill remains essential but physical load threatens workforce sustainability. A robot-as-helper configuration may remove non-value-adding work without disrupting the core process. A human–robot tandem may preserve human judgement while improving precision, quality or ergonomics. These configurations can be strategically superior to higher autonomy when tasks are variable, volumes are unstable or the cost of standardisation is too high.

Fourth, robotisation should be governed as a portfolio of substitution levels. Different operations should be assigned different target levels according to task characteristics, performance potential and transition readiness. Some tasks should remain human-centred; some are suitable for assistance or helper automation; others should develop through collaborative or teleoperated configurations to generate data and reduce uncertainty; and a smaller set of stable, high-volume tasks may justify semi-autonomous or fully autonomous solutions. This portfolio logic supports strategic prioritisation and helps build a staged robotisation roadmap. Such roadmaps may also be aligned with external enablers, including European policy instruments supporting Industry 4.0 investments and the broader role of automation in reshoring production activities within the European Union (Xu et al., 2026).

Fifth, transition gates should be embedded into investment decisions. Before progressing to a higher level, managers should ask: Can the system perform the target function reliably? Can the configuration be deployed without unacceptable risk? Is there sufficient operational evidence to justify the transition? Are roles, responsibilities, escalation procedures and accountability mechanisms defined? These questions prevent automation projects from being evaluated only through ROI or technical feasibility. A project may have an attractive payback period but still be premature if the process is unstable, safety cannot be assured or the organisation lacks supervision and maintenance capability.

Finally, the framework highlights safety, data and human capabilities as strategic assets. Safety capability includes risk assessment, compliance with standards, incident learning and clear accountability. Data capability means collecting structured evidence about task variability, interventions, defects, downtime, near-misses and exception cases. Human capability is equally important because substitution changes work roles: as autonomy increases, humans move from direct execution toward supervision, exception handling, maintenance, programming, data interpretation and governance.

The framework also improves communication with employees, top management and suppliers. Internally, it clarifies that robotisation does not always mean replacing humans: Level 2 removes transport or preparation tasks, Level 3 requires cooperation, and Level 5 shifts the operator's role toward supervision. For top management, it translates robotisation into performance language such as OEE, quality, safety, labour productivity, flexibility and capital productivity. For suppliers, it provides a structured language for requirements, acceptance criteria and performance evaluation.

In summary, the framework helps engineering enterprises avoid both technological conservatism and automation determinism. It supports an approach that is ambitious enough to use robotics for productivity, quality and sustainability, but disciplined enough to recognise when higher autonomy is unsafe, uneconomic or organisationally premature.

8. Conclusions

This paper addressed the question of how robotic systems can contribute to performance improvement in engineering enterprises when the relationship between robotisation and performance is neither automatic nor uniform. Existing literature provides useful insights into automation levels, autonomy taxonomies, Industry 4.0 maturity, safety standards and human–robot collaboration, but these streams do not sufficiently explain how progressive substitution of human labour can be structured as a performance-oriented managerial process.

The paper responds by proposing a six-level framework of robotic substitution of human labour. The framework shifts the unit of analysis from system autonomy to work substitution. Instead of asking how autonomous a

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robot is in technical terms, it asks which elements of human work are being supported, shared, remotely controlled, conditionally automated or fully substituted, and under what performance, safety, data and governance conditions.

The first research question asked how the stages of robotic substitution can be structured so that each stage is linked to specific performance outcomes. The answer is provided through six levels: Assisted Work, Robot as a Helper, Human–Robot Tandem, Teleoperated Robotic Work, Semi-Autonomous Robotic Work and Full Robotic Autonomy. Lower levels mainly contribute through ergonomics, safety and workforce sustainability; intermediate levels through reduction of non-value-adding work, complementarity and hazardous-exposure reduction; and higher levels through throughput, OEE, labour productivity, quality stability, unit cost, capital productivity and long-term reliability.

The second research question asked what role safety and operational data play as conditions governing progression. The answer is that safety and data function as governing conditions rather than secondary considerations. Safety acts as a gatekeeper: a higher level of substitution is permissible only if the target configuration can be deployed without unacceptable risk. Operational data act as an enabler: each level generates evidence that reduces uncertainty and supports informed decisions about whether and how to progress. Progression is therefore justified only when capability, safety, data and governance are aligned with enterprise performance objectives.

The theoretical contribution is threefold. First, the paper reframes robotisation from a system-capability problem into a work-substitution problem. Second, it connects robotic substitution with enterprise performance by linking each level to distinct performance mechanisms and indicators. Third, it integrates safety and operational data into the logic of progression, treating them as structural conditions of staged substitution rather than secondary implementation issues.

For managers, the framework provides a structured language for planning and evaluating robotisation. It helps distinguish between technological possibility and managerial desirability, and it legitimises intermediate and lower levels of substitution when they provide a better balance of productivity, flexibility, safety, cost and human capability. In this way, the framework helps engineering enterprises avoid both technological conservatism and automation determinism.

The study has limitations. The framework is conceptual and has not yet been empirically validated through case studies, quantitative analysis or longitudinal research. It does not provide universal quantitative thresholds for progression, because engineering tasks differ in risk, variability, volume, safety requirements and economic logic. The illustrative mapping is therefore not empirical validation, but a demonstration of how the framework can be applied to typical engineering operations. The paper also focuses on enterprise-level performance and does not fully address broader labour-market or societal consequences of robotisation.

Future research should validate the framework empirically. Comparative case studies could map existing robotic applications onto the six levels and examine whether managers recognise them as meaningful decision categories. Longitudinal studies could investigate how firms progress between levels and whether safety and data actually function as transition conditions. Quantitative research could measure how different substitution levels affect OEE, labour productivity, defect rates, ergonomic load, downtime, intervention frequency, value added per employee or capital productivity. Further work should also develop sector-specific adaptations for welding, assembly, internal logistics, machine loading, quality inspection and maintenance, and examine how firms can preserve tacit knowledge, prevent deskilling and build new capabilities as workers move from execution toward supervision, exception handling, maintenance, programming and governance.

The central conclusion is that robotisation should be understood as staged, performance-oriented and governed by safety and data. The value of robotic systems in engineering enterprises does not lie in autonomy for its own sake, but in their ability to transform specific units of work in ways that improve enterprise performance under acceptable safety, organisational and economic conditions.

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THE IMPACT OF MINIMUM WAGE ON ENTERPRISE BIRTHS IN EUROPEAN UNION COUNTRIES*

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Abstract. This study examines how increases in the minimum wage affect entrepreneurial dynamics in European Union countries, with a particular focus on enterprise births. The research is motivated by the growing need to understand the broader impact of wage regulation on economic activity and the structure of the business sector. The main research question is to what extent changes in the minimum wage influence the decision of potential entrepreneurs to enter the market and whether these effects vary by enterprise size. The empirical analysis is based on panel data from 21 EU member states covering the period from 2015 to 2023. We employ panel regression models, supplemented with robustness tests and size-based differentiation of results. Control variables such as unemployment rate, GDP per capita, and average earnings are also considered. The results show that a higher minimum wage has a statistically significant negative effect on the total number of enterprise births. Regarding enterprise size, this negative effect is more pronounced among newly established businesses with more than 10 employees compared to those with fewer than 10. A possible explanation is that larger new enterprises are more likely to operate in formal sectors with stricter compliance requirements, making them more exposed to wage regulation from the outset. The findings highlight the need to consider the minimum wage not only as a social policy tool but also as a factor that shapes the structure and development of the entrepreneurial environment across different types of economies within the EU.

Keywords: minimum wage; enterprise births; panel analysis; firm size; European Union

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JEL Classifications: J38, L26, E24, C23

1. Introduction

Minimum wage (MW) as a wage policy instrument serves an important social function by ensuring a decent income for workers at the lower end of the income distribution and by reducing income inequality. In recent years, however, interest has been growing in examining the broader effects of MW on economic dynamics, including the entrepreneurial environment. A particularly timely question in this context is how increases in MW affect the decisions of individuals and firms to enter the market and establish new businesses. Entrepreneurial activity is a key driver of long-term growth, innovation, and regional development (Dustmann

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et al., 2022). Recent evidence from the eurozone further shows that the prevalence of high-growth firms is shaped by a combination of macroeconomic and competitiveness conditions, including economic growth, credit growth, labour-market efficiency, market size, and business sophistication (Li et al., 2023; del Olmo-García et al., 2025).

Recent developments in the European Union, particularly discussions on the introduction of a common framework for MW (e.g., the 2022 EU Directive on adequate minimum wages) and its coordination at the EU level, add new relevance to this issue (Müller & Schulten, 2020; Drahokoupil & Müller, 2021; Lillie, 2022; Müller & Schulten, 2023). Countries such as Germany, Spain, and France have implemented significant increases in MW over the past decade, allowing for the analysis of cross-country differences in impacts depending on productivity, labor market structure, and the entrepreneurial environment. These differences offer an opportunity to better understand how MW influences entrepreneurial dynamics in diverse contexts (Harasztosi & Lindner, 2019).

While traditional discourse on MW has focused on its effects on employment and wage structures (Neumark & Shirley, 2022), more recent economic literature has begun to systematically analyze its impact on enterprise births and exits, technological choices, the rate of innovation (Aaronson et al., 2018; Luduvice et al., 2024), and the reallocation of workers to more productive firms (Dustmann et al., 2021; Rao & Risch, 2024). This research is based on the premise that wage regulation affects firms' cost structures and thus their decision to enter or exit the market. Moreover, MW has the potential to reshape the entrepreneurial sector by selecting firms based on their productivity and capacity to absorb higher labor costs (Mayneris, Poncet & Zhang, 2018).

The aim of this study is to contribute to the existing literature by examining the impact of MW on entrepreneurial dynamics in EU countries. Specifically, we analyze whether and to what extent increases in MW affect the number of enterprise births and whether this impact varies according to the size of the newly established enterprise. The study seeks to highlight the possible consequences of MW increases, while acknowledging the positive social and economic benefits of MW for employees. Unlike studies focusing on the U.S. or China, we focus on the European institutional framework, where it is necessary to account for differences in the level and pace of MW increases across countries.

This issue has important implications for public policy. If MW acts as a constraint on entry for small and new firms, it may have adverse effects on competition, innovation, and regional convergence (Kong et al., 2021; Luca & Luca, 2019). Conversely, if it creates pressure to raise productivity and fosters the selection of efficient actors, it may support qualitative shifts in the structure of the business sector (Dustmann et al., 2022; Mayneris et al., 2018). These effects are particularly relevant in regions with weaker business environments, where even moderate cost increases may significantly influence entrepreneurial decision-making. The aim of our research is to empirically test these opposing hypotheses using panel data from EU countries.

2. Theoretical background

2.1 The Concept of Minimum Wage in EU Countries and Its Impact on Entrepreneurship

The minimum wage (MW) is an important policy instrument within the EU to ensure decent working conditions and to reduce wage inequality. With the adoption of Directive (EU) 2022/2041 on adequate MWs, the EU has significantly strengthened its social dimension. The directive requires Member States to ensure that statutory MWs are adequate and set in a transparent manner. The use of reference indicators such as 60% of the median or 50% of the average gross wage is recommended (European Parliament and Council, 2022). A key part of the directive is the support for collective bargaining. Countries where less than 80% of employees are covered by collective agreements must develop an action plan to increase this share (Hassel, 2023). Haapanala, Marx, and Parolin (2023) demonstrated that in countries with high collective bargaining coverage, fewer workers are exposed to low wages, confirming the importance of combining statutory wage floors with collective agreements.

Significant differences exist in MW systems across the EU. Some countries (e.g. Sweden, Denmark) do not have a statutory MW and rely exclusively on collective agreements. Others, including the Visegrád Group,

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apply centrally determined statutory MWs. These differences reflect historical and institutional approaches to labor market regulation (Müller & Schulten, 2020). In response to the directive and rising inflation, several countries such as Poland and Hungary implemented significant MW increases, approaching the recommended thresholds (Müller, 2023). Nevertheless, in many Member States, MWs still do not cover living costs and collective bargaining remains underdeveloped. The directive does not establish a unified MW level, but creates common standards for adequacy and promotes social dialogue as a key tool for effective implementation.

On the one hand, MW increases are intended to protect low-wage workers' rights to a decent standard of living. On the other, they are often perceived negatively by employers as a threat that could increase costs and reduce profitability. Alexandre et al. (2022) analyzed the effects of ambitious MW reforms in Portugal (since 2014) and found that MW increases reduced employment growth and profitability, particularly in financially weaker firms, while also increasing the likelihood of firm exits. Gorjón et al. (2023) examined the 22% increase in the Spanish MW in 2019 and found that the probability of unemployment for workers previously earning below the MW increased significantly (+1.7 percentage points), while work intensity declined (-0.9 points) compared to the control group. Laporšek et al. (2024) studied the MW increase in Slovenia and observed strong and persistent employment declines among "subminimum" wage workers, whose productivity fell below the new wage floor. Firms thus shifted hiring toward slightly higher-wage segments, while the most skilled workers remained complementary to the lowest paid.

Link (2024), analyzing the introduction of a national MW in Germany (2015), concluded that most firms increased output prices to cover rising wage costs, with no significant layoffs. Firms that passed costs on to consumers more aggressively experienced weaker employment effects. Arabzadeh et al. (2024), using both empirical and model-based methods, studied German firms facing financial constraints. They found that higher MWs reduce hiring and turnover (leading to lower overall employment) and push firms to adopt more selective hiring practices, narrowing the wage dispersion. Highly indebted firms showed stronger employment declines in response to MW increases. Gregory and Zierahn (2022), in an experimental setting, found that very high MWs reduced wages and employment among high-skilled workers at the top of the wage distribution. While medium-skilled workers just above the MW saw a modest increase in wages and employment, the overall market adjustment increased labor costs and reduced demand for higher-skill categories.

All these studies highlight that MW increases raise business costs, whether through higher wages, price adjustments, cost-saving efforts elsewhere, or employment reductions. The most significant negative effects—declines in employment and profitability—are observed especially among low-productivity and financially vulnerable firms. This cost channel is also relevant from a competitiveness perspective: recent evidence from Czech enterprises identifies production costs as a critical factor in firm competitiveness and highlights the importance of firm-size heterogeneity in organisations' responses to changing economic conditions (Heinzová et al., 2026).

2.2 Minimum Wage and Its Potential Impact on Enterprise Births

The literature identifies several mechanisms through which the minimum wage (MW) may influence entrepreneurial dynamics. The first is the selection effect, which implies that raising the wage floor creates a productivity threshold below which firms are no longer viable in the long term, discouraging entry by less productive entrepreneurs (Bachmann, Bauer & Frings, 2014). This can also contribute to firm exits, thus reshaping the market structure. This mechanism tends to be more pronounced in sectors with a high share of low-skilled labor, such as services, retail, and hospitality (Luca & Luca, 2019).

Another mechanism is the so-called putty-clay effect, where new firms entering the market adopt technologies adapted to higher labor costs, whereas existing firms remain technologically rigid. Aaronson et al. (2018) show that in such contexts, there can even be a short-term increase in enterprise births, particularly when new firms take advantage of market opportunities created by the exit of less efficient competitors. MW also has the potential to restructure the business sector by selecting firms based on their productivity and ability to absorb higher labor costs.

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Empirical evidence from EU countries often points to a modest negative effect of MW on enterprise births. Draca et al. (2011) found that in the UK, following the introduction and increase of the MW, the rate of enterprise births declined in sectors with a high share of low-skilled labor. Bachmann, Bauer, and Kröger (2014) conducted a survey of 800 German service firms and found that many employers supported sectoral MW as a tool to limit entry by new competitors. This support was stronger in regions with low natural entry barriers (especially in eastern Germany) and among highly productive firms facing competition from low-cost entrants. This suggests that higher wage floors may be perceived as a way to raise entry costs for potential newcomers. Following the introduction of MW in 2015, there was an increase in solo self-employment, but many start-ups also reported difficulties (wage adjustments, administrative burdens) (Egeln, 2016). Dustmann et al. (2022) confirm that MW in Germany led to a modest decline in the number of firms due to increased selection, with allocation effects dominating as workers moved to more productive firms. Ganserer et al. (2022) support this view using panel data and the implementation of initial sectoral MWs (e.g. in construction, painting, and electrical work), finding that MW significantly increased the share of solo self-employed individuals (micro-entrepreneurs without employees). After six years, solo employment rose by 1–5 p.p., especially in industrial sectors in eastern Germany. These findings are consistent with Medrano-Adán et al. (2015), who found that MW led to more solo self-employment among entrepreneurs unable to afford employees and a decline in small employer firms. Thus, MW acts as a barrier for entrepreneurs intending to employ workers, leading to a reduction in total business output and a shift in income from the lowest and highest earners toward the middle class.

Harasztosi & Lindner (2019) found that shock increases in MW in Hungary reduced the number of enterprise births, particularly in low-productivity sectors. This inspired Casanova et al. (2025), who examined Spanish firm-level panel data and the 22% MW hike in 2019. They compared firms by the share of affected employees and differentiated effects by firm size. Their main finding was that the negative employment effects were concentrated in microenterprises (up to 5 employees), where employment growth slowed. In affected firms with up to 250 employees, worker inflows and outflows increased, resulting in poorer job quality (more part-time transitions). The study shows that the MW increase in 2019 slowed workforce expansion and increased labor turnover in small Spanish firms. Regional variation is also documented by Zeman (2018), who found that after MW hikes, eastern Slovakia saw a sharper decline in new business registrations compared to western regions.

Significant studies on MW effects on firm dynamics have also come from the US and China. Lyu and Fossen (2025), using U.S. county panel data (2001–2020), found that MW increases reduced the number of nonemployer businesses. A $1 increase in MW was associated with a 0.5–0.9% decline in such enterprises. Moreover, MW decreases the likelihood that these businesses would transition into employer firms, while increasing exits and transitions into wage employment. Kwapisz (2020) found no major overall MW effect on hiring among U.S. startups, but did observe that higher MW reduced hiring likelihood among female entrepreneurs. Among firms that did hire, higher MW was linked to lower profitability and a higher likelihood of premature closure. Kong, Qin, and Xiang (2021), using Chinese microdata, showed that a 10% MW increase reduced enterprise births by about 6%, with the strongest effects in small service firms. The effect was stronger in low-productivity regions with a high share of informal labor. These results are consistent with Meer & West (2016), who observed long-term employment declines due to constraints on small firm growth. Li et al. (2023) explored how local MW adjustments in China affect enterprise entry. They found that a 10% MW increase reduced firm entries by 2.69%, especially in low-wage or low-skill labor sectors.

An important aspect is impact heterogeneity. Ludovice et al. (2024) found that new firms without prior business experience face higher exit rates due to increased wage burdens and are more vulnerable to MW hikes, while established entrepreneurs are more resilient. Cordier and Bade (2023) explored how regulatory costs influence entrepreneurial decisions, especially among new entrants. They found that stricter labor regulations combined with rising MW could discourage enterprise births. Cui and Li (2023) observed similar dampening effects from cost uncertainty in trade policy, showing parallels with rising labor costs. The most affected sectors are small services and retail. Bachmann et al. (2014) documented that MW acts as a market entry barrier for low-productivity firms in labor-intensive sectors. These findings support the hypothesis that MW induces restructuring toward higher productivity, albeit at the cost of reducing entry opportunities for low-capital entrepreneurs. Dustmann et al. (2022) confirm that the strongest effects are concentrated among small firms (up

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to 5 employees), which experienced employment declines, while larger firms expanded. This vulnerability is consistent with recent entrepreneurship research showing that new ventures often operate under pronounced resource constraints and that their ability to acquire, combine, and deploy limited resources is central to maintaining competitiveness (Wu et al., 2025).

Overall, the impact of MW on entrepreneurial dynamics is not uniform. Most studies point to a mildly negative effect on enterprise births. The effect depends on a country's specific conditions, sectoral composition, firm size, and entrepreneur type. The evidence also suggests that microenterprises are the most vulnerable, particularly due to their lower productivity and limited reserves. These firms often aim to hire a few employees in low-cost sectors, making them especially susceptible to wage floor constraints. A recent fuzzy multi-criteria assessment of SME entrepreneurship indicators likewise identifies organisational innovation and risk-taking among the most influential dimensions, reinforcing the view that firms' responses to external cost pressures depend on a broader configuration of entrepreneurial capabilities rather than on a single economic factor (Rostamzadeh et al., 2026).

3. Methodology

The aim of this study is to analyze the impact of rising minimum wages on entrepreneurial dynamics in European Union countries, with a specific focus on the number of enterprise births. For this purpose, we used panel data covering the period from 2015 to 2021 for a selected group of 21 EU member states. Countries such as Denmark, Italy, Cyprus, Austria, Sweden, and Finland were excluded from the analysis due to the absence of a unified national minimum wage or lack of available data during the observed period. The data sources include statistics from Eurostat.

Based on the theoretical framework and previous empirical findings, we formulated the following research hypotheses:

H1: An increase in the minimum wage has a negative effect on the total number of enterprise births.
H2: The sensitivity to minimum wage growth is higher among newly established microenterprises (1–9 employees) than among larger enterprice births with more than 10 employees.

To verify the formulated hypotheses, statistical models were tested using the R programming language. The dependent variable is the number of enterprise births per 100,000 inhabitants (*ln(births)*). This indicator was calculated based on Eurostat's Business Demography statistics and is used to capture the dynamics of entrepreneurial activity and the entry of new economic units into the market. The main explanatory variable in the models is the minimum monthly wage in euros (*ln(MW)*), with data sourced from Eurostat reflecting nominal changes in the minimum wage over time. Control variables include gross domestic product per capita (*ln(GDP)*) as an indicator of a country's economic performance, the unemployment rate (*Unemp*) as a measure of labor market conditions, and the average net earnings (*ln(Earn)*) as a proxy for compensation levels and purchasing power. All variables are annual and expressed in euros or percentages.

For the dependent variable, the number of enterprise births per 100,000 inhabitants, a logarithmic transformation $ln(1 + x)$ was applied. Adding one eliminates the issue of potential zero values, which would otherwise prevent log transformation. Logarithmization was used to stabilize variance, reduce heteroskedasticity, and mitigate the influence of extreme values.

The observed period was divided into two sub-periods 2015–2020 and 2021–2023 due to changes in the methodology for reporting enterprise births. These methodological changes, implemented by Eurostat in 2021 as part of the European Business Statistics (EBS) regulation, marked a significant shift in how business demography is measured. The goal of the revision was to enhance the accuracy, consistency, and international comparability of data on business entries and exits. Under the new definition, an entity is classified as an enterprise birth only if it represents a new combination of production factors—meaning a genuinely new economic entity entering the market. Enterprises that were merely reactivated after a temporary suspension of activity (e.g., for less than two years), as well as cases of mergers, demergers, spin-offs, or changes in legal

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form, are no longer included in the "births" category. Similarly, changes in business activity that do not involve the creation of a new unit are also excluded (Eurostat, 2025). Another major innovation was the introduction of Statistical Business Registers (SBR) as the primary data source. This significantly improved the quality and consistency of the data and enabled tracking of linkages between economic units. Eurostat also implemented unified rules for data validation and systematic cleaning of databases, thereby eliminating duplicate or non-standard records and enhancing cross-country comparability.

These adjustments also had a significant impact on time series data. Since 2021, the number of enterprise births is no longer fully comparable with earlier series (2015–2020), as the stricter definition and the exclusion of reactivations led to a decrease in the recorded number of "births" in some countries. For this reason, the sample was split into two periods—before and after the methodological change—to minimize the risk of bias resulting from the revision and to enable a clearer interpretation of differences between them. Currently, data on enterprise births are only available through 2023, which also limited the sample size.

