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Turinys / Contents

EDITORIAL

"Vadyba / Journal of Management" is periodically published applied sciences journal by Lithuania Business College. The journal is constantly publishing articles since 2002 and has gained significant experience and international recognition. This year the journal is celebrating its 23 years anniversary. It has been well renowned by foreign scientists and number of international scholars publishing continues to increase. Currently, 41th number of the journal is released to readers. Only those articles that meet thorough requirements set by the Editorial Board are being published. Authors of these articles represent various Lithuanian and foreign countries science. From Lithuania the following institutes are represented Lithuania Business College, School of Economics and Business Kaunas University of Technology, Vilnius University Business School, Klaipėda University, Klaipėda University and other. The following institutes from foreign countries: Bucharest University of Economic Studies (Romania), Budapest Metropolitan University, Alexander Dubček University of Trenčín (Slovakia) and other.

Editorial board of "Vadyba / Journal of Management" seeks for published academic researches to cover different economic directions and to be relevant to different industries and countries around the world. At the same time, the focus remains on ongoing changes in various industries, human resources, and governance. Based on these criterions, articles are chosen for publication in the journal. Focusing on relevant areas of change is expected to encourage further scientific discourse and development of social science ideas.

The article by Vinogradov, S. and Nagy, B. presents a nuanced comparative analysis of the innovation performance of the Visegrad Group countries (Czechia, Hungary, Poland, and Slovakia). By integrating the European Innovation Scoreboard (EIS) 2024 and the Global Innovation Index (GII) 2024 with Data Envelopment Analysis (DEA), the study offers a dual-framework approach to assess relative innovation efficiency. Despite common historical and socio-economic backgrounds, the research identifies significant performance gaps among the countries. Slovakia emerges as a regional benchmark, showing a balanced innovation system, while Hungary's underperformance signals the urgent need for systemic reforms. The findings underscore structural inefficiencies, such as weak commercialization processes and limited innovation collaboration, which hinder the full realization of innovation potential across the region.

The paper by Ovchynnykova, O. and Navickas, V. focuses on the sectoral structure and sustainability of the Blue Economy in EU coastal regions. Utilizing a multi-dimensional analytical model grounded in Blue Indicators data, the authors examine gross value added, employment, and structural indices over a twelve-year period. The study reveals a dual narrative–some coastal countries, dominated by labour-intensive tourism sectors, exhibit signs of economic vulnerability and declining employment trends due to automation and structural rigidity. Others, with diversified and capital-intensive maritime sectors, display greater regional resilience and sustainable development prospects. Importantly, the study highlights how digitalization, rather than COVID-19, serves as the main driver of employment transformation in the Blue Economy. These insights point to the necessity for differentiated policy approaches tailored to specific structural conditions in coastal economies.

Kordoš, M., Ivanová, E., and Struharňanská, S. contribute a timely investigation into the impact of digitization on the competitiveness and sustainability of Visegrad 4 (V4) economies. Drawing on multiple international indices (e.g., World Bank Doing Business, IMD, DESI, EIS), the authors apply correlation and regression analyses to assess how digital adaptation influences SME development in high-tech sectors. The research confirms that digital skills development and

investment in digital infrastructure are critical for enhancing sustainable economic growth in the V4 countries. It highlights the transformative role of smart technologies in creating competitive advantages, particularly for small and medium-sized enterprises. The authors argue for more strategic alignment of national digitization agendas with EU-level policy frameworks to close the competitiveness gap within the single market.

However, Editorial cannot review all of the researches, therefore we encourage familiarizing with them in the Journal, which currently is under the indexing process with Scopus and WoS.

We invite scientists to actively publish in the Journal, share their research results and methodological insights. We expect for close cooperation.

Prof. Dr. (H/P) Valentinas Navickas, Editor-in-Chief

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FROM HURDLES TO HIGHWAYS: STRENGTHENING INTERMODAL TRANSPORT FOR EUROPE'S GREEN FUTURE

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Abstract
Intermodal transportation has become a crucial solution to increase effectiveness, sustainability and resilience of transportation system in the European Union. This article explores the main challenges and opportunities of intermodal transportation networks emphasizing on the interconnectedness, eco-friendliness and integration important for smooth operations. As the EU aims to decrease its carbon footprint and improve transportation efficiency, intermodal systems- combining rail, road, waterway and air transport, are becoming extremely important. However, even after all the benefits, the development of intermodal transport faces a number of barriers such as limited infrastructure, complicated regulations and technological difficulties. This article offers a thorough analysis of these obstacles and proposes strategic suggestions for improving intermodal transport network. It demonstrates how the technological innovations, regulatory harmonization and infrastructural investment can address these challenges by thorough evaluation of existing literature and case studies. The paper also presents opportunities to improve environmental sustainability, lessen traffic and boost economic growth across the EU. With a specific focus on policy frameworks, industry cooperation and emerging trends, this study aims to add to the current discussion on sustainable transport and the role of intermodal systems in accomplishing EU climate targets.
Keywords: Intermodal Transportation, Logistics and supply chain management, Sustainable transport, Transport Infrastructure Development.
JEL classification: R40, R42, Q56

Introduction

Modern logistics networks can be made more efficient, sustainable and connected by the adoption of intermodal transport. The combining of multiple modes of transport like rail, road, waterway and maritime shipping- within a single supply chain framework is central to achieving European Union's green transition goals and boosting economic competitiveness. Intermodal freight system presents a viable option to reduce emissions, alleviating road traffic and encourage modal change to rail and inland waterways, as the EU continues to address the environmental impacts of transport (Chowdhury & Srai, 2021; Islam & Dinwoodie 2019). Despite its potential, the implementation of intermodal transport systems across the EU remains fragmented and uneven. Particularly in cross-border infrastructure disparities, policy misalignments and institutional barriers continue to exist (Woxenius, 2021; Mankowska et al. 2021). Although a modal shift from road to rail and waterways has been encouraged by EU policy tools, it has been difficult to achieve operational consistency among member states (Islam & Dinwoodie 2019).

Frameworks for sustainable supply chain management emphasize on how it is important to incorporate social, economic, and environmental factors into logistics choices (Bask et al. 2018). Intermodal transport closely complies with these principles by promoting resource efficient and low-carbon logistical operations. By reducing environmental effects of last mile of delivery, city logistics strategies can further enhance intermodal transport in urban environments (Russo & Comi 2020).

Many academics have made extensive contributions to the body of knowledge pertaining intermodal transport. To lessen supply chain bottlenecks, Rodrigue (2020) emphasized the role of multimodal hubs and global logistics corridors. Macharis and Melo (2011) concentrated on decision making tools for intermodal infrastructure planning. While Tsamboulas and Kapros (2003) helped evaluate regulatory policies supporting modal shift, Notteboom and Winkelmans (2001) examined the governance of intermodal terminals. Liu et al. (2019) presented data-driven frameworks for evaluating intermodal performance, however Crainic and Kim (2007) addressed routing and synchronization isuues in multimodal networks. In the meantime, Caris et al. (2012) and Evangelista et al., (2014) provided perspective on the adoption of innovation and ICT integration in multimodal logistics systems. Despite major contributions, gaps remain about how technological innovations, infrastructure fragmentation, legislative harmonization affect intermodal development across EU regions.

This research problem is of increasing interest due to increased environmental concerns, the European Green deal's carbon reduction goals and geopolitical shift impacting European transport corridors.

The scientific problem addressed in this paper is: How to optimize intermodal transportation in the EU to ensure sustainable, efficient, and resilient logistics operations, especially in the context of technological innovation and regulatory complexity?

The hypothesis of this study is that the performance of intermodal transportation maybe significantly enhanced by the synergistic integration of digital technology, harmonized policies and infrastructure modernization.

The purpose of this study is to investigate the potential challenges and opportunities in EU intermodal transport sector by analyzing infrastructure, regulatory policies, technological advancements and sustainability efforts.

To accomplish this, the study pursues following objectives: the current state and structure of intermodal transport in the EU by identifying the operational, institutional, and technical barriers to effective multimodal integration; the role of the Internet of Things (IoT) in improving intermodal coordination and streamlining logistics operations; the influence of environmental regulations and EU policies on promoting sustainable freight transport across Europe; and provided strategic recommendations for enhancing EU-wide multimodal logistics systems, ensuring better efficiency, sustainability, and integration

The focus of the research -the intermodal transportation system in the EU.

The subject of the analysis is the factors effecting the efficiency and sustainability of intermodal logistics, including policy, technology and infrastructure.

Literature review

Over the past decade, intermodal transport has significantly expanded throughout the EU. Rokicki et al. (2021) examined this growth across EU nations between 2008 and 2019, intermodal transport significantly rose particularly when analyses in ton-kilometers. The study also highlighted a drop in concentration, which suggests that member states are adopting it more extensively.

Šakalys and Palšaitis (2006) focused on the new EU member states, highlighted key measure for intermodal transport development such as adoption of innovative technologies, infrastructure modernization and establishment of logistics centers. They also provided recommendations on how to encourage intermodality to both European Commission and national governments. EU policies that promote sustainable mobility, improve cross border logistics, and achieve mode balance have significantly influenced the growth of intermodal transportation in the EU. Since the early 2000s, EU has highlighted the need to shift freight from road to rail and inland waterways which are more sustainable with frameworks like the European Green Deal (2019) and the White Paper on Transport (2011) (European Commission, 2011; European Commission, 2019).

Intermodal Freight transport in EU nations increased steadily from 2008 to 2019, with countries like Germany, the Netherlands, Belgium setting the standard for both modal integration and infrastructure (Rokicki, Perkowska & Perkowski 2021). Their longitudinal analysis highlighted general increase in intermodal ton- kilometers and a gradual decentralization of market concentration, showing wider adoption across member states.

The role of digitalization and harmonized logistics was emphasized in promoting the growth of intermodal freight transport (Liedtke & Wittenbrink 2020). Their research found that the interoperability between modes of transport has increased as the outcome of EU-backed pilot initiatives like Shift2Rail and Digital Transport and Logistics Forum (DTLF), particularly through e-documentation tools and real-time tracking.

Simultaneously, research like Pernille et al. (2019) and Gnap & Surovcik (2015) have underscored the significance of public-private partnerships and stakeholder collaborations. These partnerships have been essential in establishing new terminals, expansion of rail freight capacity, and the introduction of cutting-edge technologies such as autonomous handling equipment and intelligent container routing.

Challenges in intermodal transportation

One of the most cited challenges is the absence of infrastructure harmonization among EU member states. Inefficient cargo flows and lengthier transit durations are caused by the disparity in infrastructure quality between Eastern and Western Europe (Islam & Dinwoodie 2019). In multimodal integration, poor last-mile connectivity remains a hurdle, especially between rail terminals and major highways (Liedtke & Wittenbrink 2020).

Additionally, a major barrier to the efficient operation of intermodal transportation is regulatory fragmentation. Each member state upholds unique technical standards, safety regulations and administrative procedures which complicates cross-border logistics. This lack of harmonization raises transaction costs and delays, particularly in interoperability and custom clearance (Macharis & Van Mierlo 2017).

Poor coordination and lack of strategic alignment leads to the dispersion of stakeholder interests, involving trucking companies, public agencies, rail operators and terminal authorities. Panagakos et al. (2020) argues that this misalignment frequently leads to underutilized infrastructure, overlapping investments and trouble in achieving economies of scale.

Despite its growth, intermodal transportation confronts several obstacles across the EU. Turi et al., (2024) analyzed Romania's intermodal sector identifying challenges like poor connectivity, terminal congestion and insufficient public investment.

Macharis and Bontekoning (2004) evaluated operational research contributions to intermodal transport, emphasizing the necessity of strategic planning and optimization to resolve inefficiencies and enhance system performance.

Lastly, the growth of infrastructure in outlying or less economically developed areas is constrained by financial barriers like high initial investments of equipment and intermodal terminals. To close this financial gap, Pernille et al. (2019) highlighted the need of public-private partnerships and long-term policy support.

Policy implications and competitiveness

Intermodal freight competitiveness is greatly impacted by transport policies. Macharis et al., (2014) examined Belgium's transport policies highlighting the ways in which subsidies, terminal locations and internalization of external costs impacts the appeal of intermodal choices.

Taking into notes both internal and external considerations, Janic (2007) examined the total costs of intermodal versus road freight transport. The study concluded that intermodal transport might become more competitive by internalizing external costs.

A recent study by Bergqvist and Monios (2021), points to the 'institutional asymmetry' between the peripheral regions and the main EU transport routes. They argue that whereas policy like TEN-T has been successful in boosting investments in strategic corridors, they have also widened the development gap for smaller nations and less connecting areas, weakening overall intermodal competitiveness.

Furthermore, Aljhoni and Thomson (2019) highlight the need for multi-level governance in designing policies, especially for urban intermodal integration. Stakeholder uncertainty and fragmented implementation strategies arise from local policies pertaining from zoning, truck access, and noise regulations frequently clashing with national or EU level transport aims.

Another obstacle identified in the literature is the absence of performance-based evaluation frameworks for assessing the efficacy of policy interventions. Nikitas et al. (2021) suggested developing harmonized KPI's (Key Performance Indicators), for inter modal policy evaluation, which would improve transparency and enable data-driven modifications over time.

In response to these challenges, Bosch and Kuipers (2020) propose a more participatory approach to EU transport policymaking. Their research shows that the chances of policy acceptance and long-term competitiveness are significantly increased when industry stakeholders, city authorities, and logistics companies are included early in the planning process.

Technological innovations and Digitalization

Digital technology integration plays an important role in the development of intermodal transportation. Kine et al. (2022) conducted a systematic evaluation of enabling technologies, identifying the extensive use of wireless communication, sensors and web-based platforms. They also discussed how these technologies can potentially be used in low-income nations.

Caris et al. (2013) put a new research agenda emphasizing on decision making support systems in intermodal transport, highlighting the importance of information and communication technologies in improving decision making processes.

Gupta and Singh (2021) state that blockchain technology is gaining traction in intermodal transport for its ability to enhance traceability, eliminate document fraud and boost trust in logistics network. Similarly, operators can do predictive maintenance and dynamic rerouting by using IoT based telematics systems to track container status, location and conditions in real-time (Chpra & Sodhi 2019).

Gonzalez Feliu & Morana (2020) emphasized that digital twin technology is being investigated to improve capacity planning and stimulate intermodal terminal operations. These stimulations can optimize with contingency planning, bottlenecks predictions, and space utilization, especially for large-scale multimodal hubs.

Automation also plays an important role in enhancing terminal efficiency. Pan et al. (2020) discovered that automated cranes, autonomous guided vehicles (AGVs) and robotic handling systems can drastically reduce Labour costs and turnaround times, although costly capital investment remains an obstacle in widespread adoption in small and mid-sized terminals.

Despite technological advancements, lack of standardization and interoperability remains a major obstacle. Data sharing among many stakeholders and transport modes is difficult since many logistics systems still function in silos. Smaller businesses often struggle to meet the technical and financial requirements for digital adoption (Zuidwijk & Veenstra 2020).

Sustainability and Environmental considerations

It has been demonstrated that intermodal transport can reduce its effects on environment. In their examination of sustainability, Behrends and Floden (2012) explored the facts that shifting freights from road to intermodal can significantly reduce the impact of greenhouse gas emissions and congestion.

Janic (2008) assessed the performance of European long intermodal trains, emphasizing their environmental advantages and efficiency.

According to Chowdhury & Srai (2021), the system's operational efficiency and technical maturity have significant impacts on environmental benefits of intermodal transportation. The advantages of sustainability may be undermined by inefficient transshipment procedures and outdated terminal equipment because of increased fuel consumption and larger cargo idling times.

Urban sustainability has also gained attention. Russo and Comi (2020) state that intermodal transportation can reduce last-mile emissions and alleviate urban congestion. This is particularly important for urban dense centres where intermodal terminals are located near ports and rail hubs.

Christodoulou and Christidis (2021) highlight the importance of integrating of environmental indicators into the formulation of transport policy. They propose assessing infrastructure projects and funding eligibility using performance based environmental indicators, like emissions per ton-kilometers.

Challenges remain, however, Woxenius (2021) argues that if intermodal terminals infrastructure development is not controlled within a broaden sustainability framework, it may contribute to biodiversity loss and land use conflicts.

Furthermore, Tsamboulas et al. (2016) warns that sustainability goals must be linked with political wills and long-term investment strategies, particularly in less developed EU regions.

Operational Efficiency and Infrastructure

For intermodal transportation to be successful, operational efficiency is crucial. Ishfaq and Sox (2010) investigated how operational, financial and service issues in intermodal logistics concluded that resolving these challenges is essential for enhancing system performance.

Limbourg and Jourquin (2009) concentrated on optimal locations for rail-road terminals in Europe, emphasizing the need of strategic infrastructure placement for enhancing intermodal transport efficiency.

In benchmarking research on European intermodal terminals, Oliveira and Santos (2021) discovered wide variability in terminal efficiency, especially between Western Europe and developing regions of Eastern Europe. Their study underlined the need for standardized Key Performance Indicators to measure throughput, reliability, and service quality across terminal operations.

The lack of automation in small and mid-sized terminals imposes another challenge. Pan et al. (2020) report that, automated stacking cranes, self-driving vehicles and smart sensors can significantly lower human error, enhance handling speed and reduce operational costs. However, widespread deployment is limited due to high investments costs and lack of technical capacity.

Last but not least, Gonzalez-Feliu & Morana (2020) highlights the role of simulation tools and digital twins in improving infrastructure planning. Planners can anticipate congestion, and assess different investment scenarios in advance.

Methodology and Research methods

The philosophical orientation of this research is *interpretivism:* it emphasizes the subjective nature of reality and the importance of understanding social phenomena through the perspectives of the research participants. This research adopted a *qualitative research design combining systematic literature review, case study analysis and semi-structured interviews* to examine key challenges and opportunities in the intermodal transportation in the EU.

Systematic literature review was conducted to investigate the theoretical and empirical foundations of the intermodal transportation. WOS, Scopus and many peer reviewed journals were used to identify challenges and opportunities.

The selection criteria included relevance to intermodal transport in the EU, publications within the last 20 years, and contribution to key subjects like policy frameworks, sustainability and technology integration.

Table 1 presents the main criteria of the systematic literature review that served as the conceptual basis-framework for the research.

Table 1. Main Criteria of Systematic Literature Review: Conceptual Framework

Themes/ Codes	Key Findings/ Descriptive result and interpretation in text	Implications/ Criteria to be addressed
1.Challenges in Intermodal Transportation	Fragmented regulations, infrastructure disparity and lack of coordination between modes	Need for harmonized standards and collaborative planning mechanisms.
2. Policy implications and competitiveness	Policies impact modal shift and competitiveness, differential enforcement weakens integration	Stakeholder participation and harmonized policy frameworks are essential for competitiveness.
3. Technological innovations and digitalization	Digital tools like IoT, blockchain and automation are transforming operations, but adoption varies	All EU regions must invest in digital trainings and compatible systems.
4. Sustainability and Environmental considerations	Intermodal transport reduces emissions but depend on cleaner energy use and system efficiency	Integration with financing, policy and technological advancements is necessary for sustainability.
5. Operational efficiency and Infrastructure	Infrastructure performance is uneven, Terminal location and automation are key drivers	Efficiency requires performance measurements and strategic infrastructure investments.

Sample Justification

The cases for this study were selected based on their relevance to the research objectives of assessing the efficiency and sustainability of intermodal transport in the EU. The selected cases include Germany, Poland, Spain, the Netherlands and Italy that represent both successful implementations and ongoing challenges in integrating multimodal logistics systems. This diversity allows for a comprehensive analysis of the barriers and opportunities for intermodal transport across different EU contexts.

Furthermore, the *data sources* were chosen for their reliability and the availability of detailed information on policy, infrastructure, and technology, ensuring that the study provides an accurate reflection of the current state of intermodal transport in the EU.

Research Instrumentation

This study employed *semi-structured interviews* as the primary data collection method. Semi-structured interviews allow for flexibility in data gathering, providing participants the freedom to elaborate on their experiences and insights while ensuring that specific research questions are addressed. A questionnaire was used as a guide to ensure consistency across interviews and to capture relevant data on the technological, operational, and regulatory dimensions of intermodal transport in the EU.

The *criteria for participants (Experts) selection* were based on their direct involvement with or expertise in intermodal transport. Specifically, 10 experts from various sectors of the transportation industry were selected based on the *following indicators:*

- *Professional Role*: Informants included policymakers, logistics managers, and sustainability consultants with direct experience in intermodal transport operations, regulation, and environmental sustainability.
- *Experience:* Informants had 2-5 years of professional expertise in their respective fields, ensuring they could provide informed and relevant insights.
- *Educational Background:* held advanced degrees in fields such as business administration, logistics, public policy, or transportation, ensuring a high level of knowledge and competence.

Logic and Design of the Research

The design of this research follows *a qualitative approach* aimed at gaining in-depth insights into the challenges and opportunities of intermodal transport in the EU.

The *semi-structured interview design* allows the researcher to explore specific areas of interest while maintaining the flexibility to follow up on emerging themes or responses. This approach facilitates a rich understanding of the factors influencing efficiency and sustainability within EU intermodal logistics systems.

The research logic is grounded in the assumption that expert perspectives will provide valuable context and reveal the operational, institutional, and technological barriers to achieving seamless multimodal integration.

Additionally, expert opinions will inform an understanding of the role of EU policies and regulations in shaping the future of intermodal transport.

The research process was guided by *descriptive research design.* It should be stressed that the main purpose of a descriptive research design is to describe the situation or case of the research object.

This methodological approach served us as the most appropriate and reflective of our research question.

Presentation of the Research Procedure

Participants: 10 experts in the field of intermodal transport were selected, including 4 policymakers, 3 logistics managers, and 3 sustainability consultants.

Data Collection Method: The interviews were conducted virtually using the Zoom platform to accommodate geographical dispersion and overcome practical limitations. Each interview lasted between 45 to 60 minutes, providing ample time for in-depth discussion.

Timing: Interviews were conducted between June and July 2024, a period during which the industry faced several significant regulatory changes in the EU, allowing the research to capture current perspectives on emerging challenges.

Interview Structure

The semi-structured nature of the interviews allowed for flexibility in responses, while the questionnaire ensured that *core topics* such as **policy**, **technology**, and **logistics** were consistently addressed.

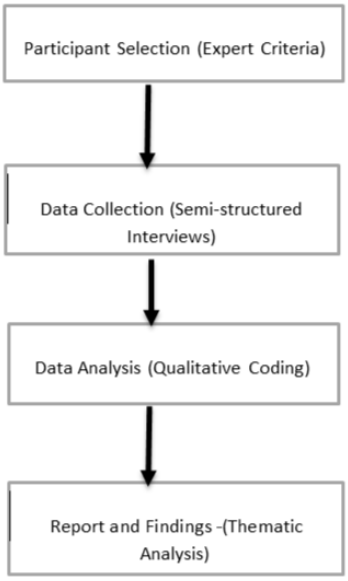

Fig. 1. Research Design and Process Flow

Content Analysis: Interview Data, Coding, Categories, and Sub-Categories

Data Analysis Method

A *thematic analysis of interview transcripts* followed Braun and Clarke's six-step approach. This involved:

Reading and rereading the transcriptions constituted the first step of data familiarity.

Initial codes emerged from scanning meaningful parts of the data.

A researcher develops *themes through the process of collecting similar codes into group*s.

The researcher *conducts theme assessment which leads to the finalization of appropriate themes*.

Defining and naming themes. The final report contained participant themes together with their quotations.

Categories and Sub-Categories Identified: The theme development process alongside coding methods resulted in identifying four distinct areas with their corresponding *sub-categories*. *Regulatory Barriers*: National policies do not match up across EU borders which results in failure to coordinate intermodal transport systems between different member states. Quantum bureaucracy triggers unacceptable time delays when project execution occurs because of prolonged decision processes together with entangled

regulatory paperwork. *Technological Opportunities:* Digital Platforms represent the combination of IoT technology and blockchain capabilities for monitoring and improving product delivery routes. Actively managed vehicles and robots possess the ability to enhance operational efficiency in intermodal logistics routes. *Coordination Challenges*: The integration between transportation networks remains inadequate because transport modes lack proper physical connectivity together with inclusive digital capabilities. Public and private entities fail to maintain alignment during intermodal transport operations. *Sustainability Considerations:* Intermodal transport serves as an important factor for lowering carbon emission levels. Intermodal transport serves as an important factor for lowering carbon emission levels. *Green Technologies:* Adoption of sustainable technologies, such as electric trucks or biofuel-powered ships.

Table 2. Summary of Key Challenges, Opportunities, and Implications in EU Intermodal Transport

Theme	Category	Example Quote
Regulatory Barriers	Divergent safety and customs rules causing delays	National-level differences in safety standards are a major cause of inefficiency.
Technological Opportunities	IoT platforms and automation enhancing logistics	Automation will be the future, but we lack standard infrastructure right now.
Coordination Challenges	Lack of multimodal terminals and investment misalignment	Private and public sectors do not align their investment strategies effectively.
Sustainability Considerations	Green technologies (electric trucks, biofuel vessels)	More funding is needed to make sustainable transport practical across all regions.

Results and Discussion

The most common obstacle operating across EU member states emerged from diverse **regulatory systems existing independently**. Participants recognize that variable safety requirements together with emission standards and customs rules result in major operational delays which hurt transport efficiency between countries. The participants identified bureaucratic delays as a major problem since extended review periods for infrastructure planning and environmental implementation required to complete intermodal solutions.

Technological Opportunities: Multiple experts considered digital platforms and IoT systems as major logistics optimizers that improve real-time coordination capabilities. Standardized systems must exist between modes to accomplish full integration. The industrial sector viewed automation as a promising technology of the future. Various participants anticipated automated systems to appear in port terminals and self-driving trucks but the readiness of underlying infrastructure was considered uncertain.

Coordination Challenges: The lack of sufficient infrastructure proved to be the main reason organizations faced coordination challenges. A lack of multimodal terminals which should connect rail transport, road transport and maritime transport interfered with effective cargo transfer between EU member states. Public and private stakeholders faced limitations in their successful coordination due to non-aligned investment strategies and regulatory frameworks.

Sustainability Considerations: The group affirmed that intermodal transportation offers considerable emission reduction benefits mainly through rail and maritime transport substitution of road transport services. The participants stated that sustainable technology infrastructure needed better support because existing facilities were insufficient for electric vehicles and green ports. Green technological initiatives along with specific measures such as electric trucks and biofuel-powered vessels received high importance from study participants. Exponents of sustainable technology stressed that both financial support and government backing would enable these solutions to become practical options.

Conclusion

The **central research question** asked: *"How can the European Union enhance the efficiency and eco-friendliness of its intermodal transportation systems amidst existing logistical, regulatory, and technological challenges?* To answer this, the study pursued the **objectives** to arrive at the conclusion below.

The analysis discovered that members across the EU understand the strategic value of intermodal transport yet they have unsuccessful in bringing the system together at a national level. The differences between structural infrastructure and investment distribution across member states obstruct the development of a single network. The research investigates obstacles at operational, institutional and technical levels which obstruct successful multimodal coordination. Multiple sources from interviews and literary evidence revealed that fundamental obstacles in intermodal collaboration persist because member states maintain incompatible regulations and digital systems are not compatible between platforms and terminals and networks do not integrate well. The research evaluates how the Internet of Things (IoT) functions to enhance intermodal coordination. Expert interview thematic analysis exposed IoT as a powerful tool for real-time data sharing and predictive logistics while standards and governance policies act as obstacles. The examination investigates how environmental regulations together with EU policies affect sustainable freight transport. The Green Deal along with the Sustainable and Smart Mobility Strategy under EU-

wide programs has accelerated the progress toward greener transportation. Different regions execute practical implementation of these rules at highly different levels. The paper presents strategic advice for maximizing the effectiveness of EU-wide combined logistics system operations. The suggested strategic paths to enhance EU-wide logistics include the creation of connected digital networks and unified regulatory frameworks as well as raising public-private partnership involvement and establishing dry ports and intermodal terminals.

Recommendations

The following strategic recommendations stem from this research work to solve existing complications while maximizing intermodal transportation benefits across the European Union domain. These recommendations were developed to meet the needs of **four stakeholder groups: EU institutions, national policymakers, infrastructure investors and private sector logistics actors.**

Investment in Infrastructure Modernization

The target audience consists of EU Commission along with National Transport Ministries and Infrastructure Development Agencies. Targeted and substantial investment leads to the necessary improvement of infrastructure to eliminate operational bottlenecks and capacity constraints. Intermodal terminals require improvements which boost their efficiency when handling large volumes. Vertical expansion of rail freight systems through modernization projects that include both electric utility power and double-track lines. The necessary investment aims to develop improved transportation connections between ports and terminals and inland logistics facilities. Boosting physical infrastructure enables better speed reliability in transport services while creating conditions that will propel people to shift their transport options to rail or water.

Harmonization of Regulations across Member States

The target recipients of this proposal are EU Legislators together with European Council members and National Regulatory Bodies. Create and establish uniform rules that control the following aspects: Safety, emissions, and transport documentation. Customs procedures and digital compliance requirements. Standards for intermodal equipment include containers as well as handling machinery. Regulatory standardization guides industry towards reduction of administrative obstacles and delivers seamless cross-border activities as well as optimized European market logistics processes. Speed up transformation procedures that enhance intermodal logistics.

Operations EU Digital Strategy Units together with Transport Ministries and Logistics IT Developers make up the target audience for this proposal. Actions should include: The integration of both real-time data platforms and tracking systems should receive organizational support. Logistics planning together with freight handling operations will benefit from increased implementation of AI and IoT and automation systems. Organizations should establish common cyber security requirements and interoperability standards between different transport systems. The modern multimodal logistics system requires digital transformation because this enhancement creates better transparency alongside effective efficiency and predictive decision capabilities.

Support developments for dry ports and hinterland terminals throughout the nation

The target groups consist of Regional Development Authorities, Port Authorities together with Private Investors. Stimulate dry port development through: Public funding, incentives, and regulatory facilitation. Enhancing rail-road exchange system operations between seaports and interior consumption areas. National and EU Transportation Network-Tangent program administrators should integrate dry port facilities into their planning as part of corridor development. Dry ports serve a dual purpose by easing port congestion and by providing remote distribution centers for previously unreachable lands.

Foster Public-Private Collaboration and Knowledge Exchange

The target recipients include Logistics Companies together with Industry Associations and Municipal Governments and Research Institutions. Develop collaborative mechanisms such as: Sustainable transport infrastructure receives funding support through coordinated investment plans which unite different entities. Interdisciplinary platforms will help organizations to match their approaches and build multi-modal answer sets together. Shared innovation hubs for testing new technologies and sustainable practices. The implementation of intermodal transport needs public-private entities to work together for shared infrastructure ownership and combined resources and collaborative innovative efforts.

Strategic intermodal development needs to match requirements of the EU Green Deal initiative

The target group includes directorates from the EU Climate and Transport divisions together with Environmental NGOs and Urban Planners. The efforts to develop intermodal transport must enact the following functions: CO_2 emissions reduction targets. Urban air quality improvements and congestion mitigation. Every region must have equal opportunities to use sustainable transportation systems. Intermodal systems remain essential for the EU to reach its 2050 climate neutrality goal therefore these systems must follow long-term sustainable development paths.