Table 1. Overview of monitored variables

Abbreviation	Variable Name	Unit	Note
ln(births)	Number of enterprise births	Number of new enterprises	Adjusted per 100,000 inhabitants and log-transformed as ln(1 + x)
MW	Minimum monthly wage in EUR	EUR / month	Semi-annual data averaged to yearly basis
GDP	Gross Domestic Product per capita (chain-linked volumes)	EUR per capita	Estimate of the country's economic performance
Earn	Average net monthly earnings of employees	EUR / month	Adjusted for full-time equivalent employees
Unemp	Unemployment rate (total)	Percent (%)	Share of unemployed in the economically active pop
population	Total population	Number of persons (thousands)	Used to recalculate the number of enterprise births per 100,000 inhabitants

Source: authors

After analyzing the overall impact of the minimum wage (MW) on the number of enterprise births, we extended the research to include an analysis by size categories of newly established enterprises. The aim was to examine whether the effect of the minimum wage differs depending on the scale of business activity, specifically the number of employees that new enterprises hire. In line with Eurostat methodology, we distinguished four size classes of new enterprises: enterprises with no employees, enterprises with 1–4 employees, enterprises with 5–9 employees, and enterprises with 10 or more employees. This approach allows us to capture potential heterogeneous effects of the minimum wage, as smaller enterprises may be more sensitive to rising labor costs, while larger new entities may have better financial or organizational capacities to absorb them. The analysis thus provides a more detailed view of how minimum wage policy influences entrepreneurial dynamics across different segments of enterprise births.

The estimated model has the following structure:

$$ln(births_{it}) = \beta_0 + \beta_1 ln(MW_{it}) + \beta_2 ln(GDP_{it}) + \beta_3 Unemp_{it} + \beta_4 ln(Earn_{it}) + \alpha_i + \lambda_t + \varepsilon_{it}, \quad (1)$$

- i = country,
- t = year,
- $ln(births_{it})$= dependent variable (logarithm of the number of enterprise births per 100,000 inhabitants),
- $lnMW_{it}$ = logarithm of the minimum wage in euros,
- $Unemp_{it}$ = unemployment rate in %,
- $lnEarn_{it}$ = logarithm of average (net) earnings,
- α_i = country fixed effect,
- λ_t = year fixed effect,

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- ε_{it} = random error term.

To verify the suitability of the panel structure and determine the optimal model specification, a series of diagnostic tests was conducted, representing a standard procedure in empirical panel data analyses. First, the F-test for fixed effects (pFtest) was applied to assess the existence of heterogeneity across countries and over time, and to determine whether fixed effects significantly improve the explanatory power of the model compared to a pooled OLS estimate. Subsequently, the Lagrange Multiplier test (Breusch–Pagan LM test) was conducted to test for the presence of random effects and to evaluate whether a random effects model is preferable to the pooled model. The final decision between the fixed effects and random effects model was based on the Hausman test, which compares the consistency and efficiency of the estimates from both approaches. Rejection of the null hypothesis in this test indicates a preference for the fixed effects model. To increase the reliability of the estimates, robust standard errors were used in all model specifications (White HC1, clustered by country or year, or Driscoll–Kraay), accounting for potential heteroskedasticity and serial correlation in the panel data.

4. Results and Discussion

4.1 Development of Minimum Wage and Enterprise Births in the EU

The aim of this study is to determine the impact of the minimum wage (MW) on the number of enterprise births in the EU. Before constructing statistical models, it is necessary to examine the overall trends and basic relationships between the variables, which may indicate the existence and direction of this impact. Within the European Union, the level of the minimum wage varies significantly across countries, reflecting differences in economic performance, labor productivity, and price levels. Comparing the development of the minimum wage over time allows for an assessment not only of absolute differences between countries, but also of the pace at which they are converging toward the EU average. Figure 1 illustrates the variability of minimum wages in EU member states from 2015 to 2023.

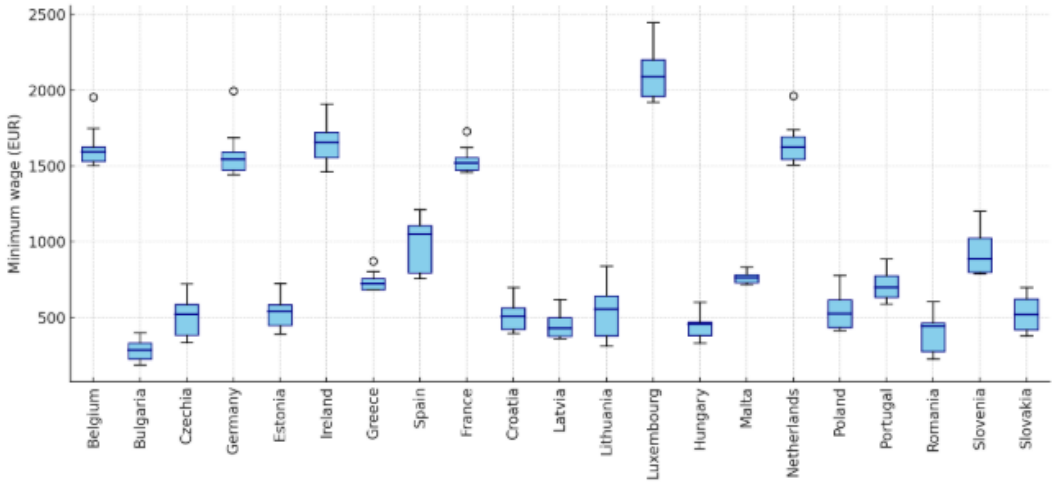


Figure 1. Distribution of Minimum Wage Levels by Country (2015-2023)
Source: Eurostat

Figure 1 illustrates the distribution of minimum wages in EU countries between 2015 and 2023. Western European countries (Luxembourg, Ireland, the Netherlands, Belgium, Germany) consistently reach the highest levels with low variability, while Eastern European countries (Bulgaria, Romania, Hungary, Slovakia) show lower wage levels but faster growth and greater dynamism in changes. The gap between the upper and lower quartiles remains significant, confirming persistent regional disparities, although the gradual convergence of minimum wage levels indicates a slow process of wage harmonization within the EU. In the long term, MW growth supports domestic demand and consumption, but on the other hand, it represents rising costs for

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employers, especially in sectors with lower labor productivity (services, retail, agriculture). For enterprise births, this may constitute a barrier to entry.

The analysis of enterprise births provides important insights into the dynamism of the business environment and the economy's ability to generate new jobs. Comparing the average number of new firms between the periods 2015–2020 and 2021–2023 allows us to identify regional differences in entrepreneurial activity and capture changes potentially linked to macroeconomic developments, wage growth, or the effects of the COVID-19 pandemic. The following maps (Figure 2**)** visualize the average number of enterprise births in EU member states for both observed periods.

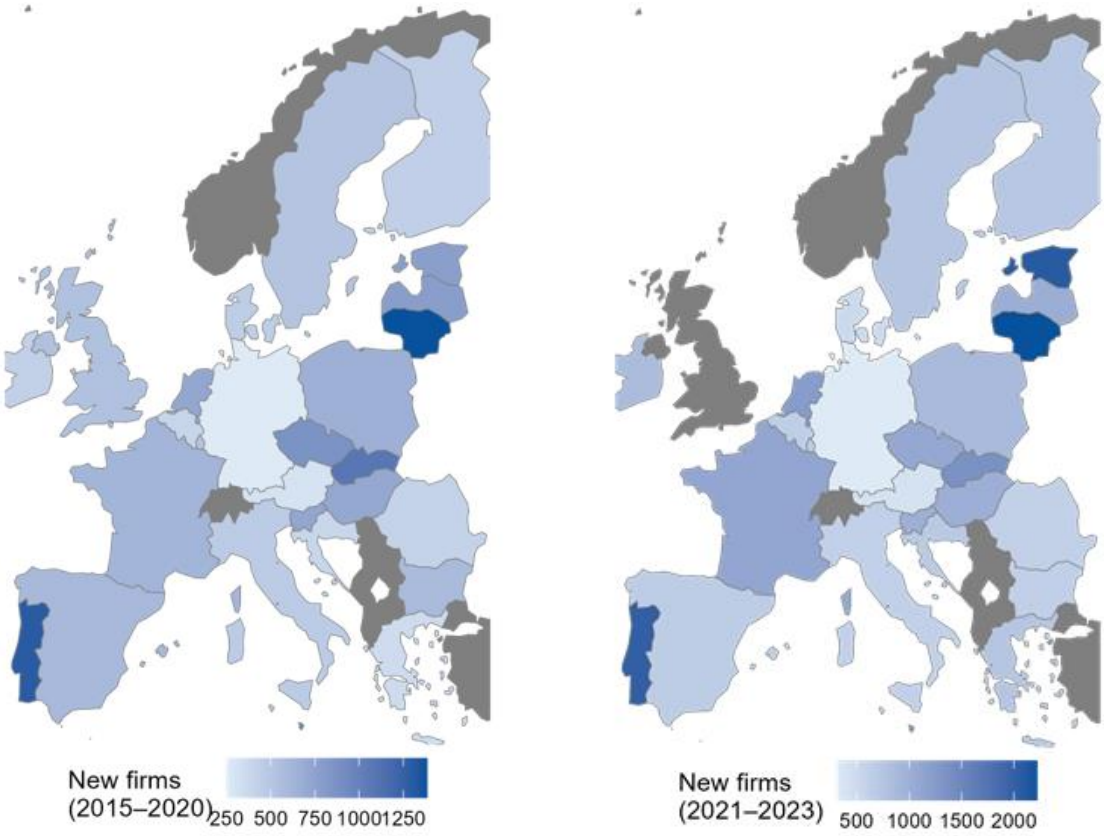


Figure 2. Average Number of Enterprise Births (New firms) in the Periods 2015–2020 (Left) and 2021–2023 (Right)
Source: Eurostat (own processing)

The comparison of both periods in Figure 2 clearly shows that entrepreneurial activity across the European Union evolved differently across regions. Between 2015–2020, new business registrations were concentrated mainly in the Baltic states and parts of Western Europe (e.g., Portugal, the Netherlands), while after 2021 a more pronounced increase emerged in Central and Southeastern Europe. This shift suggests a gradual recovery of the business environment following the pandemic period, while also highlighting persistent differences in entrepreneurial dynamism between countries. A higher number of enterprise births may reflect improved economic expectations, greater access to capital, or a response to rising labor costs in certain sectors.

To illustrate the relationship between the level of the minimum wage and business dynamism, we compare the average values of minimum wage and the number of enterprise births per 100,000 inhabitants in EU countries. The following Figure 3 displays this relationship for two time periods—before and after the change in the methodology for business statistics.

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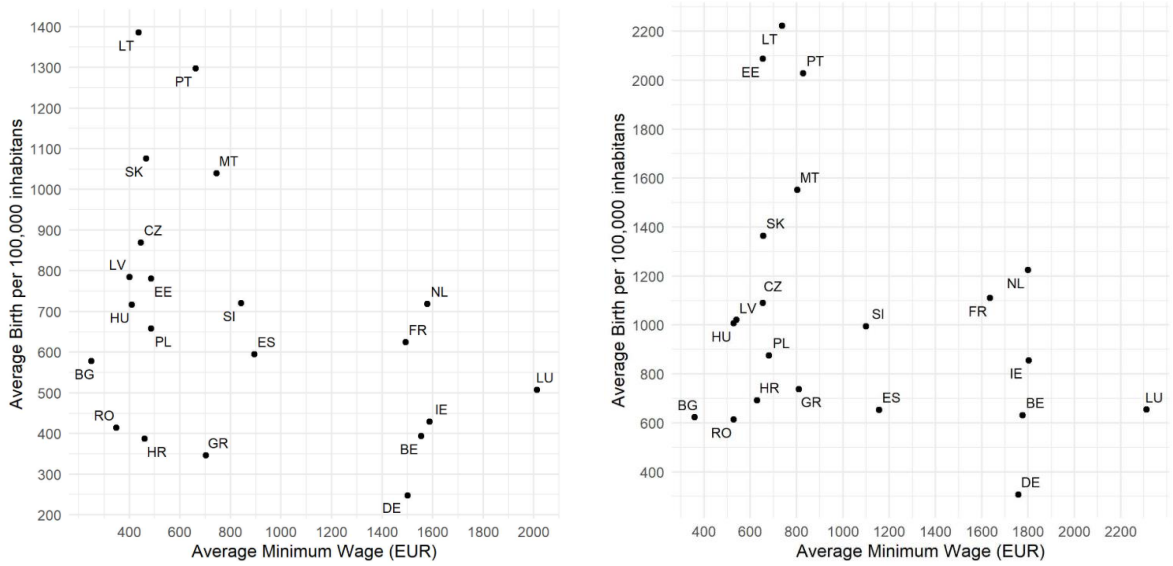


Figure 3. Relationship Between Average Minimum Wage and Average Number of Enterprise Births for the Periods 2015–2020 (Left) and 2021–2023 (Right)
Source: Eurostat (own processing)

Figure 3 shows that in the period 2021–2023, the relationship between higher minimum wages and a lower number of enterprise births appears more systematic than in the previous years. Countries with higher wage levels exhibit lower entrepreneurial activity, visually supporting the hypothesis of a negative impact of rising minimum wages on business formation. This trend may result from stronger regulatory interventions, changes in statistical methodology, or higher entry costs associated with formal entrepreneurship.

4.2 The Impact of the Minimum Wage on the Total Number of Enterprise Births

To test Hypothesis H1, a series of models was created for two distinct periods, 2015–2020 and 2021–2023, based on the methodological changes in the Eurostat database that affect the calculation of enterprise births. Tables 2 and 3 present the results for five statistical models.

Table 2. Results of Panel Models for the Period 2015–2020 (All Enterprise Births, Old Methodology)

Variable	Pooled OLS	FE (ind.)	FE (time)	FE (2W)	RE (ind.)
ln(MW)	−0.675* (0.370)	−0.238 (0.344)	−0.723*** (0.141)	−0.156 (0.119)	−0.207 (0.317)
ln(GDP)	0.013 (0.379)	0.361 (0.474)	0.133* (0.073)	0.841 (0.636)	−0.002 (0.307)
Unemp	−0.024 (0.017)	−0.025** (0.011)	−0.018*** (0.004)	0.005 (0.005)	−0.028*** (0.010)
ln(Earn)	0.399 (0.428)	0.283 (0.563)	0.372** (0.148)	−0.363 (0.315)	0.181 (0.437)
Constatnt	7.402*** (1.235)	—	—	—	6.400*** (1.554)
Obsetvations	126	126	126	126	126
R^2	0.169	0.133	0.173	0.033	0.105
Adj. R^2	0.142	−0.073	0.109	−0.259	0.076

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Source: authors

According to both diagnostic tests and economic logic, the most appropriate model in Table 2 is the RE individual model (random country effects). In all model specifications, the minimum wage variable has a negative coefficient. It is strongly statistically significant in the FE-time model ($\beta = -0.723$, $p < 0.01$), and moderately significant in the pooled OLS model ($p \approx 0.07$). In the most suitable RE model, the effect remains negative but is not statistically significant. This suggests that a higher minimum wage may contribute to a reduction in the number of enterprise births—i.e., rising wage costs may act as a barrier to market entry for new businesses. The panel models for the period 2015–2020 show that control variables such as GDP have a positive effect, supporting entrepreneurial activity. Unemployment consistently shows a negative effect, and higher

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average earnings are associated with a more favorable business environment. Table 3 presents results for the period 2021–2023, following the implementation of the new methodology for calculating enterprise births.

Table 3. Results of Panel Models for the Period 2021–2023 (All Enterprise Births, New Methodology)

Variable	Pooled OLS	FE (ind.)	FE (time)	FE (2W)	RE (ind.)
ln(MW)	−0.787 (0.727)	−0.599 (0.474)	−0.811*** (0.137)	−1.046*** (0.227)	−0.550 (0.422)
ln(GDP)	−0.110 (0.489)	0.661 (0.679)	−0.042 (0.088)	0.924*** (0.062)	−0.120 (0.328)
Unemp	−0.012 (0.036)	−0.050* (0.026)	−0.008 (0.008)	−0.020 (0.013)	−0.053*** (0.017)
ln(Earn)	0.585 (0.659)	0.642* (0.373)	0.561*** (0.151)	0.396* (0.204)	0.532* (0.320)
Constatnt	7.382*** (1.545)	—	—	—	6.539*** (1.391)
Obsetvations	63	63	63	63	63
R^2	0.086	0.233	0.089	0.174	0.132
Adj. R^2	0.023	−0.252	−0.008	−0.423	0.072

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Source: authors

Based on the diagnostic tests, the most appropriate model for this dataset is the country random effects model (RE individual). For the 2021–2023 data, the coefficient on the minimum wage (in euros) is negative across all models, suggesting that an increase in the minimum wage tends to reduce the number of newly established firms. The effect is statistically significant in the time and two-way fixed effects models (FE time, FE two-ways), where $\beta = -0.811$***** (FE-time) and $\beta = -1.046$***** (FE two-ways). This indicates that increasing the minimum wage raises fixed labor costs, which may discourage small and new businesses from entering the market. In the pooled OLS and RE models, the effect remains negative but is not statistically significant, implying that the impact is weaker when cross-country differences are taken into account. Overall, higher minimum wages appear to have a dampening effect on firm creation, while economic growth (GDP) clearly contributes positively.

Unemployment remains a significant negative determinant, as was the case in the previous period. According to Wosiek (2024), it is also important to consider the structure of unemployment. A higher share of highly skilled unemployed individuals increases the rate of firm formation, especially in knowledge-based services and manufacturing. Conversely, a higher proportion of long-term unemployed negatively affects the emergence of new businesses, particularly those with employees. According to our findings, higher earnings may indicate a more attractive business environment.
In summary, labor costs in the EU context have a real and quantifiable impact on business dynamics, as evidenced by the negative and economically significant minimum wage coefficient in the fixed effects models. The statistical model results, depending on the methodology used to calculate business births, are summarized in Table 4.

Table 4. Comparison of Model Results for the Periods 2015–2020 and 2021–2023

Variable	Old Methodology (2015-2020)	New Methodology2021-2023)	Trend
MW	Negative, significant	Negative, but not significant	Weakened effect
GDP	Positive, insignificant to mildly significant	Positive, stable	Consistent effect
Unemp	Negative, significant	Negative, significant	Stable effect
Earn	Positive, significant in FE-time	Positive, not significant	Weaker effect after methodology change

Source: authors

The results of the models presented in Tables 2, 4, and 4 confirm H1: *An increase in the minimum wage has a negative effect on the total number of newly established enterprises.* This effect should be interpreted as moderately negative, and it is important to point out the relatively low explanatory power of the models given

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the R^2 values. Thus, while the primary function of the minimum wage (MW) is to protect low-income employees, it can also act as a barrier to the formation of new enterprises in EU countries. Our findings are supported and explained by previous studies. A higher wage floor increases entry costs and creates a productivity threshold below which new enterprises cannot survive (Bachmann et al., 2014). This effect is confirmed by international studies by Draca et al. (2011) in the United Kingdom, Harasztosi & Lindner (2019) in Hungary, and Kong et al. (2021) in China. The literature also highlights that some potential entrepreneurs respond to wage regulation by shifting into non-employer entrepreneurship (Ganserer et al., 2022), which can result in a decline in the number of formally registered businesses. Therefore, a higher MW not only selects entrepreneurs based on productivity but also alters the structure of new businesses in favor of smaller and more informal types (Cordier & Bade, 2023).

4.3 The Impact of Minimum Wage on Newly Established Firms by Size

To test hypothesis H2, a total of eight models were developed to examine the effect of MW on the number of newly established enterprises across four size categories during the two observed periods: 2015–2020 and 2021–2023. The results of selected models are presented in Table 5, while the complete set of MW coefficient estimates across all examined models can be found in Table 6.

Table 5. Results of the Models Estimating the Effect of Minimum Wage on the Number of New Enterprises by Size

Model	2016-2020				2021-2023			
	Model 1 (0)	Model 2 (1-4)	Model 3 (5-9)	Model 4 (10+)	Model 5 (0)	Model 6 (1-4)	Model 7 (5-9)	Model 8 (10+)
ln(MW)	0.095 (0.430)	-0.622 (0.408)	-0.974 (0.557)	-0.781* (0.411)	0.197 (0.206)	0.010 (0.085)	-0.057 (0.111)	-0.155 (0.162)
ln(GDP)	0.097 (0.519)	0.332 (0.515)	1.289 (1.075)	0.816 (0.707)	-0.710** (0.321)	0.131 (0.125)	0.222* (0.115)	0.405*** (0.107)
Unemp	-0.036* (0.019)	-0.011 (0.014)	-0.038* (0.020)	-0.029* (0.016)	-0.029*** (0.011)	-0.004 (0.007)	-0.016** (0.008)	-0.019*** (0.007)
ln(Earn)	-0.034 (0.678)	0.027 (0.572)	-0.572 (0.858)	-0.571 (0.676)	0.229 (0.214)	0.070 (0.111)	0.076 (0.128)	0.133 (0.113)
constant	5.858** (2.490)	7.388*** (1.807)	-	-	8.418*** (1.369)	6.387*** (1.033)	-	4.148*** (0.597)
R2	0.102	0.084	0.214	0.243	0.417	0.077	0.241	0.310
Adjusted R2	0.069	0.050	0.025	0.060	0.376	0.013	-0.239	0.262

Note: The presented values reflect the results of the model with random individual effects. In case of the symbol (-), the most suitable model was the one with fixed individual effects. *** p<0.01, ** p<0.05, * p<0.1

Source: authors

Table 6. Results of Models Estimating the Impact of Minimum Wage on the Number of Enterprise Births by Firm Size

Model	2015-2020				2021-2023			
	Model 1 (0)	Model 2 (1-4)	Model 3 (5-9)	Model 4 (10+)	Model 5 (0)	Model 6 (1-4)	Model 7 (5-9)	Model 8 (10+)
Pooled OLS	-0.688	0.031	-0.688	-1.039	-0.432	-0.582	-0.346	-0.746
FE (ind.)	0.054.	-0.891	-0.974*	-0.781*	0.234	-0.006	-0.057	-0.068
FE (time)	-0.732*	-0.005	-0.723**	-1.053**	-0.442*	-0.628*	-0.364	-0.765*
FE (2W)	-0.019	-0.469*	-0.795***	-0.576***	-0.080.	0.203	-0.034	-0.174
RE (ind.)	0.095	-0.622	-0.845*	-0.810**	0.197	0.010	-0.077	-0.155

Note: The reported coefficients refer to the variable ln(MW). *** p<0.01, ** p<0.05, * p<0.1

Source: authors

When testing H2, it was expected that micro-enterprises (0–9 employees) would be more sensitive to increases in the minimum wage (MW), but the results show the opposite trend. The strongest negative effect appears among enterprises with more than 10 employees, particularly in the years 2021–2023 (Model 8), where the

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coefficient for MW is consistently negative and statistically significant. For micro-enterprises (Models 5 and 6), the results are less pronounced and mostly insignificant. These findings do not confirm hypothesis H2 and suggest that MW increases may more strongly limit the entry of larger new businesses that plan to employ a greater number of workers from the outset. This can be explained by the fact that rising labor costs have a greater impact on enterprises that must hire a larger workforce, compared to entrepreneurs without employees.

This result does not fully align with expectations from the literature (Harasztosi & Lindner, 2019; Dustmann et al., 2022), which suggests that smaller firms are the most vulnerable. Another possible explanation is that larger new businesses more often operate in regulated sectors with a higher share of manual occupations, where the effect of MW is amplified (Mayneris et al., 2018). Micro-enterprises (0–9 employees), on the other hand, may be temporarily more flexible or less visible to formal regulations.

The control variables in most models confirm the expected direction: higher GDP (ln(GDP)) is associated with a higher number of new firms, with the coefficient being statistically significant in the more recent models (e.g., Model 7). Unemployment (Unemp) generally shows a negative and statistically significant effect, indicating that higher unemployment may discourage business entry. However, these results may vary depending on the sector in which the business enters, as noted by Wosiek (2024). Wages (ln(Earn)) exhibit only limited effects, with no consistent direction or significance. These results suggest that, in addition to the minimum wage, broader macroeconomic conditions also play a crucial role in shaping entrepreneurial dynamics.

Conslusion

This study aimed to examine the extent to which increases in the minimum wage (MW) influence the dynamics of new firm creation in EU countries. Based on panel data analysis, we tested two hypotheses related to the overall number of newly established enterprises and their size structure. The results provide important insights into the broader implications of wage policy on the business environment and highlight the specific vulnerabilities of certain types of enterprises.

Our findings support the first hypothesis (H1), which states that MW growth has a negative effect on the number of enterprise births. This effect is especially noticeable in countries and periods that experienced more significant increases in MW. These results are consistent with existing European studies such as Harasztosi & Lindner (2019) in Hungary, Dustmann et al. (2022), Ganserer et al. (2022) in Germany, and Casanova et al. (2025) in Spain, all of which emphasize that the sector a business seeks to enter plays a critical role. In general, the impact of MW on new businesses appears to be mildly negative.

Interesting findings emerged from testing the second hypothesis (H2), which expected that MW growth would primarily affect micro-enterprises (0–9 employees). However, our results show that the strongest negative impact was observed among firms with more than 10 employees. This outcome partially contradicts expectations but may relate to the cost structure and employment rigidity of larger firms. Micro-enterprises (0–9 employees) may be more flexible in adapting to changes (e.g., adjusting working hours or shifting activities to the informal sector), whereas medium-sized firms are more subject to strict labor regulations. These interpretations align with the framework presented by Aaronson et al. (2018), which highlights different firm responses to labor costs depending on their technical and organizational flexibility. A possible explanation is that larger new firms are more likely to operate in formal sectors with higher compliance requirements, increasing their exposure to wage regulations early in their lifecycle. The response to MW by firm size may differ significantly between existing firms and potential entrants. If a firm intends to employ more than 10 workers, MW hikes may present a greater barrier to entry than for smaller firms, which could explain our results.

From a theoretical standpoint, our research confirms the selection effect of MW and supports the argument that MW creates an implicit threshold for market entry (Bachmann, Bauer & Frings, 2014), potentially acting as a barrier especially for entrepreneurial initiatives with lower capital and productivity. However, the overall effect is only mildly negative for the full sample, more pronounced for firms with over 10 employees, and does not outweigh the social benefits of MW increases. The primary purpose of MW growth is to ensure a decent income for workers, reduce in-work poverty, and promote social justice. It also aims to strengthen household purchasing

power, contributing to aggregate demand. Within the EU, it serves as a tool for narrowing living standard gaps between member states and reinforcing the Union's social pillar. Overall, while MW increases can entail negative consequences for business dynamics—especially in areas with a high prevalence of MW-paid jobs—wage policy must be considered in the context of the broader economic environment and business conditions. The main goal of this study is to highlight potential downsides, not to advocate for halting MW increases across the EU.

Despite robust relationships observed, this research has several limitations. First, it uses aggregated panel data at the country level, which prevents analysis of sectoral or regional heterogeneity. Second, we lacked micro-level data on individual firms, making it difficult to identify mechanisms such as technological adaptation, legal entry forms, or shifts to the informal economy. Moreover, we did not account for factors such as entrepreneurial culture, credit availability, or tax incentives, which may interact with the effects of MW. Another limitation is the time series covered (2015–2023), which had to be split into two periods due to a change in Eurostat's enterprise birth methodology after 2020.

For future research, it would be valuable to analyze the MW effect on firm creation at the sectoral or regional level, and to complement the quantitative analysis with qualitative data—for instance, surveys of entrepreneurs on their perceptions of wage regulations as barriers to entry (Cui & Li, 2023). Such findings would be important for implementing sector-specific or regional MW levels in EU countries that do not yet use this approach. We also recommend including variables such as entrepreneurial expectations or regulatory changes over time. Finally, it would be beneficial to compare the effects of wage regulation in EU countries with those outside the EU (e.g., the USA or China), where labor market institutions differ.

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THEORETICAL AND CONCEPTUAL FOUNDATIONS OF EUROPEAN ENERGY SECURITY

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Abstract. In recent years, the energy security of the European Union has become one of the most significant issues in European public policy and legal regulation. Its importance has been profoundly shaped by geopolitical disruptions, risks to energy supply, and Russia's military aggression against Ukraine. This publication aims to examine the theoretical and conceptual foundations of European energy security by identifying the principal elements of energy security, the risks arising from energy dependence, and the significance of diversification, while also assessing the role of energy security in the evolution of European Union policy**.** The study employs general scientific analytical, comparative, and systemic research methods. The analysis is based on recent academic literature, European Union legislation, and official documents issued by the European Commission, the International Energy Agency (IEA), the Agency for the Cooperation of Energy Regulators (ACER), and other international organisations. The findings indicate that contemporary energy security is a multidimensional concept encompassing not only secure and uninterrupted energy supply but also the resilience of energy systems, the protection of critical energy infrastructure, economic security, sustainable development, and the capacity to adapt to geopolitical challenges. The analysis demonstrates that the diversification of energy suppliers and transport routes, the expansion of renewable energy sources, improvements in energy efficiency, and the key instruments of the European Union's common energy policy—including the Energy Union, the European Green Deal, and REPowerEU—constitute the foundation for strengthening European energy security. The results of this study provide a theoretical basis for analysing the legal framework governing European Union energy security and its future development in the context of armed conflict and other emergency situations.

Keywords: energy security; security of energy supply; energy dependence; diversification; Energy Union; REPowerEU; European Union; legal framework.

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1. The Concept of Energy Security

Over the past several decades, energy security has evolved into one of the central interdisciplinary concepts in international security policy, economics, and legal scholarship. Particularly following Russia's full-scale invasion of Ukraine in 2022, the concept of energy security within the European Union has expanded considerably, encompassing not only the availability and uninterrupted supply of energy resources but also the resilience of energy infrastructure, market flexibility, climate policy, the security of critical raw materials supply, and the capacity of energy systems to adapt to geopolitical disruptions (Al-Saidi, 2023). Consequently, energy security is no longer regarded solely as an issue of the energy sector but rather as an integral component of both national and regional security (Azzuni & Breyer, 2018; International Energy Agency [IEA], 2020; IEA, 2021; Ivančík, & Andrassy, 2026a, b; Ivančík & Dušek, 2026).

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The most widely accepted international definition of energy security has been proposed by the International Energy Agency (IEA), which defines it as "the uninterrupted availability of energy sources at an affordable price." This definition highlights two interrelated dimensions—physical availability and economic affordability—while recognising that the content of energy security continues to evolve alongside the transformation of energy systems. Whereas earlier discussions primarily focused on the security of oil and natural gas supplies, the ongoing energy transition has shifted increasing attention towards electricity security, the resilience of energy networks, the availability of critical minerals, and cybersecurity (IEA, 2021; IEA, 2024).

The academic literature does not provide a universally accepted definition of energy security. Azzuni and Breyer (2018), after reviewing more than eighty definitions, conclude that energy security is inherently multidimensional and that its meaning has evolved in response to geopolitical, technological, and environmental changes. According to the authors, earlier definitions primarily concentrated on the availability of fossil fuels and import security, whereas more recent approaches place greater emphasis on sustainability, climate objectives, social accessibility, and the resilience of energy systems. Accordingly, energy security should be understood not as a static condition (Teivāns-Treinovskis, Jefimovs et al., 2023), but rather as the dynamic capacity of an energy system to anticipate, withstand, absorb, and recover from disruptions of various origins.

Contemporary academic research also widely applies the so-called “4A framework”, which conceptualises energy security through four interrelated dimensions: availability, accessibility, affordability, and acceptability from environmental and societal perspectives. Although this framework was originally developed several decades ago, recent studies continue to employ it as an important conceptual foundation while extending it to include such dimensions as infrastructure security, governance, flexibility, and resilience to crises (Schmitz, Flachsbarth et al., 2025). This evolution demonstrates that energy security has become increasingly intertwined with the transformation and decarbonisation of energy systems.

During the past decade, the approach adopted by international organisations towards energy security has also undergone significant transformation. Within European Union policy, energy security is increasingly interpreted through the framework of the Energy Union and, more recently, the REPowerEU initiative. Under this approach, energy security encompasses not only the provision of stable energy supplies but also the diversification of suppliers and transport routes, the integration of the internal energy market, the development of cross-border infrastructure, improvements in energy efficiency, and the wider deployment of renewable energy sources (De Rosa et al., 2022). Consequently, energy security has become closely associated with strengthening the European Union's strategic autonomy and reducing risks arising from dependence on external suppliers.

A comparison of the principal approaches reveals several important distinctions. Definitions developed by international organisations are primarily policy-oriented and focus on the practical management of risks, emphasising uninterrupted energy supply, price stability, and the effective functioning of energy systems. Academic research, by contrast, conceptualises energy security as a complex socio-economic and geopolitical phenomenon in which institutional quality, market structures, technological innovation, climate policy, and societal resilience play a central role. These perspectives should not be viewed as competing but rather as complementary. Institutional definitions establish policy objectives, whereas academic research explains the mechanisms through which energy security can be achieved, maintained, or undermined.

In summary, the theoretical literature demonstrates that contemporary energy security is a multidimensional concept encompassing the physical availability of energy resources, economic affordability, technical reliability, infrastructure resilience, sustainable development, and the capacity to adapt to geopolitical, economic, and climate-related disruptions. Within the European Union, the concept is increasingly shaped not only by the security of fossil fuel imports but also by the successful implementation of the energy transition, which reduces strategic vulnerabilities and strengthens the Union's long-term strategic autonomy. This understanding provides the theoretical foundation for the subsequent analysis of the European Union's legal framework governing energy security.

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2. Key Elements of Energy Security

Energy security is a multidimensional concept comprising several interrelated elements. Contemporary academic literature increasingly recognises that the assessment of energy security should not be based solely on the physical availability of energy resources but also on the capacity of an energy system to ensure secure, affordable, sustainable, and uninterrupted energy supply under both normal operating conditions and periods of external or internal disruption. Consequently, energy security is increasingly analysed from a systemic perspective that encompasses the availability of energy resources, the security and continuity of energy supply, price stability, the protection of critical energy infrastructure, sustainable development, and the resilience of energy systems to crises (Azzuni & Breyer, 2018; International Energy Agency [IEA], 2023).

One of the fundamental elements of energy security is the availability of energy resources. Traditionally, this concept referred to the availability of sufficient reserves of fossil fuels—oil, natural gas, and coal—to ensure the uninterrupted functioning of the economy and society. However, in the context of the ongoing energy transition, the notion of availability has broadened substantially. In addition to fossil fuels, increasing importance is attached to electricity generation capacity, the potential of renewable energy sources, energy storage technologies, and the availability of critical raw materials required for manufacturing wind turbines, solar photovoltaic panels, batteries, and other clean energy technologies. Consequently, the availability of energy resources is no longer assessed solely in terms of natural resource endowments but also in relation to a country's ability to secure access to essential technologies and resilient supply chains (IEA, 2023; International Renewable Energy Agency [IRENA], 2023).

Equally important is the security of energy supply, which reflects the capacity of an energy system to ensure adequate energy supplies under both normal and emergency conditions. In the academic literature, security of supply is commonly understood as the risk that energy deliveries may be disrupted by geopolitical conflicts, technical failures, natural disasters, or market volatility. The European Union's experience following 2022 demonstrates that security of supply is closely linked to the diversification of suppliers, adequate storage capacity, the development of cross-border interconnections, and coordinated action among Member States during crisis situations. Accordingly, security of supply constitutes not only a technical issue but also a political and legal one (European Commission, 2022; IEA, 2023).

Closely related to security of supply is the continuity of energy supply, which refers to the ability of an energy system to provide a stable supply of electricity and other energy resources without significant interruptions. Unlike security of supply, which primarily concerns the availability of energy resources, continuity of supply focuses on the operational performance of energy infrastructure, the reliability of transmission and distribution networks, reserve generation capacity, and overall system flexibility. Within electricity systems, particular importance is attached to the availability of balancing capacity, the security of digital control systems, and the capability to restore system operations rapidly following disruptions. As the share of renewable energy continues to increase, system flexibility has become one of the principal prerequisites for ensuring uninterrupted energy supply (ENTSO-E, 2022; IEA, 2023).

Another essential dimension of energy security is energy price stability. Although price fluctuations are an inherent feature of any market, sharp and sustained increases in energy prices may generate significant socio-economic consequences by reducing business competitiveness, accelerating inflation, and increasing energy poverty. Consequently, the contemporary understanding of energy security extends beyond the physical availability of energy resources to include their economic affordability for both households and businesses. The European energy crisis of recent years clearly demonstrated that price stability depends on well-integrated markets, adequate generation capacity, effective competition, and sound regulatory frameworks (OECD, 2023; European Commission, 2023).

The security of critical energy infrastructure constitutes another key element of energy security. Power generation facilities, electricity transmission networks, liquefied natural gas (LNG) terminals, gas storage facilities, cross-border interconnectors, and digital control systems all form part of the critical infrastructure whose disruption may have severe consequences for national security and economic stability. Recent

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developments—including the growing number of cyberattacks and incidents affecting subsea infrastructure in Europe—have significantly increased attention to both the physical protection and cybersecurity of critical energy infrastructure. Consequently, ensuring energy security also requires preventive measures aimed at infrastructure protection and comprehensive risk management (NATO, 2023a; European Commission, 2023).

Within the contemporary understanding of energy security, sustainable development has become an inseparable component. Whereas the traditional objective of energy security focused primarily on ensuring sufficient energy resources, climate change mitigation policies have considerably broadened the scope of the concept. Academic research increasingly argues that long-term energy security cannot be achieved while maintaining a high level of dependence on imported fossil fuels. The expansion of renewable energy sources, improvements in energy efficiency, and reductions in energy consumption simultaneously contribute to the achievement of climate objectives and the strengthening of energy system security. Sustainability has therefore evolved into a structural dimension of energy security rather than remaining solely an objective of environmental policy (IRENA, 2023; European Commission, 2023).

Closely linked to sustainability is the resilience of energy systems. Resilience refers to the capacity of an energy system to anticipate potential risks, absorb external shocks, adapt to changing conditions, and restore normal operations following a crisis. Unlike the traditional security paradigm, which primarily focuses on preventing threats, the resilience perspective emphasises the adaptive capacity of the system. This approach has become particularly relevant in the aftermath of the COVID-19 pandemic, Russia's military aggression against Ukraine, and the increasing risks associated with climate change, all of which underscore the necessity of developing flexible and decentralised energy systems (Azzuni & Breyer, 2018; IEA, 2023).

The large-scale missile and drone attacks launched by Russia against Ukrainian power plants and electricity distribution infrastructure during the winter of 2023 had profound consequences not only for Ukraine's military capabilities but also for substantial segments of its economy. These events clearly demonstrated that modern economies cannot function effectively without a stable electricity supply. This applies not only to industrial production but also to critical sectors such as agriculture and the provision of essential public utility services. Accordingly, the resilience of energy systems should be regarded as a fundamental prerequisite for maintaining both economic continuity and national resilience during armed conflicts and other major crises.

In summary, the above elements demonstrate that energy security constitutes an integrated and mutually reinforcing system in which each component complements the others. The availability of energy resources alone is insufficient without ensuring the continuity of supply, while resilient infrastructure cannot by itself guarantee energy security if the energy system remains economically or geopolitically vulnerable. Consequently, the contemporary model of energy security is based on an integrated approach that combines technical, economic, legal, environmental, and geopolitical dimensions. This comprehensive understanding provides the theoretical foundation for the subsequent analysis of European Union energy policy and its legal framework.

3. Energy Security as a Component of National and Regional Security

Energy security is now widely recognised as one of the fundamental pillars of both national and regional security. Whereas energy policy was traditionally examined primarily from the perspective of economic development and industrial growth, over the past two decades—and particularly following Russia's military aggression against Ukraine—energy security has evolved into a strategic issue directly affecting state sovereignty, economic stability, and the ability of governments to pursue an independent foreign policy. The academic literature increasingly emphasises that the interrelationship between energy security and national security has become substantially stronger as a consequence of globalisation, the growing interdependence of supply chains, and escalating geopolitical risks (Azzuni & Breyer, 2018; International Energy Agency [IEA], 2023).

From the perspective of national security, energy security refers to a state's ability to ensure the uninterrupted availability of energy resources required to maintain critical national functions, regardless of external threats. Reliable supplies of electricity, natural gas, petroleum products, and other energy resources are indispensable

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for the functioning of public administration, healthcare, transport, electronic communications, defence, and other critical sectors. Disruptions to energy supply may produce far-reaching economic and social consequences while simultaneously limiting a state's capacity to respond effectively to military conflicts, cyber incidents, or natural disasters. Consequently, energy security has become an increasingly important component of national security strategies and policies governing the protection of critical infrastructure (European Commission, 2023; NATO, 2023a).

Energy security is also closely linked to economic security, as a stable and predictable energy supply constitutes one of the fundamental prerequisites for sustainable economic development. Fluctuations in energy prices, interruptions in supply, or prolonged shortages of energy resources may adversely affect industrial competitiveness, the investment climate, and household welfare.

Moreover, the energy security and functional resilience of households directly influence social cohesion and political stability in democratic societies. Recent developments associated with Russia's war against Ukraine provide clear evidence of this relationship. For example, Ukrainian drone strikes targeting Russian oil refineries and fuel logistics infrastructure during the summer of 2026 reportedly generated not only significant economic consequences but also public dissatisfaction and increased social tensions within Russia. Likewise, the European energy crisis of 2022–2023 demonstrated that severe disruptions in energy markets can accelerate inflation, constrain economic growth, and increase fiscal pressures on governments, which are often required to implement extensive support measures for households and businesses. Energy security should therefore be regarded as one of the essential foundations of economic security (OECD, 2023; European Commission, 2023).

Contemporary security research assigns an increasingly important role to energy security within the broader framework of national security. Unlike traditional concepts centred primarily on military threats, modern national security encompasses economic, technological, informational, and energy-related dimensions. This broader understanding is based on the recognition that a state's vulnerability may arise not only from armed aggression but also from prolonged disruptions to energy supply, excessive dependence on a single supplier, or coordinated attacks against critical infrastructure. Furthermore, recent military conflicts have demonstrated that coordinated attacks on critical infrastructure have become one of the most effective means of undermining a state's resilience. This is evidenced not only by the experience of the war in Ukraine but also by confrontations involving the United States and Iran. Iran's asymmetric operations, including missile and unmanned aerial vehicle attacks directed at critical infrastructure supporting U.S. allies in the Middle East, demonstrated the capacity of such attacks to disrupt economic activity and generate wider political repercussions. Consequently, ensuring energy security is increasingly regarded as a fundamental component of national resilience, strengthening a state's capacity to prevent, withstand, and recover from crises of diverse origin (IEA, 2023; NATO, 2023a).

At the same time, energy security possesses a pronounced regional dimension. The energy systems of European Union Member States are highly interconnected, while electricity and natural gas markets operate largely on the basis of cross-border infrastructure and common market rules. As a result, disruptions to energy supply in one Member State may have cascading effects across neighbouring countries. For this reason, regional cooperation, the development of interconnections, coordinated action by transmission system operators, and solidarity mechanisms have become essential elements of European energy security. Ensuring energy security is therefore no longer solely a matter of national competence but is increasingly pursued within the framework of a common European energy policy (European Commission, 2023; ENTSO-E, 2022).

From a theoretical perspective, the regionalisation of energy security reflects the growing interdependence of states. The academic literature emphasises that integrated energy markets simultaneously enhance system efficiency and increase the need for coordinated risk management. Although market integration reduces the risks associated with national isolation and promotes competition, it may also create new vulnerabilities, including the potential for more widespread consequences arising from electricity transmission failures or cyber incidents. Consequently, regional energy security depends not only on market integration but also on effective crisis management and the strengthening of infrastructure resilience (Azzuni & Breyer, 2018; IEA, 2023).

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Energy security has also become an integral component of the European Union's Common Foreign and Security Policy. Russia's use of energy resources as an instrument of political influence has fundamentally reshaped the European Union's foreign policy priorities. The European Commission emphasises that energy security is closely linked to strategic autonomy, the strengthening of external partnerships, and the resilience of supply chains. Within this context, energy policy can no longer be regarded solely as an element of internal market regulation but has evolved into an important instrument of foreign, security, and defence policy. Consequently, the European Union has intensified cooperation with alternative energy suppliers, expanded joint infrastructure projects, and strengthened its energy diplomacy (European Commission, 2022; Council of the European Union, 2023).

In parallel with developments within the European Union, NATO has attached increasing importance to energy security by substantially expanding its approach to the protection of critical infrastructure. Alliance strategic documents identify energy infrastructure as one of the principal targets of hybrid threats. Particular attention is devoted to safeguarding subsea pipelines, electricity interconnectors, liquefied natural gas (LNG) terminals, ports, and digital infrastructure. This approach reflects the recognition that disruptions to energy supply may significantly affect both the functioning of civilian society and the operational capabilities of Allied armed forces (NATO, 2023b).

In conclusion, energy security constitutes a multidimensional component of national and regional security encompassing economic, technological, political, and geopolitical dimensions. Within the contemporary security environment, energy security cannot be reduced merely to ensuring the availability of energy resources; it also includes the protection of critical infrastructure, market resilience, international cooperation, and the capacity of states to respond effectively to a wide spectrum of threats. The experience of the European Union since 2022 demonstrates that energy security has become one of the principal prerequisites for both economic stability and the effective implementation of the Union's common security policy. Accordingly, it provides an essential theoretical foundation for further analysis of the European Union's legal framework governing energy security.

4. Energy Dependence and the Theoretical Aspects of Diversification

One of the central concepts in contemporary energy security theory is energy dependence, which characterises the extent to which a country, region, or economic sector relies on external energy resources to meet domestic demand. Traditionally, energy dependence has been measured by the share of imported energy resources in total energy consumption. However, recent academic research increasingly argues that the concept should be interpreted more broadly, taking into account not only import volumes but also the structure of supply, the diversity of suppliers, the resilience of energy infrastructure, and the capacity of energy systems to adapt to external disruptions. This broader perspective reflects the transition from the traditional notion of security of supply towards a multidimensional concept of energy system resilience (Azzuni & Breyer, 2018; Streimikiene et al., 2023).

One of the principal indicators of energy dependence is import dependency. A country that satisfies a substantial share of its energy demand through imports is exposed not only to the risk of supply disruptions but also to fluctuations in international energy prices and the political decisions of supplier countries. Nevertheless, recent studies emphasise that a high level of import dependency does not, in itself, imply a low level of energy security. The decisive factor is the structure of imports, including the number of suppliers, their political stability, the degree of competition among them, and the ability to rapidly redirect supply flows when necessary. Consequently, assessments of energy security increasingly employ diversification indicators, such as the modified Herfindahl–Hirschman Index (HHI), which measures supplier concentration and the associated level of risk (Kelly, 1981).