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SPECIFIC FEATURES OF THE RENEWAL OF PROCESS IN CIVIL AND ADMINISTRATIVE PROCEEDINGS

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Abstract
Court decisions are acts of justice and protection of human rights, which, once they have entered into force, must be complied with by all persons, institutions, organizations and public authorities. However, in order to maximize the protection of personal rights and minimize possible errors in court procedural decisions, the legislation regulating court proceedings provides for a number of forms of verification of the legality and reasonableness of court procedural decisions. In applying the renewal of process, as an exceptional stage of court proceedings, it is important to ensure the protection of legal stability, legal certainty, the protection of the rights and fundamental freedoms of persons acquired by final judgments, and the stability of the substantive legal relations established. Convention for the Protection of Human Rights and Fundamental Freedoms the right to a fair trial, guaranteed by Article 6(1) of the Convention, emphasizes one of the essential elements of the principle of the rule of law: the principle of legal certainty, which implies respect for the principle of res judicata (the court's having finally settled the matter, i.e. the prohibition of an identical action). This principle requires that, once the courts have finally settled a dispute, their decision must not be called into question, thus ensuring the stability of relations. The grounds for reopening proceedings as an exceptional stage must therefore be applied informally and in accordance with the principle of legal certainty, so that reopening of proceedings is possible only for the correction of fundamental errors in important and compelling circumstances.
The article presents and discusses on the institute of reopening of proceedings in civil and administrative court's proceedings from a comparative perspective, the main procedural peculiarities of this type of issues in different jurisdiction courts, and draws certain conclusions on the main topics of the renewal of process in both civil and administrative cases. A comparison of the procedural laws governing civil and administrative proceedings and the case-law developing them shows that the essential provisions of the institute of reopening of proceedings make this stage of the proceedings exceptional and optional. The definiteness and clarity of the legal regulation guarantee that this stage of the proceedings complies with the provisions of the Convention on the guarantee of the right to a fair trial.
KEY WORDS: reopening of proceedings, renewal of process, judicial proceedings, civil proceedings, administrative proceedings.
JEL classification: K1, K10, K19

Introduction

The aim of every legal proceeding is to do justice at trial. However, after a case has been heard and the judgment has become final, various new circumstances may arise which call into question the judgment and its fairness or the adequacy of the proceedings. Only after the trial has been concluded may it become apparent that a party has given false explanations, or that a forensic expert has given a false opinion on which a particular judgment was based. It may also be only after the judgment has become final that it becomes apparent that the case was heard by an unlawful tribunal or that the party against whom the judgment was given was not involved in the proceedings or was unaware of the proceedings. In such cases, it is necessary to reassess the case in the light of the new circumstances and to ensure that the case has been correctly dealt with by removing any appearance of illegality or unfairness in the judgment. The legal rules governing the institution of reopening of proceedings must be interpreted and applied in the light of the aims and objectives of that institution, which means that proceedings must be reopened if there are grounds for believing that the circumstances referred to in the application for reopening of proceedings, which are identified as grounds for reopening of proceedings, may render the procedural judgments of the courts rendered in the case unlawful and unfounded. The Court has noted that any plea in law relied on for the purpose of reopening proceedings must be analyzed in the context of the totality of the circumstances of the case, in order to answer the question whether the plea relied on for the purpose of reopening proceedings gives rise to a reasonable doubt as to the lawfulness and reasonableness of the procedural judgments rendered in the case (see, e.g, Ruling of the Supreme Court of Lithuania, Civil Cases Division of 30 October 2007 in civil case No 3K-3-451/2007; Rulings of the Supreme Administrative Court of Lithuania 7 August 2018 in Administrative Case No. eP-33-556/2018; ruling of 20 September 2023 in administrative case No eP-56-520/2023, etc.).

In 2023, 189,922 cases were received and 190,789 cases were heard in Lithuanian district, regional (first instance) and regional administrative courts (193,001 cases were received and 191,729 cases were heard in 2022, 188,767 cases were received and 190,888 cases were heard in 2021). Of these, 143 893 civil cases were heard in district courts, 3 779 civil cases were heard in regional courts, 2 121 civil cases were heard in the Court of Appeal of Lithuania and 330 civil cases were heard in the Supreme Court of Lithuania in the same calendar year. Meanwhile, 22 453 administrative cases will be heard in 2023 in district administrative courts and 3 199 administrative cases will be heard in the Supreme Administrative Court of Lithuania. As regards the requests for reopening of proceedings, it should be noted that in 2023, 68 requests for reopening of proceedings in closed administrative

cases were received at the Supreme Administrative Court of Lithuania, but only 5 were granted. For example, the Vilnius City District Court, the largest court in Lithuania, dealt with 69 applications for reopening of proceedings in 2023, 25 of which were returned to the applicants for various reasons, 25 were refused, 15 were reopened and 4 were dismissed.

The Constitution and laws of the Republic of Lithuania establish the validity and immutability of a final court decision, which ensures the stability of the relations resulting from the court decision and the protection of human rights and fundamental freedoms. Since it is the court's prerogative to carry out the function of justice entrusted to it by the Constitution of the Republic of Lithuania, and since final judgments must be enforced, the reopening of court proceedings is an exception to this process, which provides an opportunity, on the basis of grounds expressly laid down by law, to assess whether there are grounds for reviewing a final judgment, and in some cases for revising it by modifying it, or even by setting aside the judgment, and issuing a new judgment. However, the reopening of the proceedings may be prejudicial to the interests of the persons involved in the case in whose favor the judgment was given, may infringe the established principle of legitimate expectations, and may, in general, call into question the validity of the judgment and the existence of human rights protection. In such cases, the stability of established legal relations and legal certainty may be undermined and confidence in final judgments undermined.

The aim of this article is to analyze the main peculiarities of the legal regulation of the stage of reopening of court proceedings in civil and administrative proceedings by means of a comparative method and to draw the following conclusions from it. The object of the study is important because the renewal of proceedings, by its very nature and the application of this institute, may disturb the stability and immutability of a final judgment.

The object of the article is the peculiarities of reopening of proceedings as an exclusive stage of court proceedings and an exclusive form of control over the legality and reasonableness of procedural decisions of courts, both in civil and administrative proceedings.

The article uses the methods of analysis of legal acts, analysis of legal doctrine, synthesis, comparison and generalization. The method of quantitative and qualitative analysis of the examined cases was used in the analysis of the case law.

Theoretical Background

The reopening of proceedings is an independent stage in the judicial process, aimed at ensuring that the legality of the proceedings is guaranteed and that justice is done, as a fundamental duty of the court. It is a review of judgments which have already become final and is used when all other possibilities of verifying the legality and reasonableness of a decision in the event of doubt have been exhausted. It is not a mandatory stage of the judicial process and its use is therefore essentially discretionary, i.e. it may be invoked by the parties to the proceedings or by third parties by submitting applications for the reopening of proceedings in accordance with the procedure laid down (the exception in administrative proceedings will be discussed later). The essence and objectives of this institution are identical in both civil and administrative proceedings and, in accordance with the distinguishing features and the concepts formulated, this form of review of judgments may be defined as an exclusive form of review of final judgments, an optional stage of the proceedings and the only possibility of reviewing the lawfulness and reasonableness of the judgment in the event of doubts about it, on the basis of the grounds provided for by law.

Reopening of proceedings is not a cassation review, but an exceptional procedure, one of the aims of which is to achieve the greatest possible objectivity in the examination of cases by identifying the relevant criteria which may objectively give rise to the presumption that the case may have been wrongly decided. The establishment of strictly defined grounds for reopening proceedings is not an end in itself, but is necessary in order to safeguard the stability of legal relations, to implement the principles of legal certainty and the rule of law, since the absence of strict grounds for reopening proceedings would lead to a situation in which reopening of the proceedings would effectively become another ordinary stage of the proceedings, which would be contrary to the concept and objectives of the judicial system existing in Lithuania, and would diminish the significance of the final judgment. The task of the reopening of proceedings is not to directly review the actions of the lower courts, but to answer two questions: whether or not the grounds for reopening of proceedings set out in the law are present, and if they are present, whether or not they have had any impact on the judgment (ruling) given in the case, and on the court proceedings themselves.

The reopening of proceedings is possible only in the context of a final procedural decision of the court and in order to avoid disturbing the stability of the legal relations established on the basis of the final judgment (order). The legislator has created the stage of reopening of proceedings not as an ordinary, but as an exclusive form of control over the legality and reasonableness of court decisions, protecting the coherence and stability of the entire legal order (Resolution of the Supreme Administrative Court of Lithuania of 24 November 2021 in administrative case No eP-62-629/2021). Although other forms of review of the legality and reasonableness of court decisions, such as appeal and cassation, help to ensure these objectives, the reopening of proceedings, as an exclusive stage of judicial proceedings, performs its own unique function in the mechanism of the implementation of justice. The independence of the stage is characterized by the list of individual legal grounds for its initiation, the circle of subjects who have the right to initiate this stage, and the special procedure for the reopening of the proceedings established by the legislator, including the time limits and the peculiarities of the procedure.

Unlike in the case of instance review (appeal or cassation), in the case of reopening of proceedings, the errors of the lower court are not assessed - the proceedings are reopened on the basis of circumstances existing at the time of the trial but unknown to the court that heard the case, criminal acts of the parties or judges who heard the case, or circumstances that have arisen after the trial.

The European Court of Human Rights (hereinafter "the ECtHR") has also referred to the institution of reopening of proceedings as an exceptional procedure and has stated in its case-law that the right to a fair trial, guaranteed by Article 6 of the Convention for the Protection of Human Rights and Fundamental Freedoms (hereinafter "the Convention"), has to be interpreted in the light of the Convention's preamble, which establishes the principle of the rule of law as a part of the common heritage of the countries that have applied the Convention. One of the essential elements of the principle of the rule of law is the principle of legal certainty (e.g. Sypchenko v. Russia, judgment of 1 March 2007 (Application No 38368/0434); Volkov v. Russia, judgment of 15 March 2007 (Application No 8564/02035). The ECtHR has clarified that the Convention does not guarantee the right to reopen proceedings and that, as a general rule, an exceptional procedure such as the examination of an application for reopening of proceedings does not fall within the scope of Article 6 of the Convention (see, for example, the judgment of 1 March 2014 in the case of Dybeku v. Albania (Application No. 557/12). However, if the case is being retried, Article 6 of the Convention also applies to the procedure in which the application to reopen proceedings was considered (e.g. the judgment in San Leonard Band Club v. Malta (Application No. 77562/01) of 29 July 2004). According to the ECtHR, the application was similar to a cassation appeal on interpretation of law.

Civil proceedings are governed by the Code of Civil Procedure of the Republic of Lithuania ("CPC"), Chapter XVII of which deals with the grounds and procedure for the reopening of proceedings in civil cases, while administrative proceedings are governed by the Law on Administrative Procedure ("LAP"), Part IV of which is specifically dedicated to the reopening of proceedings in the context of the administrative proceedings. The article will then discuss, from a comparative perspective, the specific features of the reopening of proceedings in these proceedings: the grounds for reopening proceedings, the content of the applications for reopening proceedings and the procedure for their submission and examination, the subjects entitled to submit applications for reopening proceedings and the course and procedure for the examination of applications.

Research analysis results

Grounds for the renewal of process

The grounds for reopening proceedings in civil proceedings are laid down in Article 366 of the Civil Procedure Code of the Republic of Lithuania. The grounds for reopening proceedings in administrative proceedings are laid down in Article 156 of the Law on Administrative Proceedings.

The proceedings in a civil case concluded on the merits of a dispute by a final court decision (judgment, order or ruling), as well as in an administrative case concluded by a final court decision or ruling, may be reopened only on the basis of the grounds laid down in the procedural laws, which guarantee the stability of legal relations and the security of individuals and the protection of legitimate expectations. Although a number of the grounds for reopening proceedings are analogous in the CPC and the ABT Law, these proceedings have their differences in relation to the grounds on which proceedings may be reopened.

Both civil proceedings and administrative proceedings may be reopened if it is established that there is a new discovery of material facts which were not and could not have been known to the applicant at the time of the hearing (Article 366(2) of the CPC; Article 156(2) of the ABT Law); that the case has been heard by a court with an unlawful composition (Article 366(8) of the CPC); that the case has been heard by an unlawful court with an unlawful composition (Art, Article 156(9) of the ABTIA); that the Constitutional Court of the Republic of Lithuania, when examining a request of a person referred to in the fourth paragraph of Article 106(4) of the Constitution of the Republic of Lithuania, declares that a law or other act adopted by the Seimas, an act of the President of the Republic or an act of the Government (or a part of such act), on the basis of which a decision infringing the person's constitutional rights or freedoms has been taken is unconstitutional (Article 366(10) of the CPC; Article 156(13) of the ABTIA). The proceedings shall also be reopened if one of the parties to the proceedings was, at the time of the proceedings, incapacitated in a particular field and was not represented by a legal representative (Art. 366(6) of the CPC, Art. 156(6) of the ABT Law). The other grounds for reopening the proceedings are partially identical or substantially different, which gives rise to the specificity of civil and administrative proceedings.

In civil proceedings, proceedings may be reopened when the ECtHR finds that judgments, rulings or decisions of the courts of the Republic of Lithuania in civil cases are contrary to the Convention and/or its Additional Protocols to which the Republic of Lithuania is a party, or when the ECtHR removes a pending petition from the list of cases on the basis of a peaceful settlement or unilateral declaration, if it is recognized by a friendly settlement or unilateral declaration that the rights of the petitioners under the Convention and/or its Additional Protocols to which the Republic of Lithuania is a party have been violated by the judgments, decisions or rulings of the courts of the Republic of Lithuania in civil cases (Art. 366 of the CPC) 1 p.). An analogous ground for reopening proceedings is also provided for in the ABT Law, but it is narrower and does not provide for such a wide range of cases for reopening proceedings after the adoption of the petition against Lithuania as civil proceedings, since administrative proceedings may be reopened when the ECtHR recognizes that a decision of a court in a case of the Republic of Lithuania is in conflict with the Convention and its Additional Protocols. However, the ABT Law additionally provides that administrative proceedings may be reopened if the United Nations Human Rights Committee recognizes that a decision of a court of the Republic of Lithuania has violated a right of a person under the International Covenant on Civil and Political Rights (Article 156(1) of the ABT Law), which is not provided for in the Civil Procedure Code. Another overlapping ground for reopening proceedings is where a final judgment has established that a party's or a third party's explanations, a witness's testimony, an expert's report which is notoriously false, a translation which is notoriously false, or the falsification of documents or physical evidence has been proven to be false or

unreasonable, and which has led to an illegal or unfounded decision (Art. 366 of the Civil Procedure Code (CPC)). 3), which is established in the ABT Law as a case where a final court judgment establishes a knowingly false testimony of a witness, a knowingly false expert opinion, a knowingly false translation, falsification of documents or physical evidence, which resulted in an unlawful or unjustified decision (Art. 156(3) of ABT Law). It should be noted that in administrative proceedings, false explanations by a party or by third parties would not constitute grounds for reopening the proceedings, since neither parties nor third parties are sworn in administrative proceedings and do not take an oath before the court. Article 366(4) of the CPC and Article 156(4) of the ABT Law also provide for relatively similar grounds for the reopening of the proceedings in relation to criminal acts committed by the parties to the proceedings in the course of the proceedings in the civil or administrative proceedings respectively. The CPC provides that proceedings shall be reopened where a final judgment of a court establishes criminal acts committed by the parties to the proceedings or by other persons involved in the proceedings, or by the judges, during the proceedings in question, while the ABT Law provides that a final judgment of a court establishes criminal acts committed by a party to the proceedings, a witness, a specialist, an expert, an expert or an interpreter or by judges during the proceedings in question. As can be seen, the legal norms are analogous in substance, but in terms of legal technique, the ABT Law is more specific as regards the persons involved in administrative proceedings: the concept of "party to the proceedings" in the ABT Law covers the parties to the proceedings and third interested parties, whereas the CPC concept of "party to the proceedings" covers both the persons having a substantive legal interest in the proceedings (the parties, third parties) and procedural interests in the proceedings (interpreters, forensic experts, reporting authorities, persons defending the public interest etc.).

Both the CPC and the ABT Law provide that proceedings may be reopened if a court decision or a verdict, which was the basis for the decision or ruling, is annulled as unlawful or unjustified (Article 156(5) of the ABT Law). However, the CPC additionally provides that proceedings may be reopened in the case of "any other act of an individual nature of the State or municipal authorities which was the basis for that decision, ruling or order". In administrative proceedings, an independent ground for reopening the proceedings is established in cases where "an individual legal act on the basis of which the court has decided the case is annulled as unlawful" (Article 156(11) of the Administrative Procedure Law). The concepts of 'act of an individual nature' and 'individual legal act' are similar in substance.

Also, the laws regulating civil and administrative proceedings provide for the reopening of proceedings in a case where the court has ruled on the rights or obligations of persons not involved in the proceedings in a substantially analogous manner (Article 366(7) of the CPC, Article 156(7) of the ABT Law). However, the CPC does not provide for any rights or obligations as grounds for the reopening of proceedings, but only for substantive rights and obligations established by a final judgment. This provision of the ABT Law is substantially extended by the practice of administrative courts: ABT Law 156 The ground referred to in Article 4(2)(7) is intended to ensure one of the fundamental principles of fair trial - the right to be heard, therefore, only the persons who have not been involved in the proceedings may initiate the reopening of the proceedings on this ground, and the proceedings shall be reopened on this ground when two essential conditions are established: (1) the persons applying for reopening of the proceedings have not been involved in the proceedings in which reopening of the proceedings is sought without sufficient grounds; (2) the procedural decision of the court has taken a decision concerning their rights and obligations (the procedural decision of the court infringes their rights or interests protected by law) (e.g., (i) the decision of the Supreme Administrative Court of Lithuania of 23 June 2020 in administrative case No. P-31-756/2020, 21 December 2017 ruling in administrative case No. P-78-858/2017).

Civil procedure law provides that proceedings may be reopened if a decision (judgment, ruling, order or decision) of a court of first instance contains a manifest error of law which may have contributed to an unlawful decision (judgment, ruling, order or decision) and the decision (judgment, ruling, order or decision) has not been subject to an appeal. It should be noted that Article 156 of the ABT Law does not directly provide for a substantially analogous ground for reopening the proceedings, but it does provide that proceedings may be reopened if there is clear evidence that there has been a material breach of substantive law in the application of the rules of substantive law, which may have contributed to the adoption of an unlawful decision or order (Article 156(10) of the ABT Law), or if the court decision or order is without reasons (Article 156(8) of the ABT Law). However, it should be noted that failure to state reasons for a judgment is an absolute ground for setting aside the judgment of the court in the event of an appeal (Article 146(2)(5) of the ABTIA). The inclusion of a possible independent ground in the administrative proceedings is due to the fact that, if the parties to the proceedings do not appeal against the decision of the Regional Administrative Court, the proceedings may be concluded in the court of first instance, and therefore the only possibility of reviewing the final decision of the administrative court may be the reopening of the proceedings.[i] . Meanwhile, the expression "manifest error of law which may have contributed to the adoption of an unlawful decision" used in the Code of Civil Procedure can be considered to be analogous in substance to the expression "manifest evidence of a fundamental error of substantive law in the application of the substantive law which may have contributed to the adoption of an unlawful decision" used in the Code of Administrative Procedure. However, in civil proceedings, there is no emphasis on which legal rule (substantive or procedural) is at fault, whereas in administrative proceedings it is envisaged that not any error, but an error in the application of a substantive rule of law, may be a ground for the reopening of proceedings in an administrative case.

In addition, it should be noted that proceedings in administrative proceedings may be reopened where it is necessary to ensure the formation of uniform practice of administrative courts (Article 156(12) of the

Administrative Procedure Law), which closely corresponds to the grounds for cassation in civil proceedings, as set out in Article 346(2) of the CPC. In administrative proceedings, the emergence of such grounds for reopening administrative proceedings is due to the fact that administrative proceedings do not provide for cassation. The administrative procedure itself is essentially aimed at reviewing the legality and reasonableness of administrative decisions taken by public administration[ii] entities and, by its very nature, the administrative procedure before the Administrative Court of the Regions[iii] is at the second stage (and sometimes at the third stage, e.g, The administrative decision[iv] which is challenged by individuals and which determines the rights and/or obligations of individuals or imposes other obligations or sanctions of a different nature, is adopted by a public administration entity and the individuals lodge a complaint with the court for its assessment. It is therefore important that the procedural law provides additional guarantees for individuals to seek a fair trial and justice, including by providing legal grounds for the reopening of proceedings and the removal of doubts as to the legality or validity of a decision, as appropriate, due to the specificities of the existing procedure.

As it can be seen, the lists of grounds for reopening proceedings in civil proceedings set out in both the ABT Law and the CPC are exhaustive, which means that in the event of the existence of at least one of the listed grounds, reopening of the proceedings in a civil or administrative case, which has been concluded by a final court decision, may be initiated and reopened by the court in accordance with the established procedure.

However, the legislation governing the procedure also provides for cases in which the procedure will not be reopened. Article 366(3) of the CPC provides for an exception to the inapplicability of the institute of reopening of proceedings in civil proceedings: an application for reopening of proceedings is not possible in respect of final judgments on the annulment of a marriage or on the dissolution of a marriage, if at least one of the parties has contracted a new marriage or registered a partnership after the judgment has become final. Nor can proceedings be reopened in bankruptcy and restructuring cases. It is important to note that in the cases referred to in Article 366(1)(6) and (8) of the CPC (where one of the parties at the time of the proceedings was incapacitated in a particular field and was not represented by a legal representative, and where the case was heard by a court of an unlawful composition), the proceedings shall not be reopened, provided that the applicant could have relied on those grounds in his appeal or cassation appeal. However, in administrative proceedings, an application to reopen the proceedings is not possible in administrative cases in which the municipal council's request for an opinion on whether a member of the municipal council or the mayor of the municipality (hereinafter referred to as 'the mayor'), who is the subject of a procedure for the forfeiture of his/her powers, has broken his/her oath of office and/or failed to exercise the powers conferred by law (as referred to in the application) is being examined. Nor can the proceedings be reopened in administrative cases in which the State Data Protection Inspectorate is seized of a request to refer to a competent judicial authority of the European Union a decision of the European Commission on the adequacy of the standard data protection clauses or on the universal validity of the approved codes of conduct.

The list of grounds for reopening proceedings, both in civil and administrative proceedings, is clearly established at the level of the law and is exhaustive, which guarantees the stability and certainty of the substantive rights and obligations of persons established by final court decisions. However, in administrative proceedings, there are more grounds for reopening proceedings, which may be due to the existence of a two-tier system of administrative courts and the absence of cassation in administrative proceedings.

Entities entitled to lodge an application for the renewal of process

The parties to the proceedings and their representatives, as well as persons not involved in the proceedings, have the right to file an application to reopen the proceedings if the judgment or order has become final and infringes their rights or interests protected by law. However, persons who are not parties to the proceedings may file applications for the reopening of proceedings only on the sole grounds provided for in the Law on Administrative Procedure 156 Article 366(1)(7) of the Code of Civil Procedure, namely, if the decision of the court has ruled on the rights or obligations of the persons excluded from the proceedings. Although the ABT Law does not specifically provide that third interested parties may file an application for reopening of proceedings, which is provided for in the CPC, the participants in the proceedings have this right by their very nature. As regards the persons defending the public interest, it should be noted that the CPC provides that only the Prosecutor General of the Republic of Lithuania, i.e. the most senior official in the Lithuanian Prosecutor's Office, may file applications for the reopening of proceedings in order to defend the public interest. Whereas, in administrative proceedings, a request for reopening of proceedings may be filed by any public prosecutor and even public administration entities in order to protect the public interest or to protect the rights and interests protected by the law of the State and of individuals, which results in a much wider range of persons who may apply for reopening of proceedings in a pending administrative case.

The Law on Administrative Proceedings also provides for the institution of the submission of an application to initiate the reopening of proceedings in an administrative case, which is completely neglected in civil proceedings. Exceptionally, on the proposal of the President of the Regional Administrative Court or on receipt of information that there may be grounds for reopening proceedings in an administrative case, the President of the Regional Administrative Court has the right to submit a request to reopen proceedings the Supreme Administrative Court of Lithuania the President of the Administrative Court. In such a case, the application by the President of the Supreme Administrative Court of Lithuania shall be examined by a panel of judges appointed by the judge with the highest seniority. However, the referral is only an informative proposal to consider whether there are grounds for reopening the proceedings and is not binding on the panel of judges. The most notable recent case in which the President of the Supreme Administrative Court

of Lithuania exercised his exclusive right to initiate the reopening of proceedings in an administrative case concerned the assessment of the publications of the port city news portal "Atvira Klaipėda" on public procurement in the context of the legal regulation of the protection of personal data.

There is also a significant provision in the administrative procedure concerning the importance of dissenting opinions of the judge. Where a case in which a dissenting opinion of a judge has been delivered has not been the subject of an appeal, or where the dissenting opinion has been delivered by a judge of the Court of Appeal, the case and the judge's dissenting opinion shall be remitted to the Court of Justice after the judgment has become final to the Supreme Administrative Court of Lithuania and its President shall decide whether to lodge a request to reopen the proceedings (Article 158(4) of the ABT Law).

The circle of persons entitled to submit applications for the reopening of proceedings is essentially the same in both civil and administrative proceedings, but in administrative proceedings there is the additional institution of the President of the Court of First Instance applying for the reopening of proceedings.

Drafting and procedure for submitting an application for renewal of process

According to the general rule laid down by the legislator, an application to reopen proceedings in a civil case must be lodged with the court of first instance that heard the case. However, certain exceptions are provided for. The first one is if the request to reopen proceedings is based on the grounds provided for in Article 366(1)(1) or (10) of the CPC (where the ECtHR finds that judgments, rulings or orders of the courts of the Republic of Lithuania in civil cases are contrary to the Convention and/or its Additional Protocols to which the Republic of Lithuania is a party, or when the ECtHR removes a petition from the list of cases on the basis of a peaceful settlement or unilateral declaration, if the peaceful settlement or unilateral declaration recognizes that the judgments, rulings or decisions of the courts of the Republic of Lithuania in civil cases have violated the Convention and/or its Additional Protocols, the rights of the applicants established by the Convention to which the Republic of Lithuania is a party in respect of judgments, rulings or decisions of the courts of the Republic of Lithuania in civil cases, and where the Constitutional Court of the Republic of Lithuania, when examining an application of a person referred to in the fourth paragraph of Article 106, paragraph 4, of the Satversme of the Republic of Lithuania, recognizes that a law or other act adopted by the Seimas, an act of the President of the Republic of Lithuania, or a government act (or a part of an act of the government), on the basis of which a decision violating the person's constitutional rights or liberties was taken, is unconstitutional, the application is referred to the Supreme Court of Lithuania). Where the application to reopen proceedings is based on the ground provided for in Article 366(1)(8) of the CPC (where the case was heard by a court with an unlawful composition), it shall be submitted to the court whose court with an unlawful composition heard the case. The application to reopen proceedings shall be dealt with in the same civil proceedings in which the application to reopen proceedings is made.

However, the law governing administrative court proceedings provides that the application for reopening of proceedings shall be made by the applicant or his representative, except in the cases referred to in Article 158(2) of the ABT Law, and that the application for reopening of proceedings shall be made directly to the to the Supreme Administrative Court of Lithuania. This Court is the only one which hears applications for reopening of proceedings in administrative proceedings, i.e. it has exclusive functional competence in these matters. The question of whether an application for reopening of proceedings has been admitted, as well as the question of whether an application for reopening of proceedings has been admitted, shall be examined by the Supreme Administrative Court of Lithuania by a panel of judges constituted by the President.

A request to reopen civil proceedings must be accompanied by evidence supporting the grounds for reopening the proceedings. The application itself must contain, in addition to the general requirements as to the content of the application: (1) the name of the court which delivered the judgment or order; (2) the grounds for reopening the proceedings; (3) the grounds for reopening the proceedings; (4) the circumstances on which the calculation of the time-limits referred to in Article 368 of the CPC is based; and (5) the applicant's application. An application for the reopening of civil proceedings shall be subject to stamp duty, the amount of which is set out in Article 80(4) of the CPC - the amount of stamp duty payable on an application for the reopening of proceedings shall be the same as the amount payable on an application for the bringing of an action (statement of claim in special proceedings), and the amounts of stamp duty payable on an application for the reopening of proceedings shall be calculated on the basis of the amount in dispute in cases of pecuniary litigation.

An application to reopen an administrative procedure is also subject to stamp duty, which is relatively low and fixed. In addition to the general requirements for procedural documents, the law provides that an application for the reopening of proceedings in an administrative case shall, as a procedural document, also state: (1) the substance of the judgment (ruling) which has become final and the grounds for reopening the proceedings; (2) the grounds for reopening the proceedings; (3) the circumstances on which the calculation of the time-limit for filing an application for reopening the proceedings is based; and (4) the substance of the application. The application for reopening of proceedings shall be accompanied by the evidence supporting the grounds for reopening of proceedings, a certified copy of the judgment (order) which has become final, and a document evidencing the representative's authority.

It should be noted that a special rule is laid down in the administrative procedure, which provides that if an application for the reopening of proceedings is made in accordance with the provisions of this Law 156 (2)(10) and/or (12) of Article 156(2) of the Law on Administrative Procedure (where there is clear evidence of a fundamental breach of substantive law in the application of the substantive law, which may have contributed to the

adoption of an unlawful decision or order, or where it is necessary to ensure the formation of uniform practice of administrative courts), the request for a restoration of the law shall be made by a lawyer. In the cases referred to in this paragraph, an application for the reopening of proceedings by a representative of the State or another legal person may also be drafted by employees of the legal person or by civil servants who have a higher university degree in law. Where the application for the renewal of process in the cases referred to in this paragraph is made by a natural person who has a university degree in law, he or she shall be entitled to make the application. In addition, an application for the renewal of process in these cases may be made by a person authorized by this Law 47 persons referred to in Article 4(4)(4) and (7) of this Law (persons with higher university legal education, where they represent their close relatives or spouse (cohabitant); or trade unions, where they represent trade union members in cases of legal relations in the service, and 126^8 in the case referred to in Article 126(1), by trade unions or associations. In the cases referred to in this paragraph, the proceedings shall be conducted before the court by the sole governing body of the trade union or association, by members of the collective governing bodies authorized in accordance with the procedure laid down by law or the instruments of constitution, or by representatives acting on instructions from employees (in the case of the court of appeal, university graduates) and/or lawyers (legal assistants). In such cases, the application for reopening of the proceedings shall be signed by the person lodging the application and by the person drawing up the application. The signature of the applicant shall not be required if it is signed by the person authorized by the applicant to draw up the application.

A repeated request to reopen the proceedings on the same grounds is not possible (Article 158 of the ABT Law, Article 374 of the CPC).

As can be seen from the comparative legal framework, both civil and administrative proceedings impose similar content and form requirements for the drafting of an application for the reopening of proceedings, but the law on administrative proceedings provides for special cases where professional representation is mandatory in the case of reopening of proceedings.

Time limits for lodging an application for renewal of process

An application for reopening of the proceedings may be filed within three months from the date when the person filing the application became aware or should have become aware of the circumstances which constitute grounds for reopening of the proceedings (Art.368 of the CPC, Art.159 of the ABT Law). The legislation also uniformly defines the limitation period for filing an application for reopening proceedings. An application to reopen proceedings in a civil or administrative case may not be made if more than five years have elapsed since the judgment or order became final. An exception is provided for in the cases referred to in Article 366(1)(1) of the CPC (where the ECtHR finds that judgments, decisions or rulings of the courts of the Republic of Lithuania in civil cases are contrary to the Convention and/or its Additional Protocols to which the Republic of Lithuania is a party, or when the ECtHR removes the petition in question from the list of cases on the basis of a peaceful settlement or unilateral declaration, if the peaceful settlement or unilateral declaration recognizes that the judgments, rulings or decisions of the courts of the Republic of Lithuania in civil cases have violated the Convention and/or its Additional Protocols, the rights of the applicants established by the judgments, rulings or decisions of the courts of the Republic of Lithuania in civil cases to which the Republic of Lithuania is a party) and the cases referred to in Article 156(2)(1) of the ABT Law (when the ECtHR recognizes that the decision of the court of the Republic of Lithuania in a case is contrary to the Convention and its Additional Protocols, or when the UN Human Rights Committee recognizes that the decision of the court of the Republic of Lithuania has violated the rights of an individual established by the International Covenant on Civil and Political Rights), which is in itself caused by the longer time limits of the examination of cases before these international courts (institutions).