Theoretical literature devotes particular attention to single-supplier dependency. This risk arises when the overwhelming majority of energy resources is imported from a single external supplier, thereby enabling that supplier to exercise significant economic and political influence over the importing country. Such asymmetric interdependence constrains the importing state's ability to pursue independent political decisions and increases

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the likelihood that energy resources may be used as an instrument of foreign policy. This phenomenon has become one of the central issues in contemporary energy security research (Burke et al., 2007). The European Union's long-standing dependence on Russian natural gas prior to 2022 is frequently cited as a clear example of how economic interdependence may evolve into a strategic vulnerability when alternative sources of supply are insufficiently developed.

Geopolitical risk analysis also occupies a prominent position within the theory of energy dependence. Unlike market risks, which are primarily associated with price volatility and fluctuations in demand, geopolitical risks stem from international conflicts, sanctions, political instability, the disruption of transport routes, and the foreign policy interests of states. Recent events have clearly demonstrated that interruptions in energy supplies may result not from economic considerations but from political decisions. Consequently, energy security has become closely intertwined with foreign policy, security policy, and theories of international relations, particularly the realist approach, which emphasises interstate competition for strategic resources.

Contemporary security studies increasingly examine the use of energy as an instrument of political influence. The export of energy resources serves not only as a source of economic revenue but may also be employed to exert political pressure on importing countries. This phenomenon is commonly described as the geopoliticisation of energy, whereby energy supplies become instruments of foreign and security policy. Russia's manipulation of natural gas supplies to Europe fundamentally altered the European Union's perception of the need to reduce strategic dependence on a single supplier and to develop a more resilient energy system. Consequently, within the European Union, energy security is increasingly interpreted as a prerequisite for maintaining political autonomy.

In light of these risks, diversification is widely recognised as one of the principal instruments for strengthening energy security. In the academic literature, diversification is defined as the systematic reduction of an energy system's dependence through the diversification of suppliers, transport routes, energy sources, and technologies (Rubio-Varas & Muñoz-Delgado, 2019). The objective of diversification is not to eliminate imports entirely but rather to prevent situations in which disruptions affecting a single supplier or transport corridor can jeopardise the functioning of the entire energy system (Lekavičius et al., 2024). Empirical evidence suggests that countries characterised by greater diversity of suppliers and energy sources demonstrate higher levels of resilience to external shocks and price volatility.

The diversification of suppliers (Teivāns-Treinovskis, Lavrinovicha, et al., 2015) represents the most significant dimension of this strategy. Energy security theory suggests that distributing imports among several independent suppliers reduces both political leverage and the risk of supply disruptions. Nevertheless, recent studies emphasise that simply increasing the number of suppliers is insufficient. Equal consideration must be given to the political stability of supplier countries, the quality of their legal and regulatory systems, and the predictability of international relations. Accordingly, European Union policy increasingly prioritises cooperation with reliable partners while simultaneously seeking to avoid the emergence of new forms of unilateral dependence.

The diversification of transport routes is equally important. The security of energy supply depends not only on the choice of suppliers but also on the diversity of transport infrastructure. Pipeline systems, liquefied natural gas (LNG) terminals, ports, and electricity interconnectors provide alternative supply routes when one or more transport corridors become unavailable. The European Union's experience since 2022 demonstrates that the expansion of cross-border interconnections and LNG infrastructure has significantly enhanced the flexibility of the European energy system while reducing dependence on traditional pipeline routes.

Liquefied natural gas (LNG) occupies a particularly important role in contemporary energy security policy. LNG has substantially increased the flexibility of global gas markets by enabling natural gas to be transported from multiple regions independently of fixed pipeline infrastructure. Following the reduction of Russian gas supplies, the European Union significantly expanded LNG imports, thereby reducing immediate supply risks. At the same time, scholars emphasise that LNG should not be regarded as a long-term solution if it creates new forms of concentrated dependence on a limited number of exporting countries. Accordingly, LNG is best

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understood as a transitional instrument that should be complemented by the development of domestic energy resources and measures aimed at reducing overall energy demand.

In the longer term, increasing importance is attached to the diversification of energy sources, particularly through the expansion of renewable energy. Unlike imported fossil fuels, wind power, solar energy, hydropower, and sustainably sourced biomass reduce dependence on external suppliers while simultaneously contributing to the achievement of climate objectives. In this regard, Latvia possesses a significant strategic advantage through its cascade of hydroelectric power plants, which generates the majority of the country's electricity. At the same time, it should be recognised that under conditions of armed conflict, large-scale energy infrastructure such as hydroelectric power stations may become priority targets for military attacks. From this perspective, decentralised energy generation technologies—including solar photovoltaic installations and wind turbines—may provide greater resilience, as their dispersed nature makes their destruction considerably more costly and operationally demanding for an attacker. Nevertheless, it should also be emphasised that the energy transition introduces new challenges, including increasing dependence on critical raw materials and imported energy technologies. Consequently, future assessments of energy independence will need to consider not only reliance on imported fossil fuels but also the capacity to ensure secure and resilient technology supply chains.

For this reason, contemporary theoretical literature increasingly employs the concept of strategic energy autonomy, referring to the capacity of a state or region to maintain a stable energy supply while minimising vulnerability to external political and economic shocks (Hancher & De Hauteclocque, 2025). This concept does not imply complete energy self-sufficiency. Rather, it denotes a balanced energy system in which import dependence is mitigated through diversified supply structures, domestic energy production, energy efficiency, cross-border interconnections, and flexible market regulation. Over recent years, this approach has become one of the principal theoretical foundations of European Union energy policy.

In summary, energy dependence should not be assessed solely on the basis of the volume of imported energy resources but rather in terms of the overall vulnerability of an energy system to external risks. Diversification constitutes a comprehensive strategy encompassing the diversification of suppliers, transport routes, energy sources, and technologies. These elements are mutually reinforcing and collectively provide the theoretical foundation of the European Union's contemporary energy security policy, which seeks to strengthen energy system resilience, reduce geopolitical risks, and enhance long-term strategic autonomy.

5. The Role of Energy Security in the Development of European Union Policy

Energy security has become one of the fundamental principles underpinning the European Union's energy policy, exerting a profound influence on both the evolution of the Union's legal framework and its long-term strategic priorities. Although EU energy policy was initially focused primarily on establishing an integrated internal energy market and promoting competition, its scope has expanded considerably over the past decade. Climate change, increasing geopolitical instability, dependence on imported energy resources, and Russia's full-scale military aggression against Ukraine have collectively accelerated the transition towards an integrated policy approach in which energy security is intrinsically linked to economic security, climate policy, and the European Union's strategic autonomy (European Commission, 2023; International Energy Agency [IEA], 2023).

One of the most significant milestones in the evolution of EU energy policy was the establishment of the Energy Union in 2015. Its objective was to create a unified, secure, sustainable, and competitive European energy system by reducing fragmentation among Member States and strengthening solidarity in the field of energy supply. The Energy Union is built upon five mutually reinforcing dimensions: energy security, solidarity and trust; a fully integrated internal energy market; energy efficiency; decarbonisation; and research, innovation, and competitiveness. This framework substantially broadened the traditional understanding of energy security by emphasising that long-term security depends not only on the availability of fossil fuels but also on effective market integration, the development of cross-border infrastructure, and the sustainable transformation of energy systems (European Commission, 2015; European Commission, 2023).

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The Energy Union also introduced a new understanding of solidarity as a fundamental principle of energy security. In addition to the individual responsibility of Member States, it established the concept that, in the event of severe disruptions to energy supply, Member States have a collective obligation to cooperate and provide mutual assistance. This principle was subsequently incorporated into European Union legislation, particularly the legal framework governing the security of natural gas supply, which introduced joint risk assessments, preventive action plans, and solidarity mechanisms applicable during emergency situations. Consequently, energy security became not only a national responsibility but also a shared responsibility of the European Union as a whole (Regulation (EU) 2017/1938; European Commission, 2023).

A further major impetus for the development of EU energy policy was provided by the European Green Deal, presented in 2019. Although its principal objective is to achieve climate neutrality by 2050, the Green Deal also has profound implications for energy security. Academic research increasingly demonstrates that decarbonisation reduces dependence on imported fossil fuels, promotes the development of domestic renewable energy sources, and mitigates geopolitical vulnerabilities (Samaras, 2025). At the same time, the energy transition gives rise to new challenges, including growing demand for critical raw materials, electricity storage technologies, and digital infrastructure. Consequently, the European Green Deal broadens the concept of energy security beyond the security of energy supply to encompass technological and industrial security (European Commission, 2019; IEA, 2023).

A decisive turning point in European Union energy policy occurred in 2022 with the adoption of the REPowerEU Plan, introduced in response to Russia's military aggression against Ukraine and the substantial reduction in Russian fossil fuel supplies. REPowerEU aims to reduce the European Union's dependence on Russian energy resources as rapidly as possible while simultaneously accelerating the transition towards a climate-neutral energy system. The plan is based on three mutually reinforcing pillars: energy conservation and energy efficiency, the diversification of suppliers and transport routes, and the accelerated deployment of renewable energy sources. This strategy clearly demonstrates that energy security and climate policy are no longer regarded as competing priorities but rather as complementary objectives that reinforce one another (European Commission, 2022; European Parliament, 2023).

The implementation of REPowerEU has also significantly reshaped the European Union's understanding of energy independence. Whereas previous policy primarily focused on security of supply and market efficiency, since 2022 increasing emphasis has been placed on the concept of strategic autonomy. This approach seeks to reduce the capacity of external suppliers to influence the European Union's political and economic decision-making while simultaneously strengthening domestic energy production, electricity and gas interconnectivity, the development of critical technologies, and industrial capacity. This evolution reflects a fundamental transformation of EU energy policy, in which energy security has become increasingly associated with economic security, industrial competitiveness, and geopolitical resilience (European Commission, 2023; IEA, 2023).

At the same time, the European Union continues to strengthen the integration of its internal energy market, recognising it as one of the most effective instruments for enhancing energy security. The expansion of electricity and natural gas interconnections, the application of common market rules, increased cross-border transmission capacity, and the coordinated operation of transmission system operators all contribute to reducing the risk of supply disruptions and improving the flexibility of the European energy system. Empirical research indicates that more closely integrated energy markets are better able to absorb supply shocks and mitigate the impact of price volatility on consumers. Consequently, market integration serves not only the objective of economic efficiency but also the broader goal of strengthening energy security (ENTSO-E, 2023; ACER, 2023).

Contemporary European Union energy policy also places increasing emphasis on energy system resilience (Monie et al., 2025). Alongside traditional risks associated with energy supply, growing attention is devoted to cybersecurity threats, the impacts of climate change on energy infrastructure, the availability of critical raw materials, and the resilience of energy supply chains (Tvaronavičienė et al., 2025). This reflects the understanding that ensuring energy security requires not only effective crisis response but also the development of energy systems capable of anticipating risks, adapting to changing circumstances, and rapidly recovering

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from disruptions. These principles are being progressively incorporated into the European Union's legal framework governing critical infrastructure protection, cybersecurity, and the security of energy networks (European Commission, 2023; IEA, 2023).

In summary, energy security has become one of the fundamental principles underpinning the European Union's long-term development strategy. The Energy Union, the European Green Deal, and the REPowerEU Plan together constitute a coherent and mutually reinforcing policy framework aimed at simultaneously ensuring a secure, sustainable, and competitive European energy system. The contemporary EU approach demonstrates that energy security can no longer be understood solely in terms of the availability of fossil fuels. Rather, it encompasses the resilience of energy systems, technological innovation, the achievement of climate objectives, the protection of critical infrastructure, and the strengthening of the European Union's strategic autonomy.

Conclusion

The theoretical analysis conducted in this study confirms that energy security is a multidimensional concept whose scope has expanded substantially over recent decades. The traditional approach, primarily concerned with the availability of energy resources and the continuity of energy supply, has gradually evolved into a systemic perspective in which energy security also encompasses economic stability, the protection of critical energy infrastructure, energy system resilience, sustainable development, and the capacity to adapt to geopolitical and technological challenges.

The analysis of the constituent elements of energy security presented in this study demonstrates that a secure and reliable energy supply constitutes a prerequisite for economic development, societal well-being, and the safeguarding of national security. At the same time, excessive dependence on a limited number of energy suppliers and the use of energy resources as an instrument of foreign policy significantly increase the vulnerability of states. Consequently, the diversification of suppliers, transport routes, and energy sources, together with the expansion of renewable energy sources and improvements in energy efficiency, has become one of the principal long-term instruments for strengthening energy security.

The evolution of European Union energy policy—particularly through the Energy Union, the European Green Deal, and the REPowerEU Plan—demonstrates a fundamental paradigm shift from the traditional concept of security of energy supply towards an integrated approach in which energy security is intrinsically linked to climate policy, economic resilience, the protection of critical infrastructure, and the European Union's strategic autonomy. This integrated approach provides the theoretical foundation for the further development of the European Union's legal framework governing energy security and serves as the methodological basis for future analyses of its implementation in the context of armed conflict and other emergency situations.

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INTERSECTIONAL DISCRIMINATION IN THE CONTEXT OF EMPLOYMENT AND SUSTAINABILITY ISSUES: COMPARATIVE ANALYSIS IN EUROPEAN COUNTRIES*

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Abstract. Multiple intersectional discrimination refers to a situation in which multiple grounds operate and interact simultaneously, producing specific forms of discrimination. Multiple intersectional discriminations have, for a long time, caused various issues in employment and have become evident in access to employment, equal pay, and pensions. Moreover, it is an important point for gender equality and is essential to reach sustainable development. This article identifies recent changes regarding intersectional discrimination in the context of labour income and pay transparency, as well as changes in the EU legal framework, and the challenges they pose for European countries. The methodology is based on a literature review, statistical data analysis, legal regulation in EU Member States, and a qualitative study. The results showed an intersectional impact on employment, equal pay, and pensions, with varying degrees of direct impact on levels of structural inequality and on the future lack of sustainable development. Intersectional discrimination from the gender perspective might affect women with a migration background, younger and older women, women with disabilities and women with some religious or origin background. An additional point for raising compensation and sanction levels might lead victims of multiple intersectional discrimination to report it, and encourage pay and promotion law practitioners to challenge it.

Keywords: multiple discrimination; intersectional discrimination; employment; unemployment; gender equality; sustainable development

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JEL Classifications: J14, J16, K31

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1. Introduction

Multiple intersectional discrimination is a frequent phenomenon, as there are different stereotypes regarding personal features or attributes, including gender, ethnic origin, religion, migrant status, culture, age, or a combination thereof, and such discrimination with an intersectional approach can be experienced by various social groups or individuals. The issue of multiple forms of intersectional discrimination is also relevant in the context of sustainable development. For instance, one of the Sustainable Development Goals (hereinafter SDGs) is to achieve gender equality and empower all women and girls: to eliminate all forms of discrimination against women and girls; recognize and value unpaid care and domestic work through the provision of public services,

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infrastructure and social protection policies and the promotion of shared responsibility within the household; to ensure women's full and effective participation and equal opportunities for leadership at all levels of decision-making in political, economic, and public life; undertake reforms to give women equal rights to economic resources; and to adopt and strengthen sound policies at all levels (United Nations General Assembly, 2015). The SDGs and fundamental human rights are linked in pursuit of the common goal of promoting the well-being of all people, and European Union (hereinafter EU) institutions, together with EU Member States, should ensure that the future of the EU's sustainable growth strategy appropriately reflects all established SDGs and their linked targets.

To consolidate the principle of gender equality, the EU Pay Transparency Directive (hereinafter PTD) required EU Member States to bring into force laws, regulations, and administrative provisions by 7 June 2026 (European Union, 2023). In the EU legal framework, the definition of intersectional discrimination was adopted for the first time in PTD. Intersectional discrimination, which is discrimination based on a combination of sex and any other ground or grounds of discrimination protected under Directive 2000/43/EC (European Union, 2000b) or Directive 2000/78/EC (European Union, 2000a). All forms of discrimination, including multiple intersectional discrimination, create barriers to career progression in the context of employment, equal pay, and sustainable development; at the same time, addressing this is a prerequisite for ensuring consolidated and coherent EU Member States' legal systems in line with EU law.

The Gender Equality Strategy 2026-2030 highlights persistent gender inequalities, an intersectional approach in the labour market and calls on EU Member States to ensure the option to request a minimum income to be provided to individual members of the household, because individual benefits can promote gender equality, income security and the economic independence of women (European Union, 2026). The labour market is directly connected with the labour income and pensions in the future. The EU gender pension gap still stands at 25%, contributing to older women being at greater risk of poverty and social exclusion than older men and the largest gaps were recorded in Malta (40.3%), the Netherlands (36.3%) and Austria (35.6%) (Eurostat, 2026). The following situation should be interpreted as intersectional discrimination on the grounds of sex and age. The Eurobarometer surveys indicates that some groups of candidates for employment are still at a disadvantage in the employment process, particularly regarding age (52%) and manner of dress or presentation (50%), the following criteria are each mentioned by at least a third: general physical appearance (44%), disability (43%), being Roma (42%), skin colour (39%), accent (35%) and ethnic origin (34%) (Eurobarometer 535, 2023).

The purpose of this article is to analyse the intersectional discrimination challenges for employment and sustainable development, through statistics to detect unemployment across different social groups, taking into account gender, age, and other possible multiple bases, with the help of a comparison of legal regulations regarding multiple and intersectional discrimination in EU Member States and interviews with experts in the field of labour.

2. Multiple intersectional discrimination challenges in employment to reach sustainable development: theoretical, statistical and legal background

2.1 Theoretical approach by the scholars

Howard (2026) indicates that the Horizontal Equal Treatment Directive should be adopted as soon as possible to protect persons across the EU against discrimination on the grounds of religion or belief, disability, age, and sexual orientation outside the employment sphere, a protection currently lacking. Furthermore, the adoption of the Horizontal Equal Treatment Directive would increase the protection against discrimination on the grounds of religion or belief, disability, age and sexual orientation as well as against multiple and intersectional discrimination (Howard, 2026). Howard argued that the judgment of the Court of Justice of the EU (hereinafter CJEU) in the *David L. Parris v Trinity College Dublin and Others* case needs to be revisited to recognise that intersectional discrimination is covered by the EU anti-discrimination Directives (Howard, 2024).

The fact that the victims of multiple intersectional discrimination might be left without a remedy when they experienced discrimination on a combination of the different discrimination grounds. Additionally, Xenidis argues that the CJEU operates a functional differentiation in the implementation of anti-discrimination norms,

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which gives rise to a complex interpretation architecture and acknowledges three main functions: calibration, integrity, and socialisation (Xenidis, 2021).

In particular, the strength of intersectionality's theoretical foundations for explaining privilege and disadvantage remains stronger than its empirical and practical uses for informing transformational change and social justice (Rodriguez et al., 2024). Therefore, it is important to analyse critical intersectional approaches to understanding and addressing systemic inequalities in the labour market, highlighting theoretical and epistemological gaps that must be addressed to advance emancipatory practices and policies that directly confront structural racism, patriarchy, and class-based exploitation (Sott et al., 2026). Furthermore, income inequality in the EU is at an all-time high (Frese, 2022).

It became evident that the EU anti-discrimination law's starting point is the economic significance of equal pay provisions. While intersectional discrimination is now recognized with PTD, it is a challenge as the EU equality framework functions from a single-issue approach (Dube, 2024) Moreover, the gender pay gap remains a significant European social issue despite the legal efforts to address it (Ambrazevičiūtė, 2024). The fact that multiple intersectional discriminations directly affect economic inequality and are about structural inequalities in society, with limited possibilities and outcomes and pay, pension or access to employment, may cause or have a direct impact on levels of economic inequality. Economic inequalities from the labour-income and time perspectives might create obstacles to achieving sustainable development. Sustainable development is deeply embedded in the EU legislation.

2.2 EU data with the intersectional discrimination approach

Sustainable development is deeply embedded in the EU legal framework and firmly enshrined in EU law, and there is simply no sustainability without social sustainability. Statistical data clearly show that some social groups might be at risk of experiencing multiple intersectional discrimination. Moreover, statistical data on groups at risk of multiple intersectional discrimination are instrumental for assessing their vulnerable situation and for adopting effective policies (Zamfir, 2025).

Eurostat labour force survey data on barriers to employment show a 10% gap between the numbers of women and men who experience discrimination due to their foreign origin (Figure 1). Some women are structurally underrepresented in the labour market, often resulting from the intersection of gender with additional conditions of vulnerability or marginalisation, such as belonging to an ethnic or religious minority or having a migrant background. Furthermore, evidence of discrimination with a multiple and intersectional approach was found among Black people of African descent. It was indicated that the prevalence of discrimination against people of African descent was especially high among those who were perceived as wearing religious clothing in public or those who self-identified as belonging to a minority in terms of disability, gender identity or gender expression, and sexual orientation (European Union Agency for Fundamental Rights, 2024).

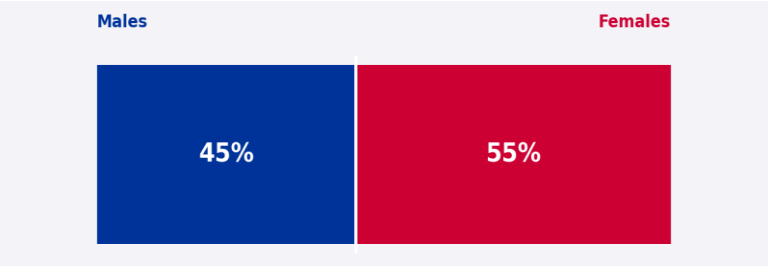


Figure 1. The foreign-born population is experiencing difficulty in getting a suitable job due to discrimination based on foreign origin, by sex
Source: Eurostat (Labour Force Survey) 2021

Stereotypes and gender roles, according to tradition, a lack of support for balancing care responsibilities for children with work, and political and corporate cultures are among the reasons why women are underrepresented in decision-making processes (European Commission, 2019).Around every third EU citizen of African origin

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with a tertiary education works in an occupation below their level of education (35 % compared with 21 % in the general population), and more than half of non-EU citizens of African descent do so (57 % compared with 40 % in the general population) (European Union Agency for Fundamental Rights, 2024).

Statistical data on income and living conditions (Figure 2) show that elderly women are at a higher risk of poverty or social exclusion than men, and income is more closely connected to employment. Furthermore, young women are experiencing the highest risk in general. It should be noted that the PTD recital specified that women with disabilities, women of diverse racial and ethnic origins, including Roma women, and young or elderly women are among the groups which may face intersectional discrimination (European Union, 2023).

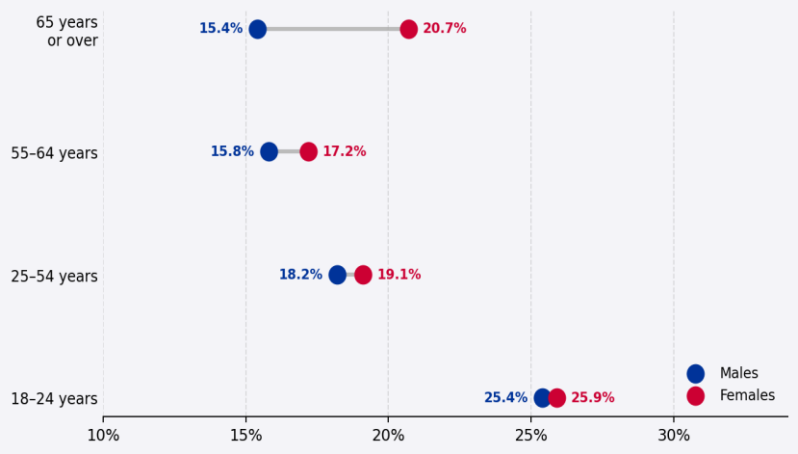


Figure 2. Persons at risk of poverty or social exclusion, by age and sex
Source: Eurostat (Income and Living Conditions) 2024

Many indicators that highlight a situation of vulnerability, such as poverty, unemployment, education level, or housing access, are insufficiently disaggregated by protected characteristics (Zamfir, 2025). Statistical data on the unemployment rate by sex and age across all 27 EU Member States shows the gender gap in unemployment. Young women have the highest unemployment rate compared to older men. It should be noted that young women are at risk compared to older women. Young men are at nearly the same percentage level as older women (Figure 3).

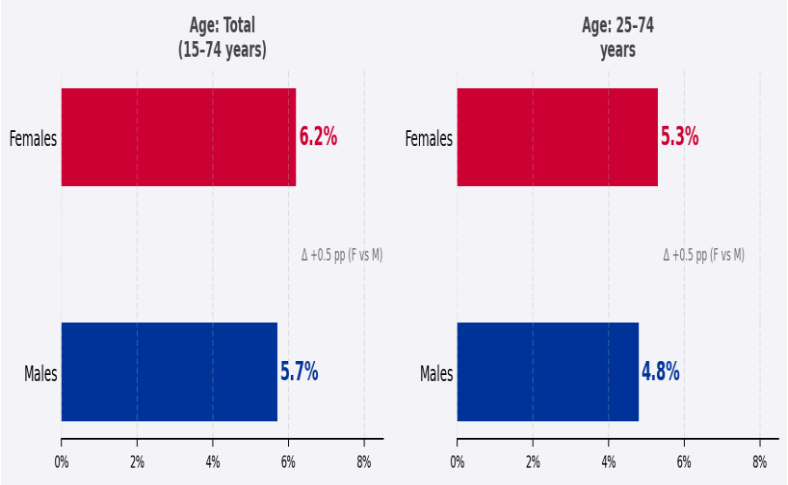


Figure 3. Unemployment rate by sex & age group, EU27, seasonally adjusted May 2026
Source: Eurostat (Labour Force Survey) 2026.

Employment security is a very important factor that influences not only well-being, but also the risk of being in poverty. The EU Charter of Fundamental Rights states that every citizen of the EU has the freedom to seek

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employment, to work, to exercise the right of establishment and to provide services in any EU Member State (European Union, 2012).

The EU unemployment rate statistics show that there hasn't been much change across all 27 EU Member States during the 2026 five-month period; it has remained stable (Figure 4).

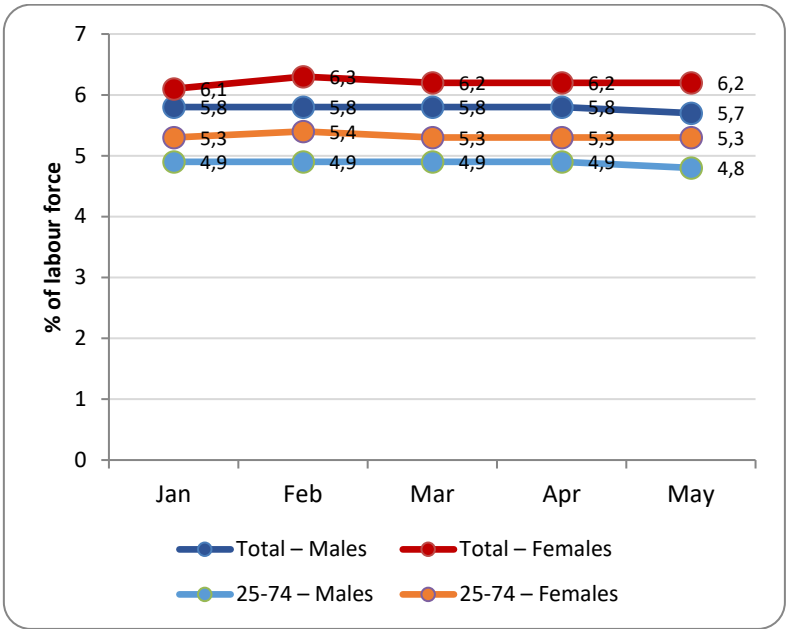


Figure 4. EU unemployment rate trends, EU27 seasonally adjusted January–May 2026
Source: Eurostat (Labour Force Survey) 2026.

Data on experiences of multiple intersectional discrimination are also important for emphasising differences between different social groups. Eurostat data about experiences of multiple intersectional discrimination are also useful for acknowledging differences between groups in society. Various data analyses show that discrimination based on multiple grounds, such as sex, racial or ethnic origin, religion or belief, disability, age and sexual orientation, persists across the EU Member States.

2.3 Legal regulation tackling multiple intersectional discrimination in EU Member states

It should be noted that just a few EU Member States have adopted legal provisions addressing either multiple or intersectional discrimination. Of the 27 EU Member States, 12 countries ban multiple or intersectional discrimination in their antidiscrimination law: Austria, Belgium, Bulgaria, Croatia, Germany, Greece, Ireland, Malta, Portugal, Romania, Slovenia, and Spain. The other 15 countries do not ban multiple or intersectional discrimination clearly in their anti-discrimination law: Cyprus, Czechia, Denmark, Estonia, Finland, France, Hungary, Italy, Lithuania, Luxembourg, Latvia, the Netherlands, Poland, Slovakia, and Sweden (see Table 1 below).

Table 1. EU Member States legal regulation on multiple or intersectional discrimination

EU Member State	Legal regulation
Austria	Multiple discrimination must be considered when assessing the number of immaterial damages.
Belgium	Both cumulative and intersectional discrimination are widely prohibited. Furthermore, the amended legislation stipulates that the courts may increase the compensation awarded in such cases by cumulating the lump-sum amounts of damages provided for by national law for the violations based on different grounds, individually.
Bulgaria	Multiple discrimination is discrimination based on more than one protected ground.
Croatia	More serious forms of discrimination include discrimination against a person on more than one ground.
Germany	A differential treatment based on several grounds has to be justified with respect to each one of these grounds separately.
Greece	Multiple discrimination associates the grounds of racial or ethnic origin, colour, nationality, ancestry and territory of origin.

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Ireland	Discriminatory practice includes a practice based on one or more prohibited grounds of discrimination, or on the effect of a combination of prohibited grounds
Malta	Multiple and intersectional discrimination in the case of persons with disabilities, without providing a definition
Portugal	Multiple discrimination associates the grounds of racial or ethnic origin, colour, nationality, ancestry and territory of origin.
Romania	Any distinction, exclusion, restriction or preference based on two or more of the criteria shall constitute an aggravating circumstance in establishing responsibility for a minor offence.
Slovenia	Multiple discrimination occurs when a person is discriminated against simultaneously due to several personal circumstances.
Spain	Multiple discrimination associates the grounds of racial or ethnic origin, colour, nationality, ancestry and territory of origin.

Source: European Commission. A comparative analysis of non-discrimination law in Europe 2024.

EU Member States should use a comprehensive set of equality data-collection tools, including large-scale quantitative surveys covering different population groups and grounds of discrimination, alongside discrimination testing, an established method for generating objective evidence of discrimination (European Union Agency for Fundamental Rights, 2022). In practice, all existing national legal regulations have had limited with the practical effect, and court practice remains very insufficient. Furthermore, in the reported cases, neither the courts nor the equality bodies have followed a specific approach to the comparator, and the multitude of grounds does not generally affect the amounts of compensation awarded.

3. Research objective and methodology

The purpose of this article was to identify the multiple intersectional discrimination impact on employment and challenges to sustainable development. The analysis of statistical data and legal regulation in EU Member States revealed general trends regarding multiple intersectional discrimination in employment. Statistical data alone is insufficient to gain deeper insights reflecting the impact of multiple intersectional discrimination in the actual employment situation. A qualitative study was conducted to reveal multiple intersectional forms of discrimination, with a comparative focus on labour income, employment opportunities, work, and independence circumstances, legal and practical challenges. Semi-structured interviews were conducted with the experts in the field of employment. Key research questions are provided below in Table 2. The chosen 19 experts were from the fields of employment services, employee representatives, and employers in Denmark (3), Germany (4), Lithuania (4), Spain (4), Sweden (2), and Switzerland (2). No personal data was collected during the interviews.

Table 2. Key research questions

Research field	Questions for experts
Employment opportunities	Has your organisation previously conducted any assessments on a possible intersectional approach to gender equality? Have any gender gaps been identified within your organisation? Please identify these gaps. Which social groups of women with multiple intersections do you think face difficulties in seeking employment? How should gender equality, with a possible intersectional approach, be ensured in recruitment?
Labour income	What factors from the multiple intersectional discrimination approach can influence the gender pay gap?
Employment and independence circumstances	Does your organisation support work-life balance and organisational culture? How should gender equality be ensured in career advancement? How to ensure gender balance in management and decision-making, taking into account possible multiple or intersectional discrimination?
Legal and practical challenges	How do you assess the prohibition of multiple intersectional discrimination in national and EU legal regulation? What gender equality measures do you think would be effective?

Source: created by the author

The research data were collected in accordance with methodological guidelines for conducting qualitative research and ethical principles (Žydžiūnaitė & Sabaliauskas, 2017). Confidentiality was maintained throughout the research. To ensure the accuracy of the research data, interviews were recorded and subsequently transcribed verbatim. After the audio material had been transcribed, the recordings were deleted to ensure data

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anonymisation. Data analysis was performed using MAXQDA software. The transcribed data collected during the study were read, and codes were assigned to significant information. After reviewing the codes, they were categorised into groups based on meaning.

4. Results and discussion

The vast majority of experts who participated in the study found that, in employment opportunities, organisations did not conduct assessments with regard to an intersectional approach, and there is insufficient attention from employers. From the gender pay gap perspective, experts indicated gender pay transparency, pay discrimination, care-related career breaks, such as child rearing or eldercare, involving an intersectional discrimination approach in hiring or returning to the workplace after the break. Gender equality, with a possible intersectional approach, should be ensured in recruitment with the paid attention to possible multiple intersectional inequalities and part-time work. Social groups of women from an ethnic or religious minority, having a migrant background or being disabled might meet difficulties in seeking employment.

Labour income, according to experts, might be influenced by unequal treatment regarding gender, such as structural segregation, complicated career development and the glass ceiling as an invisible barrier that prevents quite qualified individuals, particularly women and persons from minorities, from advancing to top executive roles within an organisation. Employment and independence should be supported by time-limited breaks, gender equality, and the promotion of career development for persons who might be affected, using an intersectional approach.

The results of the interviews with experts also reveal legal and practical challenges caused by a lack of clear legal regulation in national law and the EU legal framework, leading to insufficient attention from public authorities and courts. The multiple intersectional inequalities were affected by the lack of visibility and data, as well as by the lack of positive actions. In summary, the study revealed various social and economic factors that shape the intersectional approach to employment in relation to sustainability issues (see Figure 5). According to experts, PTD provides sufficient and effective protection through intersectional approaches to pay transparency and employment issues.



Figure 5. Essential intersectional discrimination challenges for employment and sustainable development
Source: created by the author

PTD provided that EU Member States shall ensure that the tasks of the monitoring body, including addressing intersectional discrimination in relation to equal pay for equal work or work of equal value, and this applies to obtaining gender related pay data from individual employers in the future, with different sources of gender equality data involving other vectors and grounds of discrimination it should be the effective instrument to indicate the intersectional approach. PTD enables national courts, equality bodies and other competent authorities to take due account of any situation of disadvantage arising from intersectional discrimination, in particular for substantive and procedural purposes, including to recognise the existence of discrimination, to decide on the appropriate comparator, to assess the proportionality and to determine, where relevant, the level of compensation awarded or penalties imposed. It should be noted that the collected data and positive actions might help combat multiple intersectional discrimination.

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Conclusions

An intersectoral approach is important not only for ensuring gender equality but also for sustainable development. Theoretical, statistical, legal and expert-based analyses indicated that multiple intersectional forms of discrimination have long-term consequences for employment. Furthermore, it is important not only for unemployment but also for labour income and pay transparency. Females face part-time work, care-related career breaks (maternity or other), poverty-influenced occupational segregation, and the glass ceiling, resulting in long-term consequences and affecting pay transparency and labour income, with implications for pensions.

Unemployment and reduced labour income of female constructs economic inequality as a structural inequality in society, with the lack of opportunities and outcomes to realise gender equality and sustainable development. PTD enforcement created an opportunity for EU Member States to update their national legal frameworks with a multi-intersectional approach to forms of discrimination. Moreover, pay transparency, with the potential recognition of intersectional discrimination, may affect labour income in future perspectives.

The substantial issue of intersectional discrimination influences access to employment, equal pay, and pensions, with varying degrees of direct impact on levels of structural and economic inequality, and the lack of sustainable development in the future. Furthermore, intersectional discrimination lacks visibility and receives insufficient attention from employers, public authorities, and courts. Frequent issues for women due to structural underrepresentation in the labour market are often connected to the intersection of gender with additional factors and grounds, such as belonging to an ethnic or religious minority, having a migrant background or being disabled.

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TOWARDS THE INNOVATIVE LOGISTICS MANAGEMENT SYSTEM IN THE AGRO-INDUSTRIAL COMPLEX OF THE REPUBLIC OF KAZAKHSTAN

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Abstract. This article investigates the impact of the structural transformation of agricultural enterprises on the development of an innovative logistics management system in the agro-industrial complex of the Republic of Kazakhstan. It explores the characteristics of the formation and evolution of agrarian relations, which serve as the main factors shaping the modern logistics management system in the agro-industrial complex. An analysis is conducted of indicators of structural transformation in the agricultural sector, including trends in the number of agricultural cooperatives, households, individual entrepreneurs, and peasant (farmer) farms, as well as the number of people employed in various forms of agricultural activity. The study examines the dynamics of organisational and legal forms of economic activity in the agricultural sector and the structure of employment among the rural population of the Republic of Kazakhstan by type of economic activity for the year 2025. Practical results of Kazakhstan's agrologistics development are presented. Based on the analysis, a model of an innovative logistics management chain in the agricultural sector of the Republic of Kazakhstan is proposed, taking into account the conditions of structural transformation of agricultural enterprises. A mechanism for developing an innovative logistics management system has been devised to increase the efficiency of agricultural production and integrate cooperative forms of economic activity into unified logistics chains. The results obtained can be used to formulate strategies for the sustainable development of the agricultural sector and to improve the management of logistics processes in the agro-industrial complex.

Keywords: logistics management; innovative system; agro-industrial complex; farms; cooperatives; agricultural companies; logistics centers

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JEL Classifications: Q13, Q16, L14, M11

1. Introduction

In recent years, the agro-industrial complex of the Republic of Kazakhstan has undergone a significant structural transformation, driven by changes in organisational and legal forms of business, the strengthening of cooperative processes, and the introduction of innovative approaches to the management of agricultural production. These changes are creating new operating conditions for agricultural enterprises and require a reevaluation of traditional approaches to organising logistics processes in the agricultural sector (Tleubayeva et al., 2023).

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The structural transformation of agriculture is reflected in changes in the balance between various forms of agricultural production, including agricultural cooperatives, peasant (farmer) households, individual entrepreneurs, and private subsistence farms. These processes are accompanied by changes in the employment structure of the rural population, a redistribution of resources, and a strengthening of the role of small and medium-sized agribusinesses. Under these conditions, effective logistical coordination becomes increasingly important, ensuring the sustainability of production and distribution chains and enhancing the competitiveness of agricultural products (Nurzhanova et al., 2024).

Despite the active development of the agricultural sector, systemic problems persist, including insufficient integration among participants in logistics chains, limited digitalisation, and the fragmented nature of the agricultural market's infrastructure. These factors reduce the efficiency of interactions among producers, processors, and end consumers, calling for the creation of an innovative logistics management system adapted to the current conditions of the agribusiness sector's development (Kafi et al., 2025).

The relevance of this study stems from the need to scientifically substantiate the mechanisms underlying the development of logistics management in the context of the structural transformation of agricultural enterprises. Of particular importance is the development of a model for an innovative logistics management chain that ensures alignment of interests among participants in the agri-food market and enhances the efficient use of agriculture's resource potential.

The purpose of this study is to analyse the impact of structural transformation in agricultural enterprises on the development of an innovative logistics management system within the agro-industrial complex of the Republic of Kazakhstan and to develop an appropriate model to improve it.

2. Literature review and hypotheses' development

In the academic literature, issues related to the development of the agro-industrial complex and the improvement of logistics management are examined in the context of enhancing supply chain efficiency, promoting the sustainable development of rural areas, and implementing innovative management technologies. International studies emphasise the role of integrated logistics systems in ensuring food security and reducing transaction costs in the agricultural sector (Nurzhanova et al., 2023; Omarbakiyev et al., 2023). In particular, it is emphasised that the development of cooperative business models and the digitalisation of agri-food supply chains are key to enhancing agricultural competitiveness (Pashkevich, 2021).

Studies on logistics in the agricultural sector note a shift from linear supply chain management models to network- and platform-based models founded on the principles of flexibility, sustainability, and transparency (Nuansri et al., 2023). Particular attention is paid to the concept of "smart supply chains," which use digital technologies, big data, and monitoring systems to optimise the flow of products and resources (Wang et al., 2024).

Research on the agricultural economy of the Republic of Kazakhstan examines the processes of institutional transformation associated with the development of agricultural cooperatives, family farms, and individual entrepreneurship. Scholars note that the structural transformation of the agricultural sector has a significant impact on employment, the organisation of production, and the formation of new logistical links (Sahu et al., 2023). However, existing studies do not systematically link structural changes in agriculture to the development of innovative logistics systems (Oruç & Çağlar, 2022), thereby identifying a research gap for this study.

Thus, a review of the literature demonstrates the need for a comprehensive approach to studying the relationship between the structural transformation of agricultural enterprises and the development of innovative logistics management in the agro-industrial complex.

The main hypothesis of this study is that the structural transformation of agricultural enterprises in the Republic of Kazakhstan is the primary factor driving the formation and development of an innovative logistics

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management system in the agro-industrial complex, thereby ensuring greater efficiency in agri-food supply chains.

Specific hypotheses of the study:
1. An increase in the share of cooperative and farm-based business models contributes to greater integration among participants in agricultural supply chains.
2. Changes in the employment structure of the rural population have a significant impact on the organisation and efficiency of logistics processes in the agricultural sector.
3. The development of innovative logistics infrastructure (digital platforms, coordination centres, information systems) enhances the resilience of agri-food supply chains.
4. The development of an innovative logistics management model helps reduce transaction costs and increase the competitiveness of agricultural products from the Republic of Kazakhstan (Nurzhanova, 2026).

3. Research objective and methodology

The purpose of this study is to analyse the impact of structural transformation in agricultural enterprises on the formation and development of an innovative logistics management system in the agro-industrial complex of the Republic of Kazakhstan, as well as to develop a model of an innovative logistics management chain and a mechanism for improving the efficiency of agricultural logistics processes in the context of institutional changes.

The methodological foundation of the study comprises general scientific and specialised methods of economic analysis, the systems approach, and logistics modelling, which enable the agro-industrial complex to be viewed as a multilevel, complex socioeconomic system.

The following methods were used in the course of the study:
System analysis - to examine the interrelationships between the structural transformation of agricultural enterprises and the development of logistics processes in the agro-industrial complex.
Comparative analysis - to assess trends in organisational and legal forms of business (cooperatives, farms, sole proprietorships, and household farms).
Statistical analysis - to process data on the number of agricultural enterprises and the employment structure of the rural population of the Republic of Kazakhstan for the year 2025.
Structural-functional approach - to identify the role of individual elements of the agricultural system in the formation of logistics chains.
Modelling - to develop a model of the innovative logistics management chain in the agro-industrial complex of the Republic of Kazakhstan amid structural transformation.
Induction and deduction - to generalise the obtained results and formulate theoretical conclusions.

The research's information base consisted of statistical data, analytical materials on the development of the agricultural sector in the Republic of Kazakhstan, and scientific publications by domestic and foreign authors on logistics management and agricultural economics.

The application of these methods made it possible to identify patterns in the transformation of agricultural enterprises and to substantiate directions for improving the innovative logistics management system in the agro-industrial complex.

4. Research results

Currently, research into the formation and development of agrarian relations, the causes of the crisis in agricultural production, and the innovation process in relation to logistics management, taking into account regional and sectoral characteristics, remains in high demand.

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The continued development of private subsistence farms in Kazakhstan contributes to improved logistics management efficiency; however, ongoing integration processes in the agricultural sector should be taken into account (Akimbekova, 2023).

One must agree with the scholars' view that the restoration of economic relations during the transition to a market economy is linked to the formation of various types of organisational management structures and the transition of enterprises and organisations within the agro-industrial complex to full self-sufficiency and self-financing in regional agricultural enterprises (Belloc et al., 2024).

During the process of denationalisation and privatisation, cooperative ownership was drastically reduced. Accelerated reforms involving the forced bankruptcy of cooperatives and the creation of partnerships based on them did not increase the cooperatives' operational efficiency. Addressing this issue remains a priority, as cooperation is a necessary condition for the development of farms (peasant farms) in logistics management (Ofori et al., 2024).

An analysis of trends in the structural transformation of agricultural enterprises in the Republic of Kazakhstan (Table 1) reveals sustained structural transformation in the agricultural sector. According to statistics, between 2023 and 2025, the number of active agricultural cooperatives increased from 3,911 to 4,800, indicating an expansion of cooperative forms of economic activity.

At the same time, there has been an increase in the number of households, from 21,669 to 22,323; individual entrepreneurs and peasant (farmer) households, from 17,300 to 18,122; and legal entities, from 398 to 433. This trend reflects the diversification of the organisational and legal structure of agricultural production and the formation of a more complex system of interaction among agribusiness entities (Table 1).

Table 1. Indicators of structural transformation of agricultural enterprises in the Republic of Kazakhstan

Indicator	2023	2025 vs 2023 (Quantity)	2025
Number of active agricultural cooperatives, Republic of Kazakhstan	3 911	+889	4 800
Households	21 669	+654	22 323
Self-employed individuals and family farms	17 300	+822	18 122
Legal Entities	398	+35	433
Number of employees at the agricultural cooperative	7 490	+86	7 576
Number of employees of the agricultural cooperative who are employed on a part-time basis (by other organisations)	211	+296	507
Number of employees of an agricultural cooperative who perform work under civil law contracts (CLCs)	542	-44	498

Source: Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan (n.d). Statistics on Agriculture, Hunting, Forestry, and Fisheries for 2023-2025.

From the perspective of developing an innovative logistics management system in the agro-industrial complex, these changes have both positive and negative consequences. Among the positive aspects is the strengthening of cooperative processes in agriculture. The increase in the number of agricultural cooperatives contributes to consolidating resources and developing shared infrastructure for the storage, transportation, and processing of products. Cooperation allows small and medium-sized producers to pool their production volumes, reduce logistics costs, and improve the efficiency of using innovative digital supply chain management technologies (Croitoru et al., 2021). In addition, the consolidation of economic ties creates the conditions for implementing modern information systems for monitoring cargo flows, product traceability, and automating warehouse processes.

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The growth in the number of smallholder (farmer) operations and individual entrepreneurs also indicates the development of entrepreneurial activity in the agricultural sector. This contributes to increased competition, stimulates the search for new logistics solutions, and creates demand for innovative services in transportation, storage, and the sale of agricultural products (Shen et al., 2023). Another positive factor is the increase in the number of employees at agricultural cooperatives, from 7,490 to 7,576. Expanding human resource capacity creates the conditions for adopting digital technologies, improving professional competencies in logistics management, and developing the human capital necessary to modernise the agro-industrial complex.

At the same time, this structural transformation is accompanied by some challenges. A significant increase in the number of small-scale agricultural producers leads to fragmented production and complicates the development of efficient logistics chains. The small production volumes of individual farms limit the ability to implement costly innovative technologies, automated warehouse complexes, and digital supply chain management platforms. As a result, transaction costs rise, and the efficiency of logistical coordination among market participants declines (Myssirov et al., 2023). An additional challenge is the lack of integration among producers, processing plants, and logistics operators. Despite the growing number of cooperatives, many entities continue to operate in isolation, hindering the creation of a unified logistics ecosystem and slowing the industry's digital transformation (Nursultanova 2026).