It should be noted that the ABT Law additionally provides that persons who have missed the time limit for filing an application for renewal of proceedings for important reasons may have the missed time limit restored if the application for renewal of the time limit is filed not later than one year after the date on which the decision becomes final. The law also provides that the application

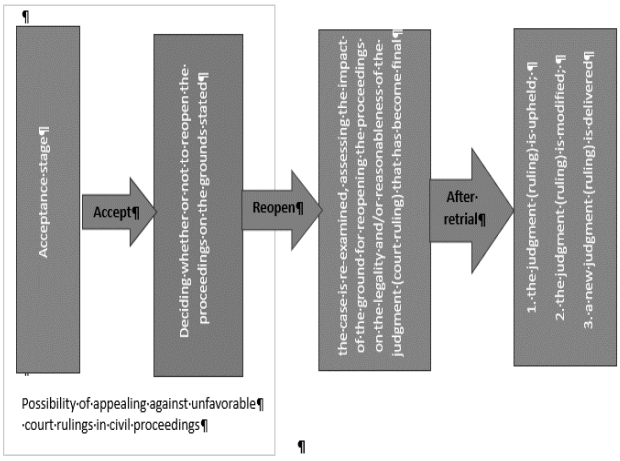

Fig. 1. Schematic outline of the general course of an application for the renewal of process

may not be amended or supplemented after the time limit for filing the application for reopening proceedings has expired. The Code of Civil Procedure does not provide for such rules. While this situation can be partly resolved by a systematic application and interpretation of the provisions of the CPC, the right to amend or modify the application for the reopening of the proceedings, as a provision limiting the rights of the parties to the proceedings, should be discussed separately in order to ensure that the proceedings are more concentrated and to safeguard the rights and interests of the other parties to the proceedings.

The time limits for filing applications for the renewal of process are identical in the court proceedings, as are the procedural possibilities for the resumption of the time limit.

Procedure for the admission and examination of an application for the renewal of process

A general scheme of the progress of an application for reopening of proceedings is shown in Figure 1.

When deciding whether to accept an application to reopen proceedings in civil proceedings, the court examines whether the application complies with the requirements for such a procedural document. If the application to reopen proceedings does not comply with the requirements as to its form and content or if the stamp duty has not been paid, the court shall decide on the question of remedying the deficiencies of the application. However, if the grounds provided for in Article 137(2)(1), (2), (2), (7) and (8) of the CPC are present (the dispute is not justiciable in a civil court; the court does not have jurisdiction over the action; the application has been lodged by a natural person who is incompetent to act in a particular field, or the application on behalf of the interested party has been lodged by a person who is not authorized to conduct the case), the court shall refuse to admit the application to reopen the procedure. An order of the court refusing to admit the application for reopening of proceedings may be appealed against by way of an individual appeal.

In administrative proceedings, Article 33 of the ABT Law (rules governing the admissibility of a complaint before a court) shall apply mutatis mutandis when dealing with the admissibility of an application. It shall also be verified whether the application complies with the specific requirements for an application for the reopening of proceedings laid down in Articles 157 , 158 , 159 and 160 of the Law on Administrative Procedure.

In civil proceedings, when the court accepts the application for reopening the proceedings, copies of the application are sent to the parties and third parties, and the court sets a date for the hearing of the application, which is not earlier than 14 days after the date of acceptance. Before the date fixed for the hearing, the persons involved in the proceedings shall have the right to lodge a statement of defense to the application for reopening of proceedings. As a general rule, applications to reopen proceedings shall be heard by written procedure, unless the court decides to hear the application by oral procedure. Where necessary, the court may require the applicant to furnish further evidence that the time-limit for lodging the application has not been exceeded or that the grounds for reopening proceedings provided for in Article 366(1) of the CPC are present.

When the court accepts an application to reopen proceedings in an administrative procedure, it shall send copies to the parties to the proceedings within 5 working days at the latest. The parties to the proceedings shall have the right to lodge a statement of defense to the application for reopening of the proceedings within fourteen calendar days of receipt of a copy of the application for reopening of proceedings. The court shall deal with the application for reopening of proceedings, once it has been admitted, by written procedure. When examining an application for the renewal of process, the administrative court shall examine whether it is based on the grounds for renewal of process laid down by law. If necessary, the court shall have the right to require the applicant to provide additional evidence on the aforementioned issues.

In the event that, after hearing the application to reopen the proceedings in a civil case, the court finds that the application was lodged within the time limit and is founded on the grounds set out in Article 366(1) of the CPC, it shall, by order, reopen the proceedings and fix a date for the hearing of the case or, by order, refuse the reopening of the proceedings, if it finds that the defects referred to in this paragraph exist. If, at the hearing at which the proceedings were reopened, it appears that no further preparation for trial is necessary, the court shall, with the consent of the parties to the proceedings, proceed to the examination of the substance of the case. Where proceedings are resumed, the grounds for resumption shall be stated in the order of the court. An appeal may be lodged against an order refusing to reopen proceedings, except where reopening of proceedings has been refused at the appellate or cassation instance. An order of the court of appeal refusing to reopen proceedings may be appealed against in cassation.

In administrative proceedings, however, where the court finds that the application is not based on the grounds for reopening the proceedings laid down in the law, the court will refuse to reopen the proceedings by order. Where the court finds that there were grounds for refusing to accept the application for reopening of proceedings, the court shall refuse to reopen the proceedings by order. Where the court finds that there are grounds for imposing a time-limit for the completion of the deficiencies in the application for reopening of proceedings, the court shall, by order, impose a time-limit for the completion of the deficiencies. If the deficiencies are not remedied, the court shall, by order, refuse to reopen proceedings. The above rulings of the Supreme Administrative Court of Lithuania are not subject to appeal.

If the application to reopen proceedings in an administrative case is made within the time limits laid down by law and is based on the grounds for reopening proceedings laid down by law, the court shall issue a decision on the reopening of the proceedings, which shall specify the administrative court that will hear the case on the merits. Once the court has issued an order for the reopening of proceedings, the case shall normally be referred back to the court of the same instance whose decision or order is being challenged for a fresh decision. In cases where the judgment or order appealed against was given after an appeal has been lodged, the case shall be reheard before the Supreme Administrative Court of Lithuania. Where proceedings in such a case have been reopened by this Law on the grounds referred to in Article 156(2)(10) or (12) (where there is clear evidence that there has been a material breach of substantive law in the application of the substantive law, which may have contributed to the adoption of an unlawful decision or order, or where there is a necessity to ensure the establishment of a uniform practice amongst the administrative courts), the case shall be referred by the Supreme Administrative Court of Lithuania to an extended panel of judges or to a plenary session for a fresh hearing.

Therefore, when a civil case is reopened, the court shall re-examine the case in accordance with the general rules of the CPC, but within the limits set by the grounds for reopening the proceedings. The legislator has laid down a strict limitation that the judge against whose judgment or order the proceedings are reopened may not be present

during the examination of the application for reopening of the proceedings and/or of the case in which the proceedings have been reopened.

The court, after examining the civil case in which the proceedings have been reopened, has the right to: 1) reject the application for amendment or annulment of the judgment (order); 2) amend the judgment or order; 3) issue a new judgment (order). Where the application to vary the judgment (order) is dismissed, the court shall make an order, and where the judgment (order) is varied or a new judgment (order) is given, the court shall give its judgment or order. If the court modifies the decision/order or issues a new decision/order, the previous court decisions/orders shall cease to have legal effect. At the same time, it is important to note that the filing of an application to reopen proceedings does not in itself suspend the execution of the judgment or order, but the court, at the request of the persons involved in the proceedings or other interested persons or on its own initiative, has the right to suspend the execution of the judgment or order pending the hearing of the case for reopening proceedings. In addition, the court may require the applicant to provide security for the claimant's loss which may result from the suspension of the judgment or order. An order made by the court suspending the execution of the judgment or order may be subject to an appeal by way of an individual appeal.

However, the law on administrative procedure states that, after the proceedings have been reopened, the proceedings shall be re-examined in accordance with the rules of procedure of the court of first instance, if the contested final judgment or order was delivered at first instance. If the judgment or order appealed against was given on appeal, the reopening of the proceedings shall be subject to the appeal procedure. The court shall deal with the reopened case within the limits set by the grounds for reopening the proceedings. Where, following the reopening of proceedings, the administrative court re-examines the case, it shall take one of the following decisions: (1) dismiss the application and uphold the judgment or order appealed against; (2) modify the judgment or order appealed against; (3) set aside the judgment or order appealed against and adopt a new judgment or order. In the first case, the order of the court shall be given; in the second and third cases, the judgment or order shall be given. If the administrative court adopts a new decision, it must also annul all previous court decisions in the case. The law makes it imperative that the judge whose decision or order is the subject of the reopened proceedings may not sit on the panel of judges constituted for the purpose of the reopening of the case, except the Supreme Administrative Court of Lithuania.

The filing of an application to reopen proceedings, as well as the court's order to reopen proceedings in an administrative case, does not suspend the execution of the contested decision or order. After accepting an application to reopen proceedings, the administrative court shall have the right to suspend the execution of the contested decision or order pending the hearing of the case for reopening proceedings. Where proceedings in an administrative case have been reopened, the execution of the contested decision or order may also be suspended pending the re-examination of the case. The order suspending the execution of the decision or order is not subject to appeal in this case.

Thus, the court first examines the question of whether to accept the application for reopening of proceedings. Only after the decision to admit the application for reopening of proceedings has been taken is the question of reopening of proceedings decided. Finally, only after the decision to reopen the proceedings has been taken, a hearing is organized for a review of the judgment within the framework of the grounds for reopening the proceedings. In civil and administrative proceedings, the procedure for applying for reopening of proceedings is essentially the same, but there are differences in the courts that hear applications for reopening of proceedings and the possibilities for applicants to appeal against procedural decisions of the court that are not to their satisfaction (e.g. a court's order refusing to admit an application for reopening of proceedings or not to reopen the proceedings). After the reopening of proceedings in administrative proceedings, the case may be re-examined by a different court from the one which decided on the reopening of proceedings, but the rights of the court to re-examine the case are essentially identical in both civil and administrative proceedings.

Conclusions

In conclusion, although the principles of legal certainty and legal certainty presuppose the general rule that a final judgment cannot be challenged, the case law of the European Court of Human Rights and the Constitutional jurisprudence of Lithuania suggest that the principle of legal certainty is not an absolute one, and that, under certain conditions, a departure from this principle is possible.

The need to reopen proceedings is based on the need, in certain cases, to rectify a final judgment (in the broadest sense of the term) in the light of new circumstances. This institution is a unique form of control over the reasonableness and legality of judicial decisions, is intended to eliminate possible inaccuracies and errors in the judicial proceedings, and is aimed at the implementation of the fundamental tasks of the court as laid down in the Constitution and in laws and international instruments, i.e. the administration of justice, the exercise of the right of defence, and the protection and safeguarding of the rights and legitimate interests of individuals.

Although the institute of reopening of proceedings cannot be fully equated with the cassation function of the courts, however, with only two levels of administrative courts in Lithuania, it can be concluded that, in principle, the Supreme Administrative Court of Lithuania, when deciding on the issue of reopening of proceedings in individual administrative cases, also performs a cassation function in a certain sense.

Convention for the Protection of Human Rights and Fundamental Freedoms 6 The right to a fair trial, guaranteed by Article 6(1) of the Convention, emphasizes one of the essential elements of the principle of the rule of law: the principle of legal certainty, which implies respect for the principle of res judicata (the court's having finally settled the matter, i.e. the prohibition of an identical action). This principle requires that, once the courts have

finally settled a dispute, their decision must not be called into question, thus ensuring the stability of relations. The grounds for reopening proceedings as an exceptional stage must therefore be applied informally and in accordance with the principle of legal certainty, so that reopening of proceedings is possible only for the correction of fundamental errors in important and compelling circumstances.

A comparison of the procedural laws governing civil and administrative proceedings and the case-law developing them shows that the essential provisions of the institute of reopening of proceedings make this stage of the proceedings exceptional and optional. The definiteness and clarity of the legal regulation guarantee that this stage of the proceedings complies with the provisions of the Convention on the guarantee of the right to a fair trial. It is also important for the purpose of ensuring the purpose of reopening of proceedings and the stability of the rights of individuals to ensure the practice of the highest courts in the unification of the interpretation and application of the grounds for reopening of proceedings and other provisions of the procedural law.

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A BIBLIOMETRIC ANALYSIS OF E-MOBILITY RESEARCH IN THE EU WITHIN THE CONTEXT OF GREEN POLICY FRAMEWORKS

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Abstract
With the major concerns such as air pollution, global warming, and the depletion of global petroleum resources, the automobile industry has redirected its attention towards electric mobility. In this context, the European Union's policies on sustainable mobility have rapidly evolved over recent times, with a strong emphasis on electric vehicles adoption. Consequently, the academic research in the field emerged rapidly as publications on specific topics have started to accumulate in the past two decades, with most of the research focusing on challenges and opportunities of the adoption, legislation, policies and drivers' barriers. Even though the field witnessed growing interest, the effects of the development on the scientific literature was not yet documented extensively. As of this, this research highlights the most recent strategic milestones of the EU on e-mobility and quantifies academic evolution of electric mobility development in the European Union between 2011, the year of European Commission's first strategic document covering electromobility, to 2024. For this objective, a bibliometric analysis was conducted for the mentioned period using the renowned Scopus database. The analysis validates that the most publications in this field were completed after the accelerating of the framework by the European Commission, starting with 2011. Over 80% of the academic documents were published in this timeframe. A direct correlation between the European Green Deal moment and the re-acceleration of the trend which started one year earlier, could not be made, however, the findings shown that the period between 2018-2022 accounted for the highest number of publications, registering a 31% increase compared to previous years. At the same time, through the keywords density map, the analysis found the following clusters in regards of Electric Mobility development in the European Union: public transport, sustainable mobility, infrastructure, electrification, market development & energy efficiency, recycling, renewable energy, air pollution and environment, sustainable transport and city logistics. With these findings based on the most recent data available, the study could provide objective indications of the evolution, trends and linkages of the academic research in the European Union area with a topic that is key for European Commission's plans for 2030 and 2050 goals respectively.
KEY WORDS: Electric mobility; Research trends analysis; Energy; European Union policies; Sustainable Development.
JEL classification: Q56, L52, L62.

Introduction

Reducing greenhouse gas emissions is a key component of all sustainability initiatives around the globe. Since the transport sector is a major contributor to greenhouse gas emissions, it requires significant transformations and adaptions to the current reality. (Maas 2022). In numbers, transport is responsible for almost 25% of greenhouse gas emissions in Europe and it is the main cause of air pollution categorized harmful by the World Health Organization. (Pietrzak & Pietrzak 2020). As of this, the main focus of the recent EU policies is to reduce these harmful emissions to 0 by 2050. This should be done through a series of gradual changes in consumption habits and the adoption of more sustainable solutions for its population. Based on the advancements in the field of automotive and other mobility providing solutions in the recent times, electromobility has become one of the key concepts that make it viable for the Net-Zero end goal to be achieved. According to Falchetta & Michel (2021), coupled with other low emissions electricity mix, EVs (electric vehicles) are an important decarbonization driver. Yet, to achieve large-scale adoption, an adequate infrastructure is required to be developed.

Due to its novelty, the field of academic research about electric mobility and its development is relatively young. Consequently, branches of research are emerging rapidly as publications on specific topics have started to accumulate in the past two decade (Fava, & Favero 2023). Most of the research focused on challenges and opportunities of the adoption, legislation, policies, drivers' barriers.

Bekiaris et al. (2017) underlined the importance of e-mobility (which is the similarly used term for electromobility) through a legislative perspective. At the same time, Rietmann & Lieven (2019) looked at the influence of policies supporting electric vehicles in 20 countries from around the globe, highlighting different kind of initiatives that promote the implementation and adoption of electric mobility.

In the academic world, even though the field witnessed growing interest, the effects of the development on the scientific literature was not yet documented extensively. (Haghani et al. 2023).

Building on this fact, this research proposes to specifically determine the scientific quantitative evolution of the electric mobility development topic in the European Union in recent years. The reason why EU was chosen is that the framework policies evolved exponentially in the region, therefore the study looked to see if the academic research followed the trend.

On the same logic, the period between 2011 and 2024 was chosen for the analysis, starting with the same year of the first strategic document of the European Commission with an emphasis on the e-mobility – the 2011 White Paper – "Roadmap to a Single European Transport Area - towards a competitive and resource-efficient transport system" to present, with possible inflection points on the road such as the European Green Deal moment. A detailed look and history of the published acts, policies and strategies of the European Commission on the topic of

electromobility in the mentioned period will be presented in detail in the Literature review chapter.

To achieve the objective of the study, a bibliometric analysis will be conducted and detailed in the Research Methodology part of the article. This methodology allows identification of trends, synthesis, analysis and even critical evaluation of the topic. It is practiced for both "mature" areas of research but also for newer, growing areas of interest to especially identify trends (Le et al. 2019).

Through this approach, the quantitative side of interest on the field could be revealed, mapping and clustering the results with the milestones of policies identified at the European Union level.

It remains to be seen if the most scientific research was conducted in the recent times. A similarity in evolution and trend with the above-mentioned events is still to be validated with this study.

With these findings, the study could provide objective indications of the evolution, trends and linkages of the academic research in the EU with a topic that is key for European Commission's plans for 2030 and 2050 goals respectively, based on the most recent data available on both sides.

Literature review

Considering the major concerns such as air pollution, global warming, and the depletion of global petroleum resources, the automobile industry has redirected its attention towards the adoption of electric mobility. In the past decades, significant advancements in the field of automotive research and development have been achieved, which have enabled the potential for scaling electric mobility adoption. An electric vehicle (EV) is powered by an electric motor instead of an internal combustion engine that undergoes combustion of a fuel and gas mixture to produce energy. Electric vehicles (EVs) offer a seamless and rapid acceleration while minimizing the emission of atmospheric pollutants. (Maheswari et al. 2022). Besides conventional passenger cars, E-mobility technology can be applied to various types of transportation, such as shipping, heavy duty trucks or trains, but it requires a specific infrastructure like charging points, which at the same type requires network grid connectivity and electric energy supply. (Filho & Kotter 2015). European Union has been at the forefront of these advancements in terms of policies. Starting from 2035, registration of new conventional internal combustion engine vehicles will be prohibited in the region. The main reason is that the internal combustion engines are a significant source of carbon emissions and pollution that negatively contribute to the climate changes (Sanguesa et al. 2021).

The change is happening due to the rising costs of fuels and materials and the growing concerns of the harmful emissions such as carbon dioxide emissions. For this reason, the EVs are becoming increasingly popular across the continent, with many manufacturers now offering their well-established car models also in electric variants while at the same time completely stopping production for other models with internal combustion type of propulsion only. (Menyhart 2024).

The history of electric vehicles (EVs) goes back to 1831, when the Scottish inventor Robert Anderson built the world's first electric car. More exactly, it was a carriage put into motion by an electric motor. Then, at the middle of the century, between 1834 and 1840, Thomas Davenport from Vermont, United States, constructed another prototype of an EV, at the same time with Sibrandus Stratingh Groningen who designed an electric vehicle using the Volta Cell in 1835. In the second part of the century, various inventors such as Gaston Planté, Zénobe Gramme or Radcliff Word build different variants of electric vehicles or components for the use of EVs (Guarnieri 2012).

At the start of the century, Ferdinand Porsche designed its first electric car. The motors were powered by electricity by an internal combustion generator. This resulted in a very heavy vehicle, weighing 1.8 tons but with very good performance, accelerating up to 60 km/h. It was the concept that later evolved into hybrid. That model of Porsche was rather an exception. The average electric vehicle of that time reaching speeds of around 32 km/h. Later, the EVs fell into disfavour with the mass production of the Ford T from 1908 to 1912. With this model, the gasoline powered cars became widely available and affordable (Maciuk et al. 2024). In the next decades, the occasional returns to electric mobility happened primarily due to shortages rather than innovations, including during the Second World War or during the global oil crisis in 1973 (Burton, 2013). Globally, it was only after 1990 when the attitude towards environmental pollution shifted and so do interest in such solutions like electric vehicles attracted renowned enthusiasm (Maciuk et al. 2024).

As stated, there is a long history on the electric vehicles' advancements before 2010s, but for Europe, the strategic vision that incorporated the electric mobility as a sustainable development pillar started taking shape around the last decade. As Kaup et al. (2021) mentions, the first strategic document that approaches the subject was the 2011 White Paper – "Roadmap to a Single European Transport Area – towards a competitive and resource-efficient transport system". The European Commission raised the need to reduce the number of internal combustion running vehicles in half by 2030 and completely phase them out by 2050. At the same time, the document mentions the called "green transport corridors", an initiative aiming to switch the transport to cleaner solutions such as trains or ships.

In 2013, the Commission re-stated, this time with an emphasis on the economic supply side, mentioning that the Europe is heavily depended on oil imports to fuel its transport system which in the long run is also environmentally unsustainable. According to the "Clean power for transport: a European alternative fuels strategy" act (2013), the imports dependency must be replaced by alternative fuels and with the necessary infrastructure. To centralize the programs for alternative fuels and infrastructure investments and to link road transport to modern fuels, the European Commission issued Regulation 1315/201, which aimed to introduce alternative fuels in the strategically important core network of TEN-T by 2030" (Kaup et al. 2021).

Following this, the directive 2014/94/EU of the European Parliament and of the Council was issued in October 2014, on the deployment of alternative fuels infrastructure. It introduced the minimum requirements for the infrastructure extension to the countries of the EU and besides gas and hydrogen refuelling, the minimum technical specifications of charging electric vehicles. The act established the base for the development and implementation of the national policy frameworks of the Member States, mentioning that the national frameworks should be facilitated by the Commission by means of exchanges of information and best practices between the Member States (Official Journal of the European Union 2014).

In 2016, the European Commission introduced the Strategy for low-emission mobility. At the time, the transport in the EU was still dependent on oil for roughly 94% of its energy needs. Through this strategy, the Commission looked to accelerate the use of low-emission energy. With this occasion, the commission looked to facilitate better synergies between the energy and the transport system, such as addressing challenges of distribution of electricity at peak times to foster easier charging for EVs.

As promoted in this strategy act, the Member States were required to implement common standards for electric mobility, such as including a common charging plug for the electric vehicles, roll-out infrastructure for these alternative fuels, while the Commission committed to develop a methodology for easier price comparison of electricity and the other alternative fuels (European Commission 2016). As the ground was established, the end of the second decade of 2000s got the European Union ready to define and launch its most ambitious Sustainability act, the European Green Deal. It built on the commitment to achieving climate neutrality by 2050, delivering on the promises made by EU countries in the Paris Agreement. As of this, the European Green Deal is the EU's strategy for reaching the 2050 goal, launched by the Commission in December 2019. It consists of a package of policy initiatives from various fields: climate, environment, energy, transport, industry, agriculture and sustainable finance, all heavily linked together, underlining the need of a cross-sectorial approach, with all relevant areas contributing to the end goal of climate neutrality (Council of the European Union 2024).

For Szpilko & Ejdys (2022) the principal aim of the European Green Deal is to prioritize the benefits of sustainability for the European Union citizens as the main reason for all the policies developed further. The authors mention 8 major fields of European Green Deal Strategy's interest: "Increasing EU's Climate ambition for 2030 and 2050, supplying clean, affordable and secure energy, mobilizing industry for a clean and circular economy, building and renovating in a way that is energy- and resource-efficient, a zero-pollution ambition for a toxic-free environment, preserving and restoring ecosystems and biodiversity, "from farm to fork" — a fair, healthy and environmentally friendly food system and accelerating the shift to sustainable and smart mobility".

On the last-mentioned topic, the European Commission has put another strategy in place immediately after the Green Deal adoption in 2019. The new act, named Sustainable and smart mobility strategy was adopted and introduced an action plan listing 82 initiatives to keep the development on track. By this, the Commission aims to achieve at least 30 million zero-emission cars on its roads by 2030 and automated mobility should also be deployed at large scale. For the end goal of 2050 it is expected that nearly all cars, vans buses and trucks to be zero-emission. It was stated that this will be achieved by strengthening the actual rules, new legislation and support & guidance measures (European Parliament, 2020). As a baseline for the Smart and Sustainable Mobility Strategy, the electric vehicles adoption is aimed to be accelerated through various measures such as financial incentives, purchase subsidies, tax breaks, all these to encourage consumers to buy EVs along with extensive charging infrastructure developments, investments in research for battery-life improvements, charging speed and recyclability. This set of measures is close to the ones classified by Wang et al. (2017) who considers three main categories: financial incentive policy measures, information provision policy measures and convenience policy measures. Out of those, the author's research finds that convenience policy measures are the most important policy measures to promote EV.

For the daily life of citizens, those policies bring significant changes. According to Kiviluoto et al. (2022), changing the environment of people without an immediate result may trigger resistance. It becomes critical to involve the citizens in the decision-making of climate policies to ensure acceptance (Wamsler & Bristow 2022) and at the same time take the proper and balanced financial incentives to boost adoption. Though, according to the European Commission (2024), based on a large survey with over 19.000 participants conducted by the European Alternative Fuels Observatory in twelve countries of the EU, the Europeans are generally positive towards EVs. Over 57% of the respondents that do not yet own an electric car are considering a change in the future. The respondents understand and highlight the cost efficiency and climate benefits of the EVs, but price remains the major obstacle in switching decision.

Similar to the expansion of policies in the European Union on the electromobility topic, the recent years witnessed a rapid expansion in terms of sales. From 2017 to 2019, or before the Green Deal, the sales annual growth rate averaged to 40%. After the COVID-19 pandemic, the sales recovered. According to (Khaleel et al. 2023), overall, the electric vehicles sales in Europe continued to rise due to the contraction in the conventional combustion engines market. The growth in EV sales after 2020 was extraordinary mainly thanks to the rapid adjustments of corporate strategies of the manufactures to their standards adopted in 2019 which had an important influence on the production and sales between 2020 and 2024 period (International Energy Agency 2023). The policies are expected to harden, in line with the optimism of the consumers and the outlook for Electric Mobility is encouraging and positive for the expectations of the policy makers at the EU level. According to the International Energy Agency's Global EV Outlook (2024), the global electric vehicle pool is expected to grow twelve times by 2035, while Europe remains one of the most advanced EV markets under stated policies.

On the other side of the outlook highlighted above, electric vehicles market also has its limitations in terms of adoption which are worth mentioning. According to Menyhart (2024), the market share remains relatively low in Europe, around 16%. Between the factors, he mentions the high price, the battery capacity issues, the lengthy charging times, the limited range and the still insufficient infrastructure in terms of charging capabilities. The author finds the last-mentioned factor as crucial for electric vehicles adoption. Progress have been made around the region but the availability of charging points for EVs is still a challenge in many European countries.

As evidenced above, the electric mobility development in the European Union over the past 14 years accelerated through a series of policies and frameworks with milestones in 2011 (the White Paper – "Roadmap to a Single European Transport Area - towards a competitive and resource-efficient transport system), 2013 (Clean power for transport: a European alternative fuels strategy), 2014 (directive 2014/94/EU of the European Parliament and of the Council), 2016 (the Strategy for low-emission mobility), 2019 (The European Green Deal) and in 2020 (Sustainable Mobility Strategy). The adoption in terms of sales kept the similar positive trend.

In terms of scientific adoption, even though the field witnessed growing interest, the effects of the development on the scientific literature was not yet documented extensively. Several publications on EVs have emerged mainly on the topics of consumer preferences, adoption, incentives, business models, charging infrastructure, connection grids or environmental impacts (Haghani et al. 2023). The similar authors, Haghani et al. (2023) conducted a computational review and their analysis suggest four categories of topics of interest regarding EVs in the recent years: charging infrastructure, EV adoption, thermal management systems and routing problems. In their findings, hybrid EV proves to have been a dominant keyword, but it is noted that it is on a declining trend in the recent years. At the same time, their research highlights that adoption, with an extended emphasis on early adopters, and market development are some of the growing research clusters, expecting to continue to grow in line with the challenges to reach 100% EV penetration in the markets. Education and awareness are required about the benefits of electric vehicles in reducing greenhouse gas emissions and combating climate change.

Debnath et al. (2021) approached another angle in computational analysis to cluster the electric vehicles topic on social media using mixed-method application of social network analysis and machine learning-based topic modelling algorithm for the public posts. Their approach was location based, with a focus on the United States. They found out that political, economic, and legal posts had dense clusters on the technology policy of EVs, and also tax and credit framework politics.

Szpilko & Ejdys (2022) were the ones who conducted a systematic literature review on the Green Deal, identifying topics and classifying their compatibility with the Green Deal areas mentioned in the official strategic document. Their bibliometric analysis identified eight thematic clusters which were linked to the eight areas of the European Green Deal strategy. One of the identified clusters was Mobility - linked to the Accelerating the shift to sustainable and smart mobility focus on the Green Deal policies.

On a global level, Soto et al. (2024) analysed the use of EVs as a viable alternative to reduce the carbon footprint. They query looked for the documents that addressed the electric vehicles and their effect on carbon footprint reduction between 2010 and 2021, in renowned databases such as Scopus, Web of Science, Science Direct and ProQuest. Their findings highlighted that the United States were leading the scientific work on the field, with over 300 documents. From the four EV types identified (pure electric, plug-in hybrid electric, plug-in hybrid and hybrid), the most researched type of EVs are the pure electric ones, these also being viable alternatives for carbon footprint reduction, by an average of 91%. In another global level analysis, Hassan et al. (2024) looked at the EV adoption and environmental sustainability from 2014 to 2024. They used Scopus database and recorded 121 documents that matched their criteria. The results showed an upward trajectory of publications in the field, especially after 2019, with the United States and China as the top contributing countries. On the other side, their analysis shown that the developing countries are underrepresented.

Another comprehensive bibliometric analysis on EVs was conducted by Veza et al. (2024) looking at the following dimensions of the topic: electric vehicles trends, policies, batteries materials and battery management, charging infrastructure smart charging. Together with those, electric vehicle-to-everything (V2X) concept was addressed. According to Noor-A-Rahim et al. (2022), V2X consists of actual and future EVs capabilities of connecting with grids, infrastructure and networks, mainly expected for future 6G networks. For example, electric vehicles to grid (V2G) allows the vehicle to contribute back to the power electricity grid when it is not used (İnci et al., 2022) and according to Elagin et al. (2020), if a vehicle connects with networks or data centres it is referred as vehicle-to-network (V2N). Based on the mentioned areas, Veza et al. (2024) recorded documents between 1990 and 2022 and their analysis also shown increased interest and exponential growth of the publications in recent years. With their applied query, China was the highest ranked country by publications on EV research in general, achieving high levels of proficiency across the field, but with special focus on the lithium-ion batteries. At the same time, the United States ranked highest in the specific keyword of "charging infrastructure". The European countries which made it to the top 10 of publications were the United Kingdom, Germany, Italy and France. Based on their findings, the authors conclude that, the success of Electric Vehicles and their ongoing expansion relies on cohesive integration of EV policies, cutting-edge battery technologies, charging infrastructures, and V2X communication.

In another angle of research on the topic, Tolani et al. (2023) conducted a systematic review on the Emergence of Sustainable Mobility for Global Ecology, preforming a bibliometric analysis on the concept of sustainable mobility and the emerging role of EVs. In the authors conclusions, the sustainable behavior and mobility adoption is rather a personal decision but one moderated by policies. Conscious sustainable behavior is believed to

be the proper way forward for the society in general. At the same time, innovation and emerging technological initiatives like Circular Economy for recycling and repurposing EVs might be the answers for sustainable mobility initiatives.

While previous research analysed various instances of the scientific interest in the field of electric vehicles globally or historically, this research proposes to specifically determine the scientific quantitative evolution of the electric mobility development topic in Europe, in the recent years, starting with the context of the strategic emphasis put by the EU regulators on E-Mobility: From 2011 White Paper – "Roadmap to a Single European Transport Area – towards a competitive and resource-efficient transport system to present, with a bibliometric analysis approach detailed in the further sections.

Research methodology

The purpose of this research is to quantitatively evaluate the academic research evolution on the topic of Electric Mobility development in the European Union in the recent years.

The objective is to find out whether the topic did receive a similar attention in the recent years equal to the emphasis that has been put by the European Union policies and like the sales evolution of this new automotive category. At the same time, it looks to find out what are the main topics of interest and exploration in regards of Electric Mobility development in the existing literature. It analyses the period starting from 2011, the year of the first strategic document of the EU in the modern era – 2011 White Paper – "Roadmap to a Single European Transport Area – towards a competitive and resource-efficient transport system" to present, mapping the Green Deal as a possible point of inflection on this proposed timeframe.

The author's assumption is that the most scientific research was conducted in the recent times, expecting a similarity in evolution and trend with the above-mentioned events in the field of Electric Mobility in the European area.

For this, the article would like to answer the following three research questions:

1. How many scientific articles were written in the chosen timeframe dedicated to the European Union's advancement in the E-Mobility field and how did the trend evolve?
2. Did the Green Deal moment have an impact on this evolution, and to which extend?
3. What were the categories of topics addressed and what is the trend of study?