The change in the structure of employment deserves special attention. The number of workers employed under civil law contracts decreased from 542 to 498, suggesting a decline in the flexibility of labour resource utilisation. At the same time, the number of part-time workers increased significantly—from 211 to 507. This trend may indicate a shortage of skilled workers in agriculture and the need to improve the effectiveness of the training system for specialists in agricultural logistics and digital management.

Thus, the structural transformation of Kazakhstan's agricultural enterprises has a multifaceted impact on the development of an innovative logistics management system in the agri-food sector. On the one hand, the growth of cooperation, entrepreneurial activity, and human resource capacity creates conditions for the adoption of innovative logistics technologies. On the other hand, persistent fragmentation of production, insufficient integration among participants in agri-food supply chains, and human resource constraints hinder the formation of an effective innovative logistics system (Nurzhanova, 2026). In this regard, the further development of the agro-industrial complex should focus on strengthening cooperative ties, digitising logistics processes, and creating a unified infrastructure to manage agricultural supply chains.

The data in Table 2 indicate ongoing structural transformation in the agricultural sector of the Republic of Kazakhstan. Between 2021 and 2025, quantitative changes were observed in the composition of various categories of agricultural entities, reflecting the adaptation of agricultural production to modern economic conditions and the need to improve the efficiency of agri-food chain management.

Table 2. Trends in the Development of Organisational and Legal Forms of Business in Kazakhstan's Agricultural Sector

Years	Farm households	Households, in thousands	State-Owned Enterprises	Non-state-owned enterprises
2021	216 715	1416	35	5748
2022	224 231	1445	37	5701
2023	245 987	1512	35	5694
2024	276 411	1643	38	5689
2025	277 321	1509	39	5769
2025 compared to 2021, %	+27,97	+6,57	+11,43	+0,37

Source: Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan (n.d). Statistics on Agriculture, Hunting, Forestry, and Fisheries for 2021-2025

As shown in Table 2, smallholder (farmer) farms experienced the most significant growth during the period under review, with the number increasing from 216,715 to 277,321, a 27.97% increase. This trend indicates the growing role of small and medium-sized agricultural enterprises in the country's economy. The expansion of

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the farming sector contributes to greater flexibility in agricultural production, fosters a competitive environment, and stimulates the search for new organisational and economic solutions in logistics and product distribution.

The number of household farms increased from 1,416 to 1,509 thousand units during the period under review, representing a 6.57% increase. The growth of this indicator confirms that private subsistence farms continue to play a significant role in ensuring food security and forming the raw material base for the agro-industrial complex. However, the high share of small-scale commercial production simultaneously creates additional challenges for organising centralised logistics processes, including the collection, storage, transportation, and sale of agricultural products.

The number of state-owned enterprises increased from 35 to 39, a 11.43% increase. Despite their relatively small share in the overall structure of the agricultural sector, state-owned enterprises continue to perform important functions in ensuring the sustainability of specific areas of agricultural production, developing infrastructure, and implementing strategic programs to support the agro-industrial complex. The number of non-state-owned enterprises changed only slightly—from 5,748 to 5,769, representing an increase of just 0.37%. The virtually stable value of this indicator suggests that this market segment has reached a certain level of saturation and that the focus has shifted from quantitative growth to improving the efficiency of existing enterprises.

From the perspective of developing an innovative logistics management system, the identified changes are twofold. On the one hand, the increase in the number of farms contributes to the expansion of the agricultural sector's production base and the emergence of new commodity flows, creating conditions for implementing digital supply chain management platforms, product traceability technologies, and modern logistics services. On the other hand, the growth in the number of small-scale producers leads to the fragmentation of the agricultural market, complicates the coordination of logistics operations, and increases transaction costs at all stages of product movement from the producer to the end consumer.

Based on this analysis, the structural transformation of agricultural entities in the Republic of Kazakhstan is characterised by the strengthening of the farming sector and the continued significant role of household farms. Under these conditions, an important direction for the development of an innovative logistics management system is the integration of scattered producers into cooperative and digital logistics networks, which ensure greater efficiency in the functioning of the agro-industrial complex. The highest-priority type of small business in agriculture is smallholder (farmer) farms, the number of which is steadily increasing. It should be noted that the growth of smallholder (farmer) farms is contributing to a decline in the registered unemployment rate in rural areas (Roldan et al., 2023). Table 3 presents data on the employment of Kazakhstan’s rural population by region, reflecting differences in the nature and form of employment.

Table 3. Employment of Kazakhstan’s rural population by type of work for 2025, in persons

Region Name	Employment at the organisation	Sole proprietors	Employment on a Farm	In a personal home garden
Republic of Kazakhstan	1 703 624	771 116	218 386	322 853
Abai	60 053	43 832	2 238	11 060
Akmola	106 994	20 425	8 055	35 476
Aktobe	76 408	7 6138	8 155	16 014
Almaty	177 475	150 982	33 697	23 536
Atyrau	111 823	16 710	2 460	1 850
West Kazakhstan	61 608	31 153	8 317	25 455
Jambyl	134 903	91 374	24 060	31 275
Zhetisu	104 730	30 516	5 552	16 139
Karaganda	70 707	6 788	6 931	8 370
Kostanay	103 775	13 536	9 844	34 304

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Kyzylorda	81 799	68 514	12 036	2 725
Mangystau	160 246	6 481	1 154	29
Pavlodar	57 110	5 919	9 793	30 395
North Kazakhstan	87 439	17 064	5 081	30 674
Turkestan	214 008	238 176	74 864	35 876
Ulytau	17 471	941	567	3 479
East Kazakhstan	77 075	21 067	5 582	16 196

Source: Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, Industries (n.d)

As shown in Table 3, the Almaty Region has a significant number of salaried employees in organisations, as does the Turkestan Region. The Turkestan Region has 238,176 self-employed individuals, which is more than double the number of wage earners. This may be due to both strong entrepreneurial activity and a shortage of permanent jobs. The situation in the Almaty Region is similar, suggesting a high level of self-employment. In the Atyrau and Mangystau regions, employment in farms and private subsistence farms is extremely low. This is due to the specific nature of the region's economy, which is dominated by the oil and gas industry—an industry that does not require many agricultural workers. In the North Kazakhstan and Kostanay regions, a significant number of people are employed in private subsistence farms—30,674 and 34,304, respectively. This may indicate insufficient agricultural production and limited opportunities for farm development, which calls for more effective support programs for small farms. In the Karaganda and Pavlodar regions, the number of individual entrepreneurs is only 6,788 and 5,919, respectively, which may indicate a lack of entrepreneurial initiative and a higher level of dependence on traditional forms of employment. In the Turkestan region, the high proportion of sole proprietors may indicate growth in small businesses, self-employment, and entrepreneurial initiatives, which are an important component of the region's logistics sector activity. In the Akmola region, 8,055 people are employed on farms, indicating moderate growth in this sector. In the Turkestan Region, the number of such workers is significantly higher—74,864 people. This may suggest that farms play a major role in the region's logistics, possibly due to favourable agricultural conditions. As a result, the Turkestan region significantly outpaces the Akmola region in the number of sole proprietors and farm workers, indicating greater activity in small business and farming. The Akmola Region, in turn, shows more moderate figures in these areas, while maintaining a significant share of workers in organisations and private subsistence farms.

This comparative study reveals that a more diversified and dynamic economy characterises the Turkestan region. In contrast, the Akmola region is more dependent on traditional forms of employment, such as salaried work in organisations and subsistence farming. It should be noted that the structural transformation of agricultural enterprises in the Republic of Kazakhstan is accompanied not only by an increase in the number of farms and cooperatives, but also by the formation of large, integrated agro-industrial structures capable of implementing modern technologies in production, processing, and logistics. Such enterprises serve as key drivers of the development of an innovative logistics management system, as they facilitate the concentration of material flows, the development of logistics infrastructure, and the implementation of digital solutions in supply chains.

A prime example is the “Rodina” agricultural firm, which operates as a limited liability partnership. The farm encompasses three settlements—Rodina, Zeleny Gai, and Sadovoye—and employs more than 520 people out of a total population of approximately 1,800. Annual production volume amounts to approximately 5.2 billion tenge, with livestock products accounting for about 50% of that total. As part of the modernisation of its production activities, the enterprise is actively investing in the development of its material and technical base, including the acquisition of high-tech agricultural machinery and vehicles, the construction of a grain terminal with a capacity of 20,000 metric tons, the establishment of its own dairy processing plant, and the implementation of energy infrastructure projects (Saparova & Sultanova 2020. From the perspective of logistics management development, having one’s own warehousing and transportation infrastructure, processing facilities, and the integration of various stages of the agri-food chain within a single economic system are of

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particular importance. Such vertical integration enables the optimisation of storage, transportation, and distribution processes, reduces logistics costs, and improves the efficiency of material flow management.

Similar processes are observed in the operations of Zenchenko & Company LLP and in large processing enterprises in the dairy, fruit and vegetable, and meat industries. The development of these enterprises demonstrates a transition from traditional forms of agricultural production to more complex, integrated organisational and economic structures, in which logistics has become a key factor in competitiveness. The successful experience of Kazakhstan's leading agro-industrial enterprises confirms that the structural transformation of agricultural enterprises contributes to the formation of a modern, innovative logistics management system through the development of production and logistics infrastructure, the introduction of technological innovations, the integration of supply chain participants, and the improvement of material flow management efficiency.

Practical results of the development of agrologistics in Kazakhstan

Over the past few years, Kazakhstan's agro-industrial sector has demonstrated steady growth in its export potential, accompanied by increasing demand for more efficient logistics infrastructure. Modern agrologistics encompasses not only the transportation of agricultural products but also the management of storage, shipment consolidation, quality control, digital support of supply chains, and the development of export channels.

At present, the total grain storage capacity in Kazakhstan amounts to 15.8 million tonnes**,** including grain elevators and grain receiving facilities. At the same time, projects are being implemented to construct new grain storage facilities and modernise the existing storage infrastructure. These initiatives aim to reduce logistics losses, improve the preservation of agricultural products, and enhance the efficiency of commodity flow management. Despite the substantial grain storage capacity, the development of Kazakhstan's logistics infrastructure remains uneven. The most advanced logistics capabilities are concentrated within large agricultural holdings, which operate their own grain elevators, transport fleets, and processing facilities. At the same time, small agricultural producers often face limited access to modern storage facilities and encounter difficulties in consolidating export shipments and organising efficient product distribution. Under these conditions, the development of agricultural cooperatives, the establishment of distribution centres, and the implementation of digital logistics management technologies become increasingly important. One of the most prominent examples of the development of Kazakhstan's modern agrologistics system is the activity of JSC National Company "Food Contract Corporation"**.** The company plays a key role in coordinating grain flows, managing the state grain reserves, and organising export deliveries. Acting as an integrator of the logistics system, the corporation facilitates cooperation among agricultural producers, grain elevator facilities, transport operators, and international buyers, thereby ensuring the efficient operation of the entire supply chain. During the first half of 2026, the national operator provided KZT 51.6 billion in financing to agricultural producers. Following the fulfilment of forward contracts and the completion of final settlements for delivered agricultural products, the total amount of financial support for farmers is expected to reach KZT 65.7 billion**.**

Under the direct agricultural procurement program, farmers supplied 191.8 thousand tonnes of grain and oilseed crops to the Food Contract Corporation, more than three times the previous year's volume **(**52.9 thousand tonnes**).** The largest share of deliveries came from producers located in Kazakhstan's major grain-producing regions. In total, the national operator received applications from 257 agricultural producers for the supply of wheat, barley, sunflower, and oil flax. Under the signed direct procurement contracts, the national grain operator transferred 20.3 billion tenge to farmers. A total of 172 agricultural enterprises participated in the forward financing program for the 2026 spring field campaign by signing contracts to supply 471 thousand tonnes of grain and oilseed crops. Farms in the Akmola, North Kazakhstan, and Kostanay regions are committed to supplying mainly third-class wheat.

In contrast, producers in the Pavlodar and East Kazakhstan regions focus primarily on sunflower deliveries. In the spring of 2026, the national operator allocated 31.3 billion tenge in advance financing to agricultural producers. Following the harvest and the completion of final settlements, the total financing provided under the program is expected to exceed 40 billion tenge**.** At the same time, the forward financing program encourages

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the expansion of high-value oilseed crop production. While forward contracts for the supply of sunflower, oil flax, and rapeseed totalled 36 thousand tonnes in 2025, this figure nearly tripled to 94.9 thousand tonnes in 2026. Under the terms of the signed contracts, agricultural producers plan to deliver 37.8 thousand tonnes of sunflower seeds**,** 51.5 thousand tonnes of oil flax seeds**,** and 5.6 thousand tonnes of rapeseed after the harvest (Corporate News 2026). Thus, the mechanisms of direct procurement and forward financing perform several strategic functions simultaneously. They provide agricultural producers with essential financial resources while contributing to the formation of the country's strategic food reserves. Through the annual procurement of agricultural products, the Food Contract Corporation replenishes the state grain reserves, establishes feed grain stocks for the livestock and poultry sectors, and maintains grain reserves for flour milling and other processing industries.

Another example of the implementation of modern logistics solutions is the modernisation of grain storage facilities operated by the Food Contract Corporation. In 2024, the volume of grain received at the corporation's grain storage facilities reached 411.7 thousand tonnes**,** nearly doubling the level recorded in the previous year. During the same period, grain shipments increased to 346.4 thousand tonnes**,** representing almost 18% **growth,** while the maximum simultaneous storage capacity reached 288.6 thousand tonnes**.** These indicators demonstrate improvements in the efficiency of the country's storage and logistics infrastructure. At the same time, modern digital technologies for logistics management are being introduced at the corporation's storage facilities. These include automated grain temperature-monitoring systems, video surveillance, digital quality-control tools, and automated warehouse-management technologies. The implementation of these solutions helps minimise storage losses, accelerate cargo handling, and improve the transparency and efficiency of material flow management throughout the logistics chain.

The obtained results indicate a gradual transformation of Kazakhstan's agrologistics, with traditional approaches to agricultural product storage being progressively replaced by digital supply chain management systems. This transformation is based on continuous monitoring of product quality, the automation of logistics processes, and the integration of information technologies into warehouse operations, thereby improving the efficiency of material flow management throughout the supply chain (Table 4).

Table 4. Practical results of agrologistics development in Kazakhstan for 2024–2025

Indicator	Food Contract Corporation	Grain storage facilities
Grain sales	1.3 million tonnes	411.7 thousand tonnes received
Export destinations	12 countries	Regional logistics
Storage	State grain reserve	288.6 thousand tonnes
Logistics innovations	Consolidation of export consignments	Digital temperature monitoring, warehouse automation
Practical impact	Growth in exports and supply chain resilience	Reduced storage losses and improved storage efficiency

Source: Compiled by the author based on data from the Ministry of Agriculture of the Republic of Kazakhstan and JSC National Company "Food Contract Corporation" (n.d)

The results indicate a gradual transition in Kazakhstan's agrologistics from a traditional transportation and storage model to integrated supply chain management. Further improvements in the sector's efficiency are associated with the development of digital technologies, the modernisation of storage infrastructure, and the expansion of export transportation routes. An important priority is to strengthen cooperation among agricultural producers, logistics operators, and government institutions to enhance the resilience of the country's agri-food system. Furthermore, the wider adoption of advanced information technologies and intelligent management systems will improve the transparency of logistics processes, reduce operational costs, and strengthen the competitiveness of Kazakhstan's agricultural products in international markets. Taken together, these measures provide a solid foundation for developing a modern, resilient, and efficient agrologistics system that meets the requirements of international trade and supports the long-term development of the country's agro-industrial sector.

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5. Model of the innovative logistics management chain in the agro-industrial complex of the Republic of Kazakhstan

The analysis conducted has shown that the structural transformation of agricultural enterprises in the Republic of Kazakhstan is accompanied not only by changes in organisational and legal forms of business and an increase in entrepreneurial activity in the agricultural sector, but also by a significant transformation of logistics processes. In this regard, there is a need to create a unified, integrated logistics system that ensures effective interaction among all participants in the agricultural value chain—from resource suppliers to the end consumer. Taking into account the identified trends in the structural transformation of agricultural enterprises and modern requirements for the organisation of logistics processes, we propose a model of an innovative logistics management chain for the agro-industrial complex of the Republic of Kazakhstan, as shown in Figure 1.

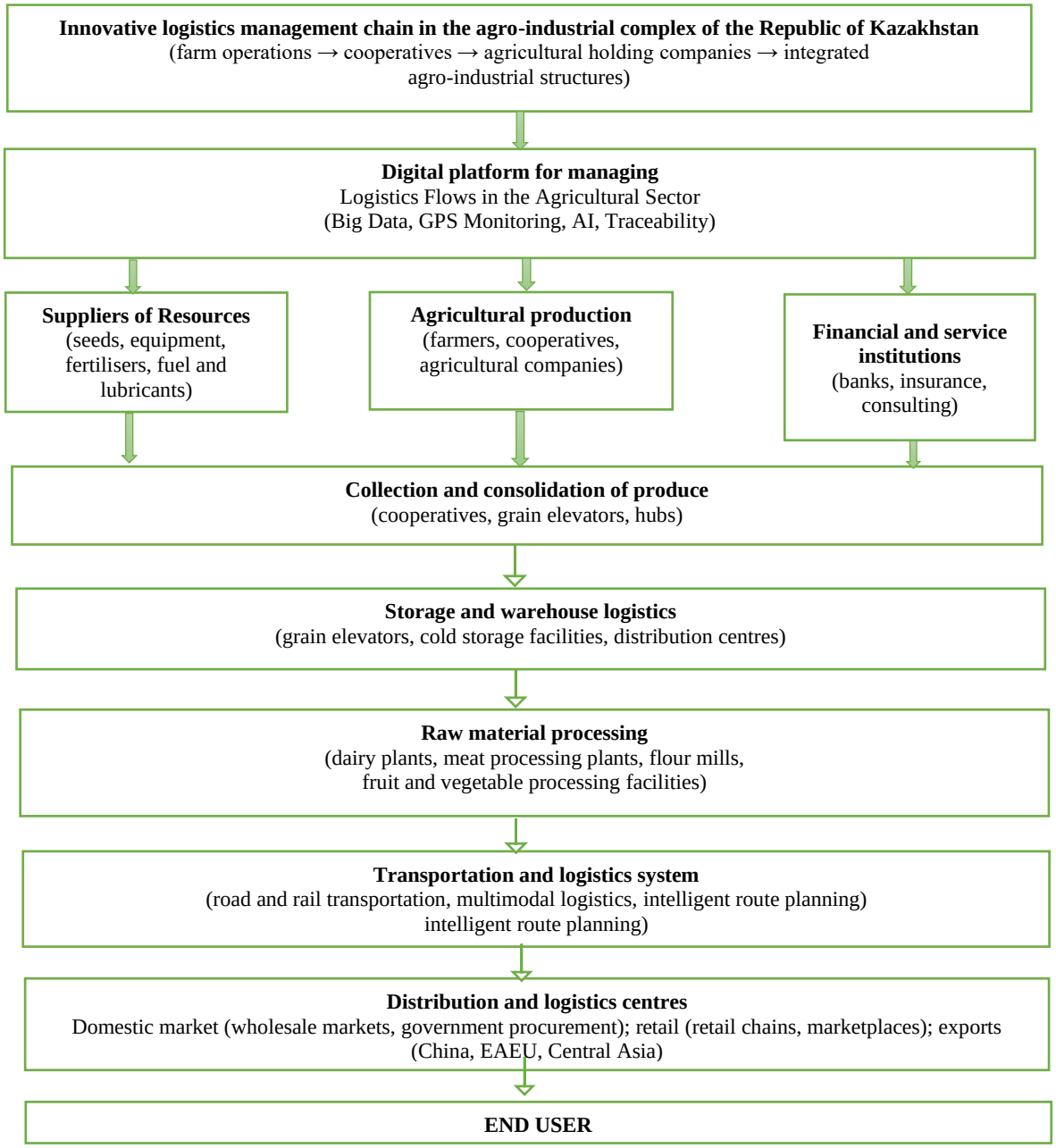


Figure 1. Model of the innovative logistics management chain in the agro-industrial complex of the Republic of Kazakhstan
Source: Prepared by the authors

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The logistics management chain presented here reflects the modern model for organising material, information, and financial flows in the agro-industrial complex of the Republic of Kazakhstan amid the structural transformation of agricultural enterprises. This model is based on changes in the organisational and economic structure of the agricultural sector, as evidenced by the development of family farms, agricultural cooperatives, agribusinesses, and vertically integrated agro-industrial entities.

The structural transformation of agricultural enterprises directly affects the organisation of logistics processes, as changes in production scale, specialisation, and cooperation among economic actors require the development of new mechanisms for managing material flows. In this context, a digital platform for managing logistics processes is playing a key role, ensuring the integration of all participants in the agri-food chain through modern information and communication technologies. The use of Big Data, GPS monitoring, product traceability systems, and artificial intelligence helps increase supply chain transparency and the speed of management decision-making (Mardenli et al., 2025).

The initial link in the logistics system comprises suppliers of material and technical resources who provide agricultural producers with seeds, fertilisers, plant protection products, agricultural machinery, and fuels and lubricants. Next, production flows are formed at the level of farms, cooperatives, and agro-industrial enterprises, where agricultural raw materials and products are produced.

The next stage involves consolidating commodity flows through agricultural cooperatives, grain elevators, and logistics hubs. The concentration of production helps overcome the problem of production fragmentation characteristic of Kazakhstan's modern agricultural sector and also contributes to reducing transportation and transaction costs. After consolidation, the products enter a storage system comprising grain elevators, cold storage facilities, distribution centres, and modern warehouses. The development of warehouse infrastructure ensures that product quality is maintained and losses during storage are minimised.

The processing of agricultural raw materials is a key element of the logistics chain. The development of modern processing complexes enables increased product added value, expanded product range, and improved efficiency in the utilisation of agricultural raw materials. As integrated agro-industrial structures develop, the processes of production, storage, processing, and sales are increasingly consolidated within a single logistics system (Kyfyak et al., 2023).

The transportation and logistics subsystem ensures the movement of goods between all links in the supply chain. The use of modern vehicles, digital technologies for monitoring shipments, and intelligent route-planning systems helps reduce delivery times, lower logistics costs, and improve delivery reliability. Of particular importance to Kazakhstan is the development of multimodal transportation, which ensures effective integration of road, rail, and international transport networks.

In the final stage, the products are delivered to distribution and logistics centres, from where they are shipped to the domestic market, retail chains, or export markets. The development of export-oriented logistics is becoming a key factor in enhancing the competitiveness of the domestic agro-industrial complex and expanding the presence of Kazakhstani products in foreign markets. The operation of an innovative logistics management system delivers comprehensive economic benefits, including reduced logistics costs at all stages of product distribution, reduced losses of agricultural raw materials and finished products, and improved efficiency in managing inventory and transportation flows (Amamou 2025).

As a result, the competitiveness of agribusiness enterprises increases, the industry's export potential expands, the country's food security is strengthened, and conditions are created for achieving sustainable development goals. The structural transformation of agricultural enterprises is not only a consequence of the modernisation of the agricultural sector but also a key factor in the formation of an innovative logistics management system in the agro-industrial complex of the Republic of Kazakhstan.

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6. The mechanism for developing an innovative logistics management system in the agricultural sector of the Republic of Kazakhstan

Based on the model's results, we propose a mechanism to develop an innovative logistics management system for the agricultural sector of the Republic of Kazakhstan (Table 5). The proposed mechanism is based on the comprehensive use of organisational, infrastructural, digital, and innovative tools that create a synergistic effect in managing agricultural supply chains.

Table 5. Mechanism for developing an innovative logistics management system in the agricultural sector of the Republic of Kazakhstan

Development of the innovative logistics management system in the agro-industrial complex
An increase in the number of farms; an increase in the number of agricultural cooperatives; the growth of entrepreneurial activity; changes in the structure of employment
Problems
Fragmentation of production: High transportation costs; insufficient integration among market participants; low level of digitisation in logistics processes; product losses during storage and transportation
Development tools
➢ *Organisational:* development of agricultural cooperatives; creation of logistics clusters; integration of producers, processors, and trading organisations. ➢ *Infrastructure:* construction of distribution centres; development of warehouse infrastructure; modernisation of transportation and logistics hubs. ➢ *Digital:* digital supply chain management platforms; GPS tracking of shipments; big data technologies; product traceability systems. ➢ *Innovative:* warehouse automation; intelligent route planning; use of artificial intelligence technologies; implementation of «smart logistics».
An innovative logistics management system
Coordination of material flows: Supply optimisation; Inventory Management; Transportation Management; Digital Monitoring of Supply Chains
Results
Reducing logistics costs: Reducing agricultural product losses; increasing the competitiveness of agribusiness enterprises; boosting export potential; strengthening food security; achieving sustainable development goals

Source: Prepared by the authors

The organisational component of the mechanism calls for the development of agricultural cooperation, the formation of logistics clusters, and the strengthening of integrative ties between producers, processing enterprises, and trading organisations. The implementation of these measures contributes to the consolidation of commodity flows, a reduction in transaction costs, and improved coordination among market participants. The infrastructure component focuses on creating modern distribution centres, developing warehouse infrastructure, and modernising transportation and logistics hubs. This will reduce the time and financial costs of product delivery, improve the quality of storage of agricultural raw materials, and minimise product losses throughout the supply chain.

The proposed mechanism places particular emphasis on the digital transformation of logistics processes. The implementation of digital supply chain management platforms, GPS-based transportation monitoring technologies, big data analytics, and product traceability systems ensures supply chain transparency, enables prompt management decision-making, and improves the efficiency of logistics resource utilisation. The innovative component of the mechanism includes the automation of warehouse operations, intelligent route planning, the use of artificial intelligence technologies, and the implementation of the "smart logistics" concept. The implementation of these solutions helps optimise material flows, reduce order processing times, improve demand forecasting accuracy, and enhance the quality of logistics services.

A key component of the mechanism is an innovative logistics management system that coordinates the flow of goods at every stage of the product's journey from the manufacturer to the end consumer. The system is designed to optimise deliveries, manage inventory efficiently, organise transportation effectively, and monitor supply chains digitally. The proposed mechanism will make it possible to achieve significant socioeconomic results, including a reduction in logistics costs, a decrease in agricultural product losses, an increase in the competitiveness of agribusiness enterprises, an expansion of export opportunities for domestic producers, a strengthening of the country's food security, and the implementation of the principles of sustainable development. Thus, the need to implement an innovative logistics management system stems from the objective processes of structural transformation in the agricultural sector and the need to improve the efficiency of the logistics infrastructure of the Republic of Kazakhstan's agro-industrial complex.

Conclusions

This study has demonstrated the key role of structural transformation in agricultural enterprises in the formation and development of an innovative logistics management system within the agro-industrial complex of the Republic of Kazakhstan.

It has been established that changes in the organisational and legal structure of the agricultural sector, associated with the growing share of cooperatives, family farms, and individual entrepreneurship, create new conditions for integrating participants in agri-food supply chains and improving the efficiency of logistics processes.

An analysis of statistical data has shown that structural changes in the agro-industrial complex are accompanied by a transformation in rural employment and a redistribution of labour resources among various forms of economic activity. This, in turn, reinforces the need to develop a flexible and adaptive logistics management system focused on cooperation, digitalisation, and reducing transaction costs.

1. This study proposes a model of an innovative logistics management chain for the agricultural sector of the Republic of Kazakhstan, taking into account the specific nature of the structural transformation of agricultural enterprises. This model ensures systematic interaction among agricultural market participants—including producers, processors, logistics centres, and end consumers—based on the principles of integration and digital coordination.

2. The mechanism developed for advancing an innovative logistics management system makes it possible to enhance the resilience of agri-food supply chains, improve the manageability of resource and product flows, and boost the competitiveness of the country's agricultural sector.

3. The results of the study confirm the hypotheses put forward and demonstrate that the structural transformation of agricultural enterprises is one of the key factors in improving the efficiency and innovation of logistics management in the agro-industrial complex of the Republic of Kazakhstan.

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QUALITY AUDITS AS TOOLS FOR IMPROVING PRODUCTION PROCESSES IN MANUFACTURING ENTERPRISES

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Abstract. The aim of this article is to identify and assess the role of quality audits in improving production processes in selected manufacturing enterprises located in south-eastern Poland. The analysis is embedded in the concept of Total Quality Management, which treats quality as the result of customer orientation, employee involvement, a process approach, and continuous improvement. The study was conducted using a methodology based on direct observation, analysis of internal documentation. The qualitative material was then compared with the results of a survey of 40 respondents with experience in audit practice in manufacturing enterprises, thereby enabling triangulation of the findings. The analysis covered three audit practices: 6S audit, final audit, and product audit. The results indicate that quality audits serve functions that go beyond formal conformity assessment, supporting process stabilisation, the identification of nonconformities, the initiation of corrective actions, and the strengthening of responsibility for quality. The survey data confirmed the particular importance of audits for process standardisation and discipline, nonconformity prevention, and work organisation, while also revealing barriers such as limited time, employee resistance, data quality issues, and fragmented IT systems.

Keywords: quality audit; quality management; process improvement; manufacturing enterprises

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JEL Classifications: M11, M42, L60

1. Introduction and review of literature

In contemporary markets, the concept of quality is no longer regarded exclusively as a set of technical product characteristics or as the outcome of final inspection. Manufacturing enterprises increasingly view quality not only as a set of a product's technical characteristics or as the result of final inspection. It is more often treated as an element that co-creates competitiveness, operational efficiency, and the organisation's capacity for long-term development (Kaynak, 2003; Phan et al., 2011; Oakland, 2014; Titu et al., 2025). This perspective is consistent with both the classical literature on quality management and the normative approach developed within the ISO 9000 family, which is oriented toward meeting customer expectations and improving the quality of products and services (PN-EN ISO 9000:2015-10; Afzal et al., 2025).

In classical concepts, quality was understood not only as technical conformity but also as usefulness and value from the recipient's perspective. Juran and Godfrey (1998) defined it as "fitness for use" whereas Crosby (1979) emphasised the economic dimension of pro-quality activities, stating that "quality is free". Both approaches remain relevant because they link quality with the ability to meet customer expectations, prevent failures, and reduce the costs resulting from nonconformities. In contemporary manufacturing, quality is therefore

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increasingly understood as the outcome of process capability, organisational decisions, employee involvement, and the systematic prevention of errors rather than merely the result of final product inspection. This broader understanding of quality is reflected in the concept of Total Quality Management. TQM is not a single method or a set of separate tools, but a comprehensive approach that integrates organisational activities around quality (Oakland, 2014; Carnerud & Bäckström, 2021; Rakyta et al., 2024; Sravanthi et al., 2025).

Ali (2024), in a bibliometric review of research on TQM in manufacturing firms, concluded that TQM remains an active and evolving research field rather than a declining management concept. The review also identified a need for further research in emerging and developing economies and for the integration of established quality management practices with contemporary technological and organisational conditions. Therefore, classical TQM principles continue to provide an appropriate theoretical framework for examining quality practices in manufacturing enterprises, although their implementation increasingly takes place in an environment shaped by digitalisation, data integration, and Industry 4.0.

It includes customer orientation, leadership, employee involvement, a process approach, and improvement based on data and organisational learning to maintain quality (American Society for Quality, 2024; Kaynak, 2003; Phan et al., 2011). Empirical studies indicate that quality management practices and ISO 9001-based solutions can support the operational performance of manufacturing enterprises, including productivity, product quality, customer satisfaction, and process stability (Kaynak, 2003; Phan et al., 2011; Nurcahyo et al., 2021). At the same time, the positive impact of a quality system depends not only on its formal implementation but also on the actual use of procedures and data, and the development of a quality culture (Bakhtiar et al., 2023; Ayyadi & Oulhadj, 2024; Setyaningrum et al., 2025).

The distinction between formal compliance and operational use is important. Gremyr et al. (2021) investigated how different ways of using quality management systems affect managerial perceptions of their cost, strategic importance, and value. Their findings showed that a compliance-oriented use of QMS, focused mainly on documentation, was more likely to be perceived as costly and of limited value. By contrast, the use of QMS as a tool for business management and improvement strengthened its perceived strategic relevance. Bakhtiar et al. (2023) similarly indicated that the influence of ISO 9001 on operational performance depends on the functioning of interconnected system elements, including leadership, planning, operational control, performance evaluation, and improvement. Consequently, certification or the formal existence of procedures alone cannot be treated as evidence that a quality management system creates operational value.

Recent research also places quality management within the context of technological transformation. Fadilasari et al. (2024) examined the challenges associated with adopting quality management practices in the Industry 4.0 era. Their study draws attention to barriers related to technological integration, organisational readiness, employee competencies, and the adaptation of established quality practices to digitally supported production systems (Liu et al., 2023). From the perspective of the present article, these developments are relevant because they increase the importance of reliable data, timely feedback, and the integration of quality information with operational decision-making. They do not, however, eliminate the importance of established quality practices. Instead, they create a need to reconsider how traditional quality management tools, including audits, can support improvement in increasingly data-intensive manufacturing environments.

Quality audits occupy a particular place among the tools used in quality management systems. ISO 19011 constitutes the basic normative reference for management system audits by defining the principles of auditing, the management of audit programmes, and the conduct of management system audits (PN-EN ISO 19011:2018-08). Audits provide systematic and documented evidence concerning the extent to which audit criteria are fulfilled. In manufacturing enterprises, however, their potential role extends beyond confirming compliance. Audit findings can support process supervision, reveal recurring nonconformities, provide information about weaknesses in organisational practices, and initiate corrective and improvement actions (Abuazza et al., 2020; Helmold & Terry, 2021). Research concerning the organisational value of quality management systems confirms the importance of this broader use of audit information. Gremyr et al. (2021) distinguished between compliance-oriented, improvement-oriented, and business-management-oriented uses of QMS, indicating that standardisation can create value but excessive emphasis on documentation may reduce the system's managerial

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relevance. Camango and Cândido (2023), in a systematic review of ISO 9001 maintenance, decertification, and recertification, showed that maintaining a functioning quality management system requires continuous monitoring, management involvement, improvement activities, and internal audits. Their findings suggest that audits should be considered part of the ongoing maintenance and development of QMS rather than an activity performed only for certification purposes. The role of internal audits was examined more directly by Lenning and Gremyr (2022), who reviewed the literature and developed a research agenda concerning their potential. The authors showed that internal audits may support control, learning, and organisational improvement, but the empirical understanding of how this value is generated remains fragmented. They also indicated that more research is needed on audit processes that go beyond the verification of compliance and provide information relevant to management and improvement. This observation is particularly important in manufacturing enterprises, where audits may be embedded at different points in the production process and may differ considerably in their subject, scope, participants, and consequences.

The development of digital manufacturing introduces an additional, emerging dimension of audit practice. Mayer et al. (2024) proposed a procedure for assessing data quality in smart manufacturing and demonstrated how an ISO-aligned, structured audit process could produce recommendations for improving the use of manufacturing data. Although their study focused on data quality rather than conventional product or workplace audits, it illustrates the broader tendency to connect auditing with digital information flows and operational decision support. This development reinforces the need to understand the organisational mechanisms through which audit findings are translated into corrective and improvement actions.

Despite the extensive literature on TQM, ISO 9001, and the relationship between quality management and organisational performance, the practical functioning of specific quality audits within the everyday course of production remains less thoroughly examined. Earlier empirical studies have primarily investigated general relationships between bundles of quality management practices and performance outcomes (Samson & Terziovski, 1999; Kaynak, 2003; Phan et al., 2011). More recent research has examined the operational effects of ISO 9001, different uses of QMS, the maintenance of certification, and challenges associated with Quality 4.0 (Gremyr et al., 2021; Lenning & Gremyr, 2022; Bakhtiar et al., 2023; Camango & Cândido, 2023; Fadilasari et al., 2024). However, these studies provide limited insight into how different audit practices are embedded at particular stages of manufacturing processes and how they support workplace organisation, final conformity assurance, process diagnosis, and corrective action.

Consequently, the research gap addressed in this article does not concern the general effectiveness of TQM or ISO 9001. Instead, it concerns the limited empirical understanding of how different types of quality audits operate as complementary mechanisms within manufacturing enterprises. In particular, further investigation is needed into how audit practices situated at different points in the production process contribute to process stabilisation, nonconformity detection, feedback generation, corrective action, and the practical implementation of TQM principles (Helmold & Terry, 2021; Lenning & Gremyr, 2022). An additional justification for undertaking the study is the limited number of in-depth analyses of the functioning of such solutions within the specific organisational and regional context of Polish manufacturing enterprises.

The identified research gap justifies an analysis of the practical use of quality audits in manufacturing enterprises operating in south-eastern Poland. The aim of the article is to identify and assess the role of quality audits in improving production processes in selected enterprises, with particular emphasis on their significance for detecting nonconformities, stabilising processes, initiating corrective actions, and supporting the assumptions of Total Quality Management. The analysis focuses on three audit practices: 6S audit, final audit, and product audit which represent different locations and functions within the production and quality management system.

2. Quality audit in theoretical perspective

A quality audit is a basic tool in quality management systems for the systematic assessment of processes, activities, and organisational solutions. Its main reference is ISO 19011, which organises the principles for planning, conducting, documenting, and evaluating management system audits. The standard applies to first-, second-, and third-party audits and requires them to be conducted in an orderly, documented manner based on objective evidence (PN-EN ISO 19011:2018-08).

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In practical terms, an audit may be understood as an organised process of collecting and analysing information concerning the conformity of specific activities with adopted criteria. It includes, among other things, a review of documentation, direct observations, analysis of process data, and the formulation of conclusions and recommendations for corrective actions (Wolniak, 2021). One of its basic functions is therefore conformity assessment, that is, checking whether processes, procedures, activities, and results meet the requirements of standards, regulations, customer specifications, and the organisation's internal standards. In this sense, an audit serves an evidential and verification function, enabling the determination of whether the quality management system operates in accordance with the adopted assumptions (PN-EN ISO 19011:2018-08; Helmold & Terry, 2021; Hariyani et al., 2025).

However, conformity assessment does not exhaust the meaning of a quality audit. An effectively conducted audit should provide information useful to management: it enables not only the confirmation of the fulfilment of specific requirements, but also the identification of areas requiring improvement, possible causes of problems, and risks affecting process effectiveness. In this approach, an audit becomes a source of knowledge about the functioning of the organisation and a basis for undertaking corrective and improvement actions (PN-EN ISO 19011:2018-08; Helmold & Terry, 2021; Wolniak, 2021; Lenning & Gremyr, 2022; Schweers et al., 2024).

In manufacturing enterprises, the significance of an audit is particularly evident where quality depends on process stability, parameter repeatability, and the organisation's ability to respond quickly to deviations. An audit may then serve as a preventive mechanism that limits the risk of passing a nonconforming product to subsequent stages of the process, as well as a diagnostic tool that enables the identification of problem sources and directions for corrective actions. Its value, therefore, results not only from the fact that an assessment has been conducted, but above all from the quality of the information obtained and the way it is used in organisational practice (Helmold & Terry, 2021; Lenning & Gremyr, 2022; Leosdottir et al., 2025).

From this perspective, a quality audit can be seen as a tool that links system requirements with day-to-day process management. It helps organise the flow of information, identify weak points in the system, support decisions concerning corrective actions, and assess the effectiveness of implemented solutions. In this sense, an audit is part of the logic of continuous improvement, as it enables the results of assessment to be transformed into concrete organisational actions (Oakland, 2014; Gremyr et al., 2021; Dandekar et al. 2026).

The significance of quality audits can also be considered in relation to the assumptions of Total Quality Management. In the TQM model, quality is not the responsibility only of the inspection department or the management system representative, but becomes a matter of joint action by the entire organisation. The audit occupies a special place in this arrangement because it combines process assessment with the generation of knowledge needed for improvement. It may support customer orientation, the process approach, continuous improvement, and the development of shared responsibility for quality, provided that its results are used for development rather than merely for formal purposes (Hawkes & Adams, 1995; Kaynak, 2003; Oakland, 2014; American Society for Quality, 2024).

As a result, a quality audit should be perceived as a multifunctional tool. It enables the conformity of activities with the requirements to be assessed, while also making it possible to recognise system weaknesses, initiate corrective actions, strengthen the flow of information, and develop a culture of continuous improvement. Its role in the quality management system is therefore not merely auxiliary. An audit is one of the practical links connecting quality requirements, process responsibility, and lasting organisational improvement (Oakland, 2014; Helmold & Terry, 2021; Lenning & Gremyr, 2022).

3. Research methodology

The core of the study was a qualitative case study of three enterprises, while the survey was treated as a supporting component, enabling the findings from the three organisations to be compared with a broader picture

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of audit practice in manufacturing enterprises. This approach made it possible to combine an in-depth description of organisational mechanisms with a synthetic assessment of the frequency of selected phenomena.

The adopted qualitative strategy was a multiple case study. The choice of this strategy resulted from the need to analyse quality audits in their natural organisational context and from the intention to capture similarities and differences between the studied enterprises. The qualitative sample consisted of three manufacturing enterprises operating in south-eastern Poland and applying quality management solutions. Due to data confidentiality, the names of the organisations studied were anonymised and designated as Enterprise A, Enterprise B, and Enterprise C.

The qualitative research was conducted between October 2024 and April 2025. In the first stage, 14 manufacturing enterprises that use quality management systems were identified and contacted with inquiries about the possibility of conducting research. Responses were received from 4 organisations, while 3 enterprises agreed to participate in the study and provide empirical material. In the next stage, the production processes of the studied organisations were initially examined, and the scope of observation and documentation analysis was specified (see Table 1).

The empirical material was based on three mutually complementary sources of data: internal documentation, direct observations, and survey among employees. Document analysis made it possible to identify the formal assumptions of quality management systems, the audit procedures used, and the manner in which nonconformities and corrective actions are documented. Observations enabled these records to be related to the actual course of selected production processes and quality supervision practices.

Table 1. Characteristics of the studied enterprises and data sources used in the case studies

Studied enterprise	Enterprise profile	Data sources	Management systems/standards
Enterprise A	Large manufacturing enterprise from the interior and office furnishing sector, with an integrated management system.	Quality and system documentation; observation of audited workstations	ISO 9001, ISO 14001, ISO 14006, ISO 45001, and selected sectoral and environmental standards.
Enterprise B	Manufacturing enterprise operating in advanced industrial production, including sectors with increased quality requirements.	Quality documentation and audit records; observation of final inspection, production, and process supervision.	AS/EN 9100, ISO 9001, ISO 14001, and requirements specific to specialised production.
Enterprise C	Large automotive manufacturing enterprise with a developed quality supervision system.	Audit procedures, measurement reports, and action plans; observation of production processes, production, and post-audit actions	IATF 16949, ISO 14001, ISO 45001.

Source: own elaboration

The quantitative component took the form of a diagnostic survey. The questionnaire included questions concerning the types of audits used, their frequency, objectives, assessed effectiveness, implementation barriers, digitalisation maturity, response time to nonconformities, use of data for improvement, and the role of leaders in the audit process. The survey included both single-choice questions and multiple-choice TOP3 questions. A total of 40 responses were obtained.

The analysis of the empirical material was oriented toward answering the question: how do quality audits support the improvement of production processes and the implementation of Total Quality Management assumptions? In the qualitative part, the focus was on three types of audit solutions: 6S audits, final audits, and product audits. In the survey section, the analysis examined which audit functions were most frequently cited by respondents and which barriers limited their effectiveness.

The advantage of the adopted methodology is the ability to capture quality audits both in an in-depth organisational context and from the broader perspective of respondents' opinions. The study's limitation remains the purposive, non-representative nature of the sample selection; therefore, the survey results should not be used

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as a basis for statistical generalisation. Its role was to supplement the qualitative material rather than to replace the in-depth case analysis.

4. Research results

4.1. Enterprise A

In Enterprise A, the use of 6S audits was identified as a tool supporting the organisation of workstations, the maintenance of operational standards, and the development of a quality culture. The 6S audit represented an extension of the classical 5S concept with an additional safety element, which gave it both an organisational and preventive dimension. The analysis of the empirical material indicates that these audits were carried out cyclically, once a month, and served to assess the conformity of production workstations with adopted standards.

The 6S system covered six areas: sort, set in order, shine, standardise, sustain, and safety. Each of these elements was assessed according to defined criteria, and the audit itself was conducted with the participation of the lead auditor, the employee of a given workstation, a supervisor, and an employee from another area of the organisation. This method of conducting the audit strengthened the multi-aspect nature of the assessment, limited the risk of a one-sided interpretation of results, and supported the development of a shared understanding of quality standards.

The results of the analysis indicate that in Enterprise A, the 6S audit was not limited to assessing order and work organisation. It was also a tool that systematised everyday operational practice, supported workplace discipline, maintained the repeatability of activities, and increased employees' quality awareness. As a result, it strengthened organisational order and operational prevention, fitting into the assumptions of TQM by combining standardisation, employee involvement, safety, and continuous improvement (Kaynak, 2003; Oakland, 2014; Ali, 2024).

4.2. Enterprise B

In Enterprise B, the key identified solution was the final audit, carried out as a form of final inspection of the product before it was passed on to subsequent stages of the process or to the customer. The analysis of the empirical material shows that it functioned as a boundary point in the production process: it made it possible to detect nonconformities at the final stage, reduced the risk of passing a defective component or finished product further along the value chain, and reduced the potential costs of complaints, repairs, and reputational loss. At the same time, the regular collection of data from final audits enabled the identification of problem sources and provided feedback to the engineering, technological, and production departments. This approach is consistent with the understanding of an audit as both a tool for conformity assessment and a support for improvement activities (PN-EN ISO 19011:2018-08; Helmold & Terry, 2021).

The research results also indicate that the final audit supported the enterprise's operational stability. The systematic use of this tool helped maintain process repeatability, increase quality predictability, and strengthen the organisation's ability to manage quality risk. In this sense, the final audit served not only a verification function but also diagnostic and improvement functions, as it generated knowledge about sources of error and supported the undertaking of corrective actions (Helmold & Terry, 2021; PN-EN ISO 19011:2018-08; Oakland, 2014).

4.3. Enterprise C

In Enterprise C, the practice of product audits was identified. These audits were carried out according to an established schedule and on the basis of precisely defined procedures. Compared with the two other solutions, this audit had the most developed process-diagnostic character, as it enabled assessment of product conformity in connection with the coherence of the entire manufacturing process. Such an approach corresponds with literature emphasising the value of an audit as a tool supporting quality management and process improvement (Helmold & Terry, 2021; Lenning & Gremyr, 2022).

An important feature of this solution was its strong embedding in customer requirements and precisely defined assessment criteria. The product audit enabled monitoring of the extent to which quality requirements were met,

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including for products with high technical complexity. The use of requirement matrices, measurement reports, and documentation of corrective actions increased process transparency and facilitated the identification of quality trends.