Research Methods

For this objective, a bibliometric analysis will be used to quantify the literature on the E-Mobility development in the European space. This methodology is often used for the identification of trends, synthesis, analysis and critical evaluation of the scientific work on the topic (Le et al. 2019). It allows identifying the state and the trends in the desired research field, like Niñerola et al. (2019) conducted, with a detailed outcome, ranging from the number of publications in the defined timeframe to the construction of rankings of the actual authors, journals, research units and geographical regions It is practiced for both "mature" areas of research but also for newer, growing areas of interest to especially identify trends (Le et al. 2019). According to de Oliveira et al. (2019), bibliometric analysis can be a valuable tool to plan future research strategies and highlight directions in scientific developments while Donthu et al. (2021) mention that bibliometric analysis aid researchers, institutions, and policymakers identify urgent research areas, quantify the impact of academic work, and comprehend the contributions of individuals, institutions or nations in a specific domain.

A specific design for systematic literature reviews was proposed by Tranfield et al. (2003). based on three stages: planning, conducting and reporting of the results. The mentioned design is followed in this study.

The bibliometric analysis conducted was completed in 7 steps. The initial step of the analysis consisted in choosing the proper database for our purpose, the second step implied starting the search process and selecting the relevant documents by keywords. The third step focused on applying the filtering criteria (timeframe and type of document). In the fourth step, the data was extracted, while in the fifth step the duplicates were removed. The final two steps consisted in analysis of the results (sixth step) and the clustering of data (seventh step).

The whole scheme of the bibliometric analysis methodology used to achieve the purpose of this research is shown and detailed in the Figure 1 below.

To carry out the analysis we chose the renowned Scopus multidisciplinary database from Elsevier. Each year, the Journals published in Scopus are quality reviewed based on four numerical criteria's: h-Index, CiteScore, SJR (SCImago Journal Rank) and SNIP (source normalized impact per paper). The listings in Scopus meet the requirements for peer review quality by degree-accreditation boards around the globe. As of 2024, Scopus holds over 94 million records (Elsevier 2024).

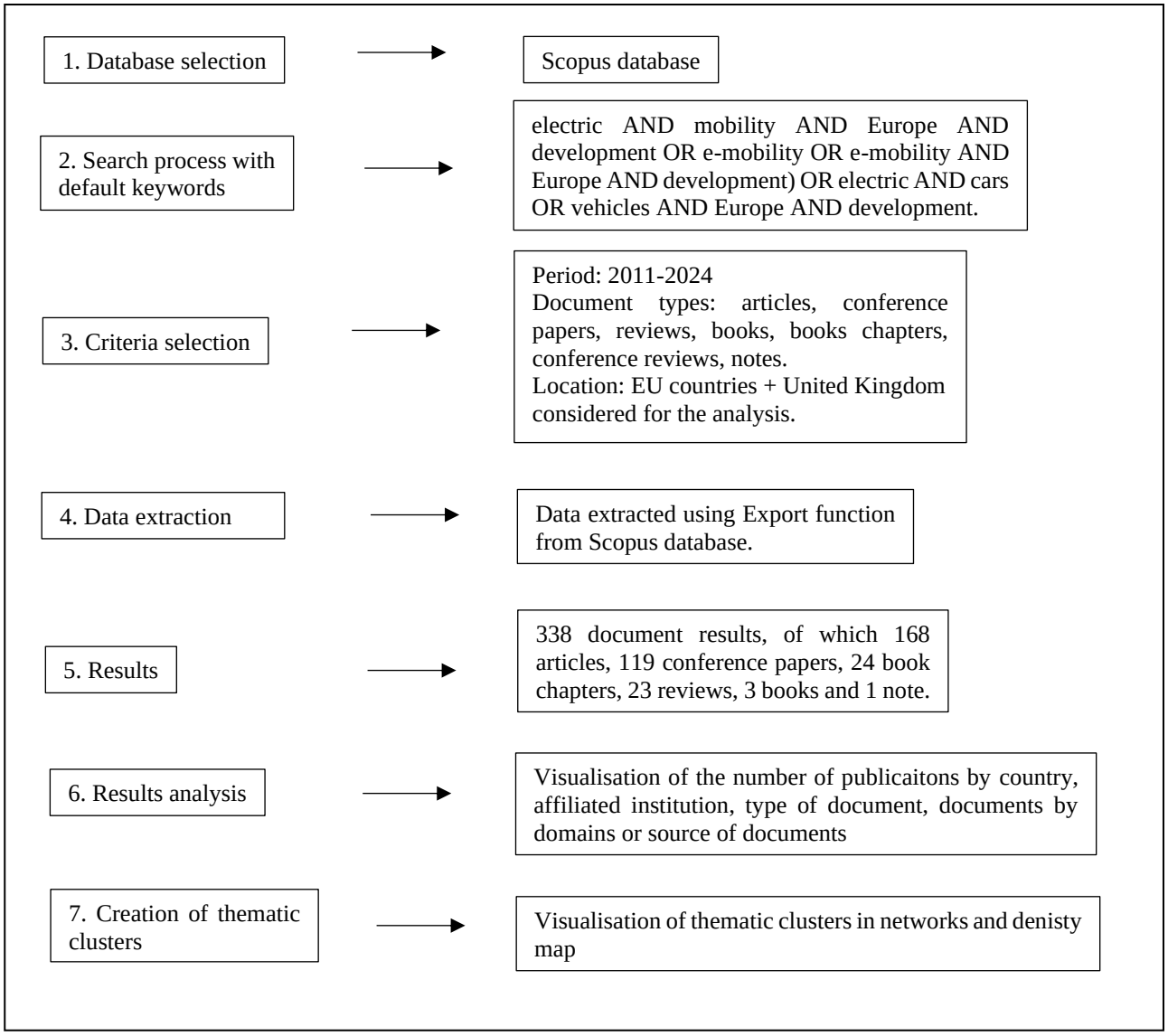

Fig 1. Seven-step bibliometric workflow—From database selection to keyword-cluster visualisation, this flow chart summarises the procedure that generated all subsequent results. *Source:* adapted from Maas (2022), p.5 and Szpilko & Ejdys (2022), p. 15

In the second step, the search process started by adding the main keywords of research in the "Search Document" section of the Scopus platform, with the following query function that includes the synonym terms used for electric mobility (emobility, e-mobility, electric vehicles and electric cars): "(ALL (electric AND mobility AND europe AND development) OR ALL (emobility OR e-mobility AND Europe AND development) OR ALL (electric AND cars OR vehicles AND europe AND development))", with "Search within" filter for "All fields" applied.

The initial search returned 41.932 documents, with the following results in terms of document types: 23.683 articles, 7.153 conference papers, 5.554 reviews, 2.923 boots, 2.320 book chapters, 104 editorials, 65 notes, 58 short surveys, 31 retraced, 26 conference reviews, 7 letters, 6 data papers and 1 erratum.

In the third step of the analysis, to increase the accuracy and relevance of the data returned, a second search was needed and conducted, keeping the same keywords but reducing the document types in focus by changing the "Search within" field to "Article title, Abstract, Keywords" and resulting the following search query function applied: "(TITLE-ABS-KEY (electric AND mobility AND europe AND development) OR TITLE-ABS-KEY (emobility OR e-mobility AND Europe AND development) OR TITLE-ABS-KEY (electric AND cars OR vehicles AND europe AND development))". With this filtering in place, 659 documents were found, spread by type as follows: 302 articles, 242 conference papers, 43 reviews, 33 book chapters, 24 conference reviews, 7 notes and 4 books.

The timeframe starting from 2011 to present (31st of August 2024 – date of data gathering by the author) was added in filters. The updated query function "(TITLE-ABS-KEY (electric AND mobility AND Europe AND development) OR TITLE-ABS-KEY (emobility OR e-mobility AND Europe AND development) OR TITLE-ABS-KEY (electric AND cars OR vehicles AND europe AND development)) AND PUBYEAR > 2010 AND PUBYEAR < 2025 " returned 471 documents, of which 217 articles, 165 conference papers, 33 book chapters, 30 reviews, 18 conference reviews, 4 books and 3 notes.

Next, location and language were two other parameters or filters added to the query search function. The "County/Territory" filter was set to "Limit to" existing EU countries from the list shown with the last-mentioned uery applied. At the same time, "Language" filter was limited to the EU members states official languages.

Because Brexit - United Kingdom's exit from the European Union area happened on 1st of February 2020, the United Kingdom was kept in the analysis. No other limits were applied to "Author name", "Subject area", "Document type", "Source title", "Publication stage", "Keyword", "Affiliation", "Funding sponsor", "Source type" and "Open access" filters, as the rest of the criteria returned were considered relevant for the purpose of the study. We considered this as the final query of the bibliometric analysis, registering 338 document results, of which 168 articles, 119 conference papers, 24 book chapters, 23 reviews, 3 books and 1 note.

For comparison purposes, an additional search was conducted using the similar query formula except the "Year" filtering. It considered all scientific documents to present and resulted in 422 findings.

Following the fourth and fifth step of the bibliometric analysis plan, the quantitative data resulted was then extracted using the "Analyse results" and "Export" functions of the Scopus database. The analysis of data was done using the similar modules of the Scopus database website and with VOSviewer software. The results and clustering of data is detailed in the next section of the article.

Results & discussion

The purpose of this research is to quantitatively evaluate the academic research evolution on the topic of Electric Mobility development in

The number of publications (documents in Scopus terminology) recorded between 2011 to 2024 had a generally positive growing trajectory, as presented in the Figure 2.

Inflection points were observed in the years after 2011, 2013 and 2018. Linking to the milestones presented in the literature review chapter on E-mobility development in EU, in 2011 the European Commission issued the first strategic document that approaches the subject of E-mobility - the White Paper – "Roadmap to a Single European Transport Area - towards a competitive and resource-efficient transport system" and in 2013 - the "Clean power for transport: a European alternative fuels strategy" act was published. Even though the European

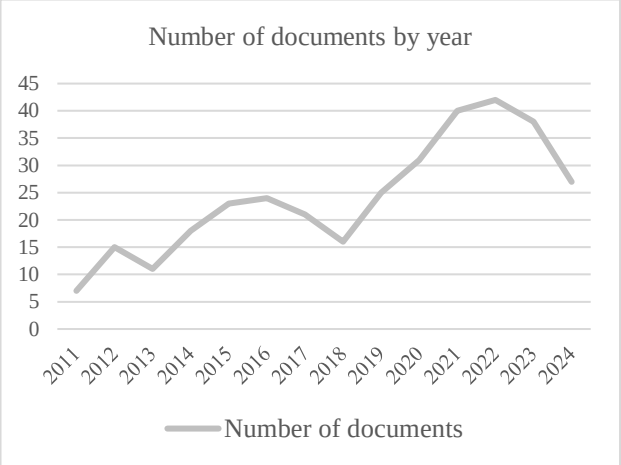

Fig. 2 . Annual EU e-mobility publications, 2011–2024 — Output climbs steeply after 2011, peaks in 2021-2022, then slips in 2023-2024. Source: author's work based on Scopus database retrieved data.

Commission introduced the Strategy for low-emission mobility in 2016, we see a drop in number of documents published, with the trend re-accelerating in 2018, a year before the European Green Deal was launched. A direct correlation between the year of re-acceleration of the trend (2018) and the year when European Green Deal was launched (2019) is not observed, however the number of documents on the subject was the highest between 2018 and 2022. The recent period between 2022 and 2024 marked another leg down in the number of publications. Forces likely to explain the pause could be that the topic maturity is beginning to curb novelty. After a decade of rapid expansion, key topics may be well-explored, yielding fewer novel studies. Bibliometric mappings presented in the literature review show that once-dominant themes such as "hybrid EV" now attract far fewer new papers, signalling that foundational questions have been largely settled (Haghani et al., 2023). Another explanation might be that funding and policy priorities have also moved on, with the geopolitical and energy crises of 2022–2023 also potentially redirected attention toward urgent energy security issues, subtly shifting focus away from academic publishing on e-mobility. It is also plausible that electric mobility moved from a nascent research topic toward the mainstream implementation.

Comparing the number of publications before and after the European Green Deal moment, there were 135 publications between 2011 and 2018 (8 years) and 178 publications between 2020 and 2024 (less than 5 years), registering a 31,8% increase. The year of European Green Deal announcement (2019) was excluded from the comparison.

At the same time, the search process conducted allowed analysing the situation of documents published before and after 2011. Out of 422 documents that matched the query search function without "Year" filtering, 80% (338) publications were registered in the 2011-2024 period, showing an exceptional increase of interest in the field after 2011 moment, the year of EU Commission's first strategic act.

Out of the 338 publications registered in the period of interest of the study, the covering majority (168) were articles, 119 were conference papers, followed by 24 book chapters, 23 reviews, 3 books and 1 note. The spread by percentage out of total is presented in the Figure 3.

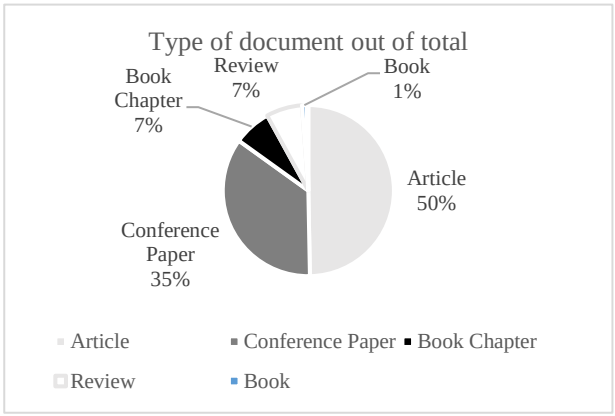

Fig 3. Document types in EU e-mobility research, 2011 – 2024 — Journal articles (50 %) and conference papers (35 %) dominate, whereas books and chapters comprise only a small fraction. Source: author's work based on Scopus database retrieved data.

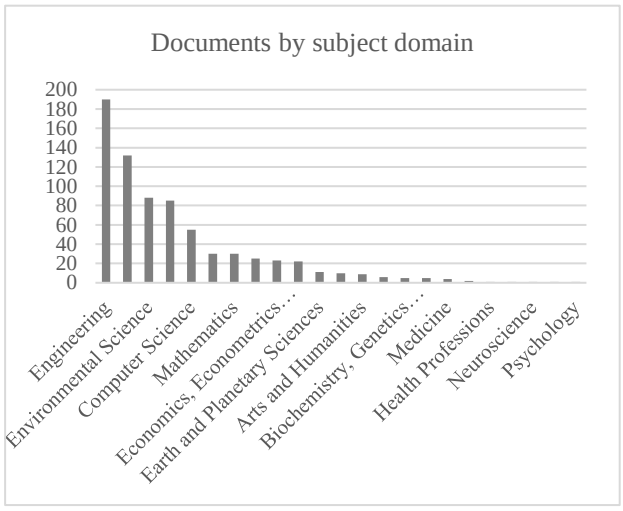

Fig. 4. Engineering and Environmental Science together account for well over half of all documents, underscoring the technology- and sustainability-centred focus of the field. Source: author's work based on Scopus database retrieved data.

The analysis of data based on the subject domain is present in the Figure 4. Engineering covered 190 publications (25.8%), followed by Energy with 132 publications (17.9%), Environmental Science with 88 publications (11.9%). Social Science with 85 publications (11.5%), Computer Science with 55 publications (7.5%) were the main domains highlighted by the research. Business Management and Accounting and Mathematics with 30 publications (4.1%) each, Physics and Astrology with 25 publications (3.4%), Economics, Econometrics and Finance with 23 publications (3.1%), or Material Science with 22 publications (3%). The other fields of study had less than 11 publications each, accounting for 54 publications in total or 7.4% from total as percentage.

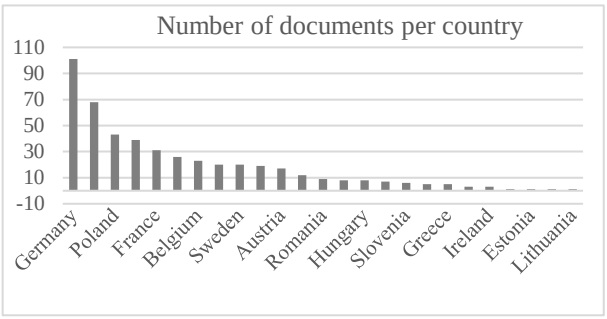

Fig. 5. National contributions to EU e-mobility writtings, 2011–2024 - Germany, Italy and Poland lead, whereas most Eastern-member states produce fewer than 10 papers, revealing a persistent West–East research gap. Source: author's work based on Scopus database retrieved data.

In terms of Country of origin, as presented in the Figure 5., the most documents were written in Germany 101, followed by Italy – 68. Other countries which registered publications had below 50 documents: Poland – 43, United Kingdom – 39, France – 31, Spain – 26, Belgium 23, Netherlands and Sweden – 20 each, Portugal – 19, Austria 17, Denmark 12, Romania – 9, Czech Republic – 8, Hungary – 7, Slovakia – 6, Slovenia - 6, Croatia and Greece – 5 each, Bulgaria and Ireland with 3 and Cyprus, Estonia, Latvia and Lithuania with 1 each. Data shows that between 2011 and 2024, An uneven distribution of research output among EU countries is evident. A few Western European countries account for the bulk of publications, while many Eastern members contribute relatively little. For example, Germany – home to a robust automotive industry – leads by a large margin in e-mobility publications. This dominance can be attributed to Germany's extensive R&D investment and its status as an automobile innovation hub. Similarly, Italy and other Western countries produce high output, benefiting from stronger research funding and active participation in EU-wide projects. By contrast, numerous Central and Eastern European countries have published only a handful of papers on e-mobility. This imbalance may reflect broader disparities in research capacity. Eurostat's R&D 2023 data show that Sweden, Belgium, Austria and Germany each spent more than 3 % of GDP on R & D, whereas Romania, or Hungary spend about 1 % (Eurostat, 2024).

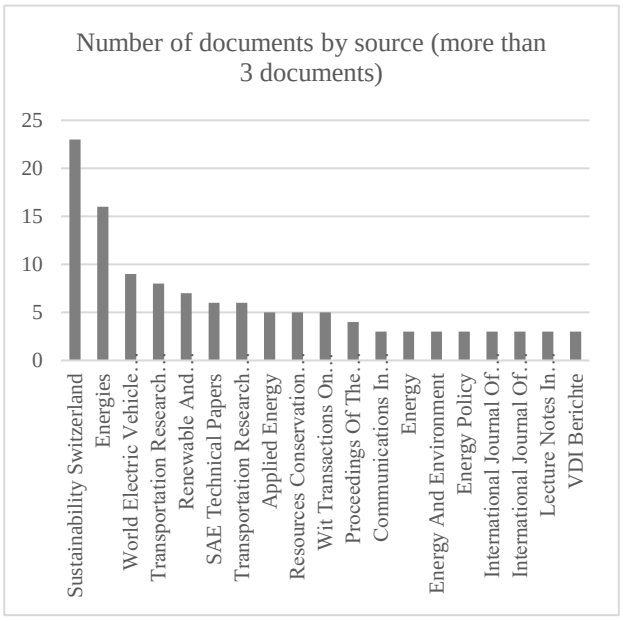

Fig. 6. Sustainability and Energies dominate the output, whereas all other journals publish fewer than ten e-mobility studies each.Source: author's work based on Scopus database retrieved data.

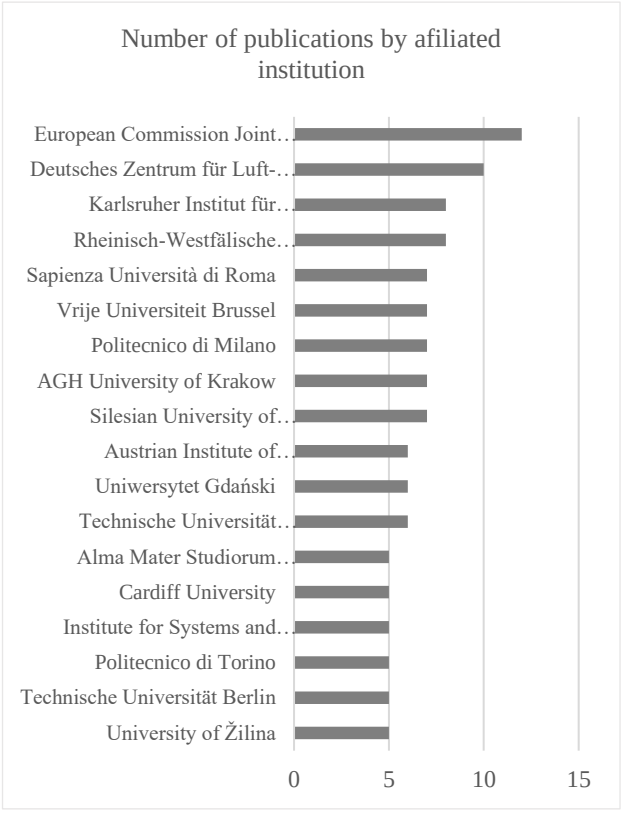

Fig. 7. Top institutional contributors — The EC's Joint Research Centre and Germany's DLR lead output, with several German and Italian universities close behind.Source: author's work based on Scopus database retrieved data.

The journals with the most publications about Electric Mobility development in the European Union was Sustainability Switzerland with 23 publications, followed by Energies with 16 publications, World Electric Vehicle Journal with 9 publications, Transportation Research Part D Transport and Environment with 8 publications, Renewable and Sustainable Energy Reviews 7 publications, SAE Technical Papers with 6 publications. The rest of the publishing sources with more than 3 publications are detailed in the Figure 6.

Comparing by the number of publications by affiliated institution (Figure 7), we observe that European Commission Joint Research Centre had the most affiliations, 12, followed by the German institutions:

Deutsches Zentrum für Luft- und Raumfahrt DLR with 10, Karlsruher Institut für Technologie and Rheinisch-Westfälische Technische Hochschule Aachen with 8 records. The top of affiliations with over 5 recordings is completed with institutes, universities and other institutions from Italy, Poland, Slovakia, Austria and Wales (United Kingdom). institutions from Italy, Poland, Slovakia, Austria and Wales (United Kingdom).

As part of the bibliometric analysis, the most used author's keywords on the topic of electric mobility development in the European were extracted based on the similar Scopus database dataset described in the Research and Methodology chapter. The analysis was conducted using VOSviewer software developed by Nees Jan van Eck and Ludo Waltman at Leiden University's Centre for Science and Technology Studies. VOSviewer is a software tool for constructing and visualizing bibliometric networks. These networks may for instance include journals, researchers, or individual publications (Centre for Science and Technology Studies 2024). According to Vargas et al. (2022), VOS viewer is the predominantly used software for bibliometric analysis type. The tool allows great visualization and can load and export types of information from various sources (Moral-Muñoz et al. 2020).

In this regard, a co-occurrence type of analysis was done, using a full-counting method, with index keywords as unit of analysis. The total keywords available in the dataset accounted for 1064 recordings. This set contained synonyms or similar terms (transport, transportation, electric mobility, e-mobility, electric vehicle, electric vehicles,).

To remove duplicates and standardize, a Thesaurus file was organized and applied to the dataset. At the end, the initial keywords used for starting the search process were also removed, along with the keywords considered irrelevant for our purpose. Minimum number of occurrences of a keyword was set to 3, similar to the approach used by Szpilko & Ejdys (2022). The final file before generating the cluster contained 49 items that meet the threshold: biofuels, decarbonization, electricity, electrification, emissions, energy efficiency, passenger cars, road transport, automotive industry, battery electric vehicle, electric propulsion, fuel cell, hydrogen, sustainable mobility, urban mobility, city logistics, electric bus, hybrid electric vehicles, sustainable transport, sustainable transportation, transport policy, market development, renewable energies, smart grids, smart metering, smart meters, air pollution, circular economy, lithium-ion batteries, recycling, sustainable development, fast charging, power system, renewable energy, smart

charging, vehicle-to-grid, energy, mobility, smart cities, smart mobility, alternative fuels, charging infrastructure, infrastructure, batteries, environment, sustainability, capacity, public transport, travel time. Those accounted for 103 links and a total link strength of 134, as presented in the Figure 8 below.

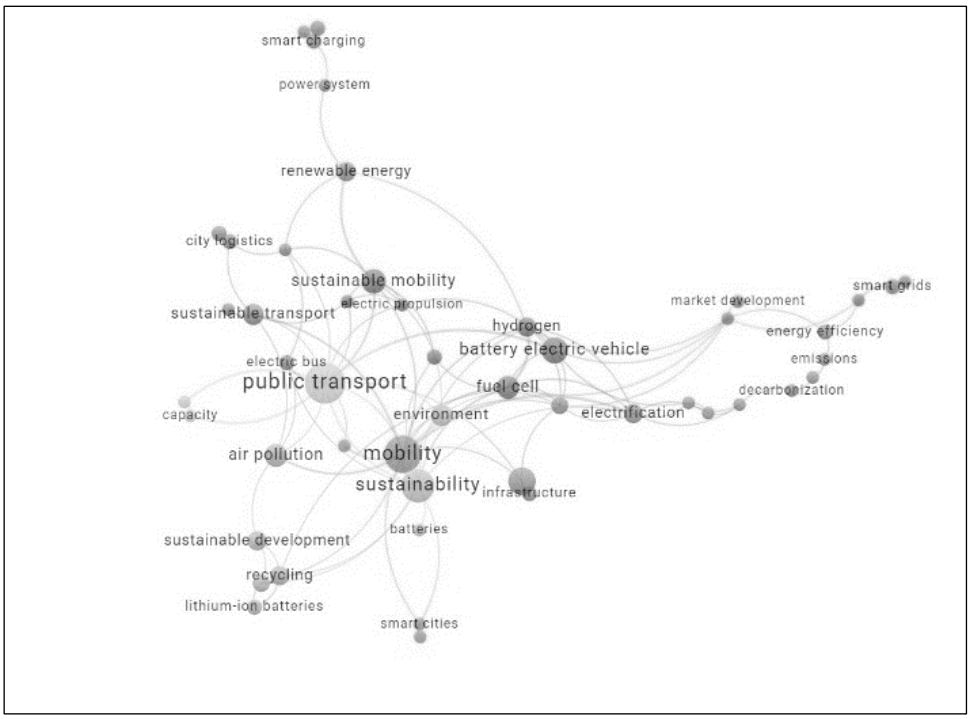

Fig. 8. Keyword co-occurrence clusters in EU e-mobility research — Nine distinct thematic groups emerge, with 'public transport' and 'sustainable mobility' forming the densest nodes. Source: author's work using VOSviewer software based on Scopus database data.

The larger the circle in Figure 8., the greater the number of occurrences of a specific keyword. The most occurrences appeared for public transport (21), followed by mobility (17), sustainability (15), charging infrastructure (11), battery electric vehicle (10) and sustainable mobility (9). The bibliometric analysis allowed

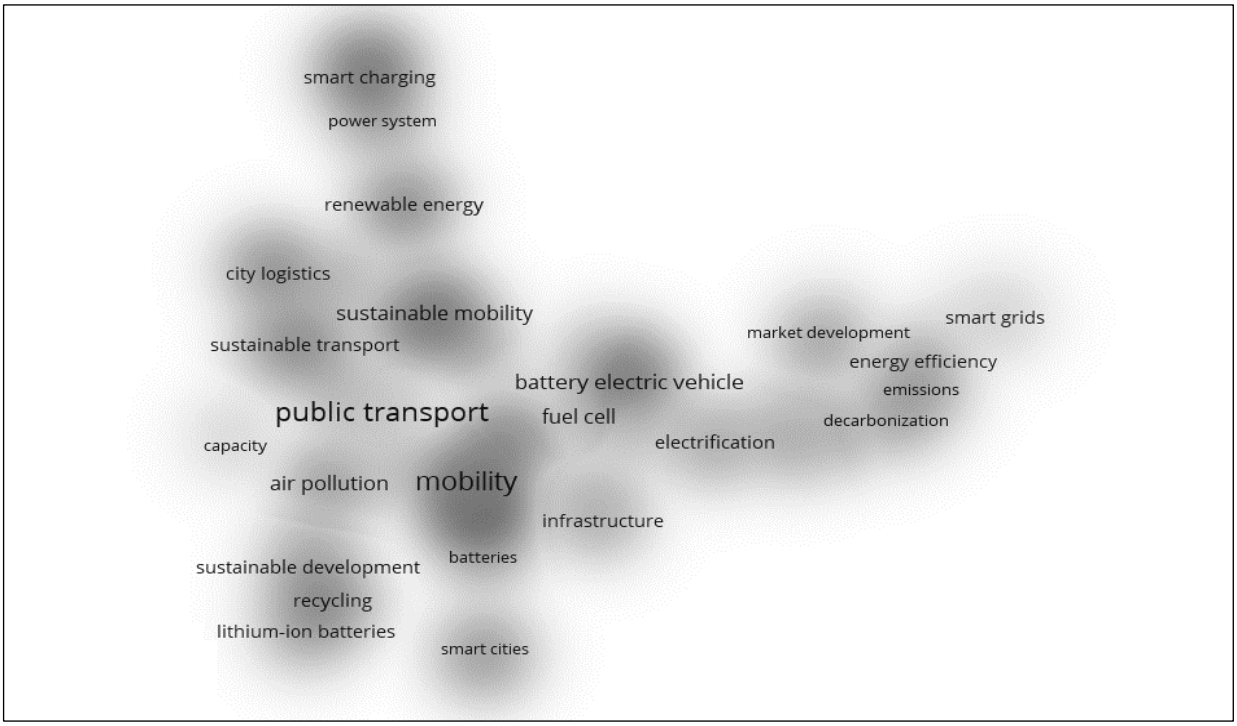

Fig. 9. Clusters Density map of EU e-mobility studies. Source: author's work using VOSviewer software based on Scopus database data

on the Clusters Density Visualization map presented in Figure 9. Public transport (blue), sustainable mobility (brown), infrastructure (rose), market development & energy efficiency (red), electrification (purple), renewable energy, recycling (light blue), air pollution and environment (orange), renewable energy (green), sustainable transport and city logistics (yellow) and "battery electric vehicle" cluster at the intersection of sustainable mobility, electrification, and environment.

For public transport, most of the topics addressed in the academic research were related to alternative fuels, electrification of urban bus fleets and the historic evolution of low-emission public transport across Europe. Case studies of various cities, regions or countries that integrated electrification for their public transport are also presented extensively.

As for the sustainable mobility cluster, the academic discussion in the selected period approached specific policies for EV adoption across EU countries and the role of incentives and solutions for sustainable economic growth in the context of CO2 emissions reduction. The infrastructure cluster, as mentioned did mainly approach the charging infrastructure developments state, optimizations and further needs in this regard that would facilitate the reduction in emissions over the long term.

As for the market development & energy efficiency cluster, the documents are mainly discussing about batteries life cycle, batteries recycling, and efficiency in design. For air pollution and environment, the topics addressed converge around the similar ones listed above for the other clusters. The reason being is that air pollution problem is a general reason and start of discussion in all scientific publications on electric mobility development.

Renewable energy is another cluster heavily linked to the other topics, based on the keywords analysis conducted. For example, the articles on the subject touch areas such as smart grids, charging integrated platforms and the impact of electric vehicles on a future renewable energy-based power system in Europe. Again, various use cases from different regions across Europe are presented.

In terms of sustainable transport and city logistics, the topics are partially familiar with the ones found for public transport.

Schemes for supporting sustainable transportation in cities are addressed, consumer preferences on the electric mobility or their willingness for adherence to alternative fuels in general, or the costs of indirect carbon emissions of e-mobility. Taking about batteries, the last observed cluster in our analysis, it touched areas such as patents, recyclability and cost effectiveness of various solutions.

Conclusions

To summarize the findings of this analysis, the objective and the research questions posed in the Research Methodology chapter are addressed below. The purpose of this research was to quantitatively evaluate the academic research evolution on the topic of Electric Mobility development in Europe, in the context of the recent policies of the European Union. Validating the relevance of the selected period for study, the bibliometric analysis showed that 80% of the existing literature on the field was published after 2011, the similar year when the European Commission published the White Paper – "Roadmap to a Single European Transport Area - towards a competitive and resource-efficient transport system", its first strategic document that addressed the E-Mobility topic.

The first research question asked how many scientific articles were written in the chosen timeframe dedicated to the topic and how did the trend evolve. In exact numbers, the search query found 338 documents