Audit results were linked to risk assessment, error classification, and formal documentation of further actions. When a nonconformity was identified, corrective and corrective actions were defined, responsibilities were assigned, and a completion deadline not exceeding two weeks was set. The scope of response could include, among other things, retesting, selection, suspension of production or shipments, conditional approval, or recurrence-related actions. The entire process was documented in an action plan, and the effectiveness of the implemented solutions was then assessed. This logic aligns with the understanding of an audit as an element of the continuous improvement loop, in which the assessment result serves as the basis for corrective actions and organisational learning (PN-EN ISO 19011:2018-08; Gremyr et al., 2021).

The product audit also had a strong cross-functional dimension. Various organisational units were involved in its implementation, from design and process engineering to logistics and quality management. This arrangement supported the building of shared responsibility for quality, increased the coherence of actions, and shortened the response time to nonconformities, which fits well with the logic of TQM, emphasising the process approach, employee involvement, and shared responsibility for quality (Oakland, 2014; Mohammed & Panchal, 2026).

From an organisational perspective, the product audit helped maintain process repeatability, stabilise production parameters, and reduce the number of deviations. Therefore, it can be stated that in Enterprise C, it performed the most developed systemic function among the analysed solutions, combining conformity assessment, analysis of problem causes, and the initiation of improvement in many areas of the organisation simultaneously (Helmold & Terry, 2021; Lenning & Gremyr, 2022).

4.4. Comparison of audit functions in the studied enterprises

The conducted analysis indicates that all three identified audit practices supported quality management, although each was embedded at a different level of organisational functioning. The 6S audit in Enterprise A focused primarily on workstation organisation, operational discipline, and the development of a quality culture. The final audit in Enterprise B served as a final process safeguard, strengthening the organisation's ability to identify nonconformities before the product was passed on. The product audit in Enterprise C was the most comprehensive and process-oriented, as it allowed quality to be assessed in relation to customer requirements, the process course, corrective actions, and the effectiveness of the organisational response.

The common denominator of the analysed solutions was that they did not perform only a control function. Each audit generated information used to undertake corrective actions, organise the process, and strengthen employees' quality awareness. The differences concerned mainly their objectives and roles in the production process: the 6S audit strengthened the organisational conditions for quality, the final audit protected the process output, and the product audit enabled an in-depth assessment of process and product quality. This means that in the studied enterprises, audits formed a complementary set of tools: from stabilising the work environment, through final inspection, to diagnosing and improving the manufacturing process (PN-EN ISO 19011:2018-08; Oakland, 2014; Kaynak, 2003; Helmold & Terry, 2021).

The results obtained, therefore, indicate that quality audits can support the practical implementation of TQM assumptions, especially in the areas of continuous improvement, the process approach, and shared responsibility for quality. The interpretation of these findings in the light of the literature is presented in the discussion section.

4.5. Survey results as a complement to the case studies

The survey enabled comparison of the conclusions from the case studies with the opinions of respondents with experience in audit practice in manufacturing enterprises.

The results indicate that audit practice is diverse. The most frequently used were process or internal audit, OHS audit, and 6S audit, which shows that audits include both activities aimed at system conformity and solutions directly related to work organisation, safety, and ongoing process supervision (Table 2).

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Table 2. Types of audits used in the studied enterprises according to respondents (multiple choice) (n = 40)

Type of audit	Number of indications	Share of respondents
Process/internal audit	25	62.5%
OHS audit	23	57.5%
6S audit	20	50.0%
ISO/system audit	17	42.5%
Final audit	11	27.5%
Product audit	10	25.0%
Other types of audit	2	5.0%

Source: own elaboration

The frequency of audits indicates that, in the studied organisations, they are not treated as a periodic form of control but as a permanent element of process management (Figure 1).

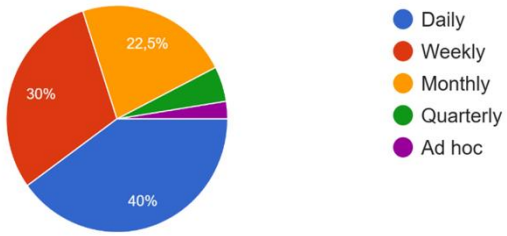


Figure 1. Frequency of conducting audits in the studied enterprises (n = 40)
Source: own elaboration

The largest group of respondents declared that audits were conducted daily, followed by weekly and monthly. This distribution of responses confirms their embedding in ongoing operational practice and their importance for systematic process monitoring (Figure 2).

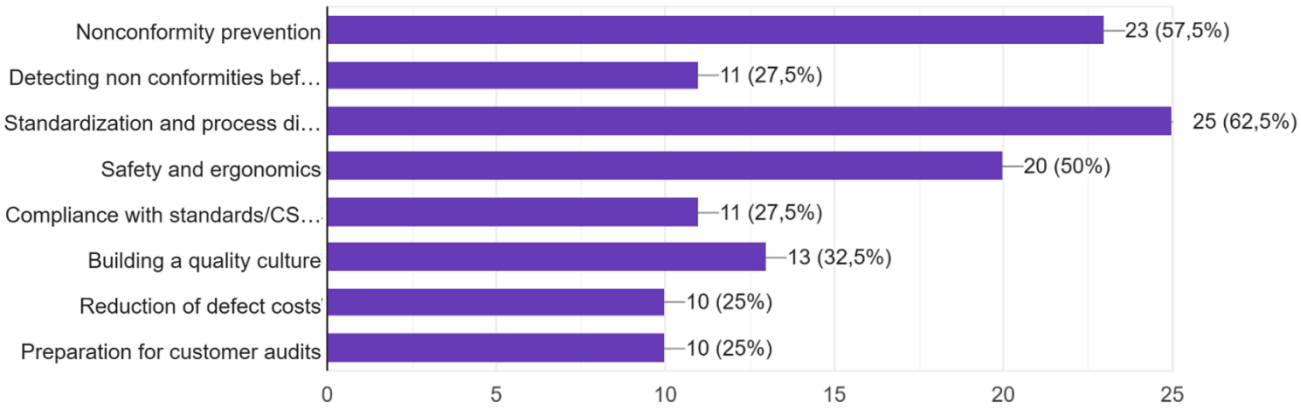


Figure 2. Main goals of audits according to respondents (multiple choice) (n = 40)
Source: own elaboration.

Respondents most often indicated that the main goals of audits were process standardisation and discipline, nonconformity prevention, safety, and ergonomics. These answers are consistent with the conclusions from the

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case studies, which show that audits serve not only a control function but also support preventive actions, improve safety, and shape a more orderly and conscious organisational practice (Figure 3).

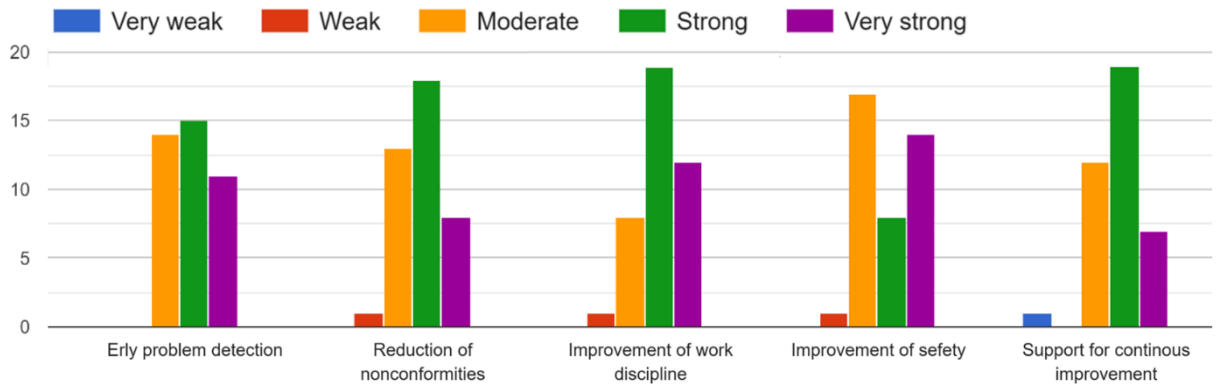


Figure 3. Assessment of audit effectiveness in the opinion of management staff (n = 40)
Source: own elaboration

The assessment of audit effectiveness was generally positive, though it varied by dimension analysed. The highest assessment concerned the impact of audits on improving work discipline. Their importance for early problem detection, reduction of nonconformities, and support for continuous improvement was also highly assessed. The impact of audits on safety was assessed as slightly lower, although still positive. These results indicate that respondents perceive the operational and improvement-oriented dimension of audits.

Table 3. Main barriers limiting audit effectiveness according to respondents (multiple choice) (n = 40)

Barrier limiting audit effectiveness	**Number of indications**	**Share of respondents**
Lack of time and resources	35	87.5%
Employee resistance	18	45.0%
Poor data quality / manual entries	17	42.5%
Fragmented IT systems	15	37.5%
Insufficient leadership involvement	12	30.0%

Source: own elaboration

The most frequently cited barrier to audit effectiveness was a lack of time and resources (see Table 3 above). Employee resistance, poor data quality or manual entries, and fragmented IT systems were also relatively frequent. This means that audit effectiveness depends not only on the existence of an audit procedure itself, but also on information quality, organisational conditions, and the enterprise's ability to consistently use audit results.

Table 4. Audit digitalization maturity according to respondents (n = 40)

Audit digitalization maturity	**Number of indications**	**Share of respondents**
Fully digitalized process	13	32.5%
Hybrid process	13	32.5%
Partially digitalized process	8	20.0%
Paper-based process	6	15.0%

Source: own elaboration

The results concerning digitalisation show that the studied organisations use digitalised, hybrid, and paper-based solutions (see Table 4 above). The level of digitalisation of the audit process is therefore diverse, which may affect data quality, the speed of information flow, and the effectiveness of post-audit actions.

From the perspective of using audit results, the response time to nonconformities is also important (Table 5 below).

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Table 5. Response time to nonconformities after an audit according to respondents (n = 40)

Response time to nonconformities after an audit	Number of indications	Share of respondents
Immediately	9	22.5%
Less than 24 hours	12	30.0%
From 2 to 7 days	15	37.5%
More than 7 days	4	10.0%

Source: own elaboration

Some respondents indicated an immediate response or a response within 24 hours, but a significant group reported a response within 2 to 7 days. This may mean that the mere detection of a nonconformity does not always lead to the rapid initiation of corrective actions.



Figure 4. Audits as a source of data for process improvement according to respondents (n = 40)
Source: own elaboration

The survey results also confirm that audits can generate data used to improve processes (Figure 4 above). Most respondents indicated "yes" or "definitely yes", which confirms their managerial value as a source of information about process functioning. At the same time, some negative or ambiguous responses show that the mere conduct of audits does not yet guarantee the use of their results.

Table 6. Recurrence of the same nonconformities after audits according to respondents (n = 40)

Frequency of recurrence of the same nonconformities	Number of indications	Share of respondents
Very rarely	1	2.5%
Rarely	14	35.0%
Moderately	14	35.0%
Often	11	27.5%
Very often	0	0.0%

Source: own elaboration

This assessment was complemented by an analysis of nonconformity recurrence (Table 6 above). Respondents' answers indicate that the same problems may recur with different frequency. In some organisations, this phenomenon occurs rarely, but a noticeable group of respondents indicated moderate or frequent recurrence of nonconformities. This result suggests that audit effectiveness should be assessed not only by the number of detected problems, but also by the organisation's ability to limit their recurrence after corrective actions are completed.

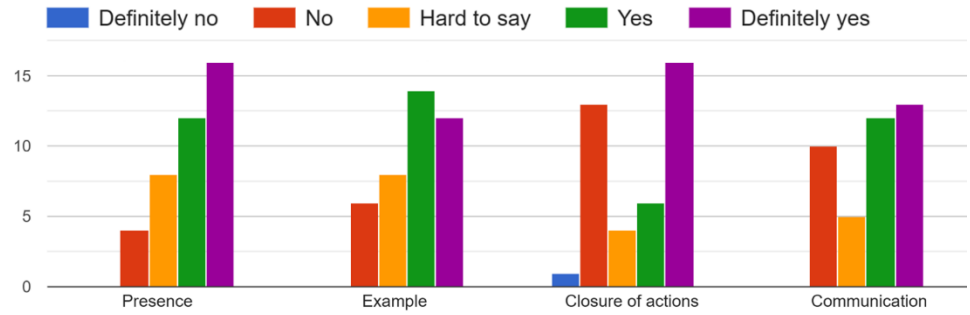


Figure 5. The role of leaders in audits and post-audit actions according to respondents (n = 40)
Source: own elaboration

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The last analysed area concerned the role of leaders in the audit process (Table 5 above). The results indicate that the presence of leaders in audits is noticed by a significant proportion of respondents, but their role in closing post-audit actions was assessed as lower. This means that the mere participation of management staff in audits is insufficient to fully realise their improvement potential. Appropriate communication of results, assignment of responsibility, monitoring of corrective actions, and enforcement of lasting improvements are key.

5. Discussion

The inclusion of the survey enabled triangulation of the results obtained from the case studies. Analysis of internal documentation made it possible to assess formal assumptions and procedures; direct observations captured the actual course of audit activities. Combining these sources with the results of a survey of people with experience in audit practice made it possible to examine more broadly the role of audits in manufacturing enterprises.

The obtained results indicate that quality audits perform a function broader than formal conformity control. Both the case studies and the survey demonstrate their importance for work standardisation, nonconformity prevention, improving safety and ergonomics, and generating information for process improvement. This approach is consistent with PN-EN ISO 19011:2018-08, according to which an audit should be conducted in an orderly manner, based on evidence, and oriented also toward providing information useful for the improvement of management systems and processes. Similarly, the literature emphasises that the value of audits becomes visible when they support quality management processes rather than merely confirm formal conformity (Helmold & Terry, 2021; Lenning & Gremyr, 2022).

These findings align with the literature on quality management, in which the effectiveness of quality practices is associated with their actual embedding in organisational processes, rather than merely with the formal implementation of a system (Oakland, 2014; Gremyr et al., 2021). Therefore, the difference between an audit treated as a system obligation and an audit used developmentally becomes particularly important. The value of an audit is revealed primarily when its results lead to cause analysis, assignment of responsibility, implementation of corrective actions, and verification of their effectiveness.

The analysed audit practices differed in their scope and place in the production process, but their common feature was the generation of information that could be used to improve processes. Audits supported the maintenance of work standards, the identification of sources of nonconformities, the planning of corrective actions, and the assessment of their effectiveness. A similar picture emerges from the survey, in which respondents indicated that the value of audits depends on the quality of information, the speed of response, and consistency in closing post-audit actions. In this sense, the research results align with the assumptions of TQM, as they present the audit as a mechanism linking data, responsibility, the process approach, and quality improvement activities (Kaynak, 2003; Oakland, 2014; Lenning & Gremyr, 2022; Gremyr et al., 2021; Xu et al. 2026).

At the same time, the study's interpretative limitations should be noted. The case studies covered three purposively selected enterprises, while the survey was diagnostic and included 40 respondents. This means that the results should not be statistically generalised to the entire population of manufacturing enterprises. Their significance lies primarily in the in-depth demonstration of the mechanisms by which audits function and in comparing these findings with a broader assessment by practitioners, which is consistent with the logic of complementary mixed-methods research (Creswell & Poth, 2018).

Consequently, the value of quality audits in manufacturing enterprises should be considered not only through the prism of their control function but, above all, through the use of their results. Their managerial significance becomes particularly evident when they lead to the identification of problem causes, the improvement of work standards, the strengthening of responsibility, and lasting process improvement.

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6. Conclusions

The aim of the article was to identify and assess the role of quality audits in selected manufacturing enterprises. The study, based on case studies of three anonymised organisations and supplemented by a survey of 40 respondents, enabled the determination of how audits support process stabilisation, the identification of nonconformities, the initiation of corrective actions, and the development of practices consistent with the assumptions of Total Quality Management.

The obtained results indicate that the value of audits becomes evident primarily when their results are used as a source of managerial information. Audits retain their classical verification function, but their significance does not end with confirming conformity. In the analysed enterprises, audit findings provided a basis for identifying the causes of problems, assigning responsibility, initiating corrective actions, and assessing the effectiveness of the implemented solutions.

The survey data strengthen this interpretation: 65.0% of respondents indicated that an audit generates data for improvement, and the same proportion assessed their impact as strong or very strong in the early detection of problems, the reduction of nonconformities, and the support of continuous improvement.

An important finding is the diversity of audit functions depending on their position within the production process. The 6S audit supported the organisation of the work environment, operational discipline, and the maintenance of workplace standards. The final audit performed a safeguarding and selective function by reducing the risk of transferring a nonconforming product to subsequent stages or to the customer.

The product audit had the most developed process-diagnostic character, as it combined product conformity assessment with process analysis, responses to deviations, and the evaluation of corrective action effectiveness. These findings indicate that audits should be treated as complementary rather than uniform quality management tools.

The novelty of the study lies primarily in the comparative identification of these different audit functions within one analytical framework. Other research has frequently considered audits at the general level of internal auditing, conformity assessment, or quality management system maintenance, with particular attention paid to the role of audits in ISO 9001 systems, compliance verification, and the improvement potential of quality management systems (Gremyr et al., 2021; Lenning & Gremyr, 2022; Camango & Cândido, 2023).

Against this background, the present study provides an empirically grounded interpretation of how audit practices located at different points in the production process may perform distinct but mutually reinforcing roles. Based on the analysis of the three case studies, three audit functions were distinguished in this article: the workplace-organisational function represented by the 6S audit, the safeguarding function represented by the final audit, and the process-diagnostic function represented by the product audit.

These functions should be understood as an analytical interpretation derived from the empirical material, rather than as a universal classification of all quality audits. This distinction does not constitute a universal classification of all quality audits; however, it provides a useful analytical framework for explaining how the location and subject of an audit influence the type of value it generates in a manufacturing enterprise.

It should therefore be treated as the author's analytical proposal, derived from the empirical material and intended to support the interpretation of audit roles in the examined manufacturing settings (see Figure 6 below).

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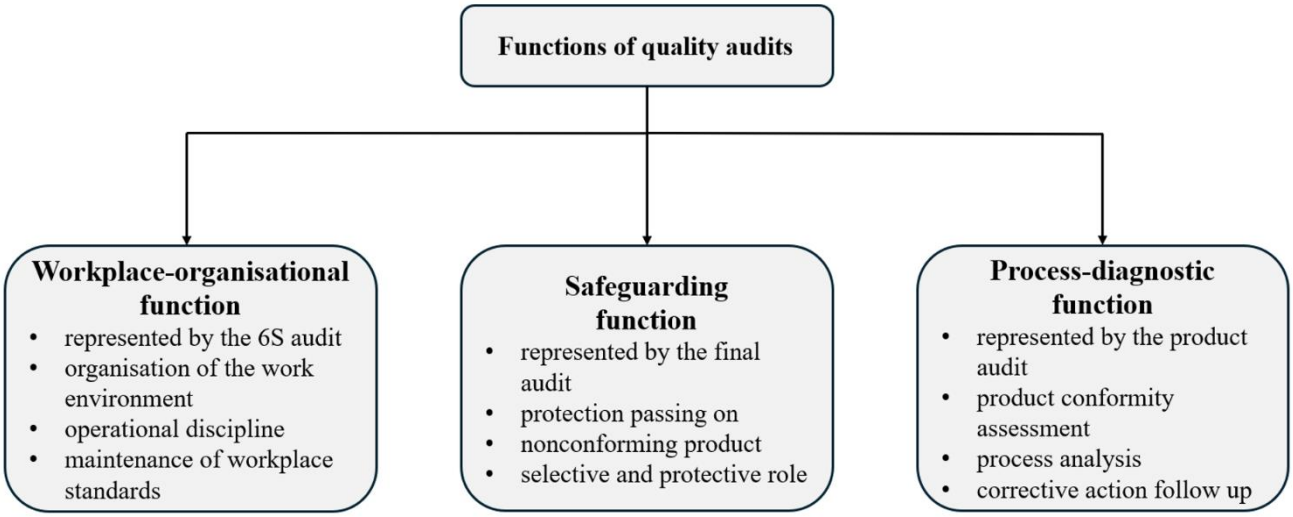


Figure 6. Proposed functional distinction of quality audits in the analysed manufacturing enterprises
Source: own elaboration.

A further contribution of the study is the identification of the mechanism through which audits may support improvement. The findings indicate that an audit does not produce organisational improvement automatically. Its potential value is achieved through a sequence of activities comprising the detection and documentation of a deviation, the communication of findings, the analysis of causes, the assignment of responsibility, the implementation of corrective actions, and the subsequent assessment of their effectiveness. This result is consistent with the literature emphasising that the value of audits and quality management systems depends on their use for management and improvement rather than solely for documentation and compliance (Gremyr et al., 2021; Lenning & Gremyr, 2022).

The study also contributes by combining evidence from organisational case studies with diagnostic survey results. The case studies provided insight into the actual functioning of three audit practices, whereas the survey made it possible to assess whether the functions identified at the organisational level were reflected in the broader perceptions of respondents familiar with quality management practices. The convergence of both sources of evidence strengthens the conclusion that audits are perceived not only as instruments of control but also as sources of improvement data and mechanisms supporting early problem detection.

The findings additionally show that quality audits contribute to the practical implementation of TQM assumptions. In the analysed organisations, they supported the process approach, developed responsibility for quality, organised the flow of information, and fostered continuous improvement. In some cases, the audit process involved employees representing different functions and organisational units, which supported a shared understanding of quality and strengthened cooperation. The results therefore suggest that the role of an audit in TQM is not determined solely by its formal position in the quality management system, but by its ability to connect information about nonconformities with coordinated organisational action.

From a practical perspective, the obtained results suggest that manufacturing enterprises may increase audit effectiveness by moving beyond their treatment as instruments used only to confirm conformity. Greater value can be achieved when audit findings are systematically connected with root-cause analysis, corrective actions, process-owner responsibility, implementation deadlines, and the assessment of action effectiveness. The results also indicate the importance of organisational barriers, including insufficient time and resources, employee resistance, poor data quality, manual data entry, and fragmented IT systems. These barriers may interrupt the transition from identifying a nonconformity to implementing and verifying an effective organisational response.

The study has several limitations. These concern the qualitative nature of the case studies, purposive case selection, the limited number of organisations, and the diagnostic rather than representative character of the survey. Consequently, the results should not be statistically generalised to the entire population of manufacturing enterprises. The proposed distinction between workplace-organisational, safeguarding, and process-diagnostic audit functions should also be treated as an empirically derived interpretation requiring verification in other organisational and industrial contexts. The value of the study lies in its in-depth presentation of the mechanisms through which different quality audits function under real organisational conditions and in the comparison of these mechanisms across several manufacturing settings.

Further research could extend the analysis to a larger number of enterprises, verify the proposed functional distinction across different industries, and examine whether similar audit configurations occur in organisations with different levels of quality management maturity. It would also be useful to combine qualitative analysis with quantitative measures such as nonconformity recurrence, response time, corrective action effectiveness, process capability, customer complaints, and selected cost-of-quality indicators. A further relevant direction concerns the relationship between audit digitalisation, data quality, the integration of audit records with enterprise information systems, and the speed and effectiveness of organisational responses.

In summary, quality audits can constitute an important element of production process improvement and the practical implementation of the TQM philosophy. The principal contribution of the study is the demonstration that different audit practices create different but complementary forms of value and that this value emerges through the conversion of audit findings into managerial information, corrective action, and verified process improvement. Their significance therefore does not result solely from their formal presence in the quality management system, but from whether the organisation is capable of transforming audit evidence into decisions, responsibility, organisational learning, and lasting improvement.

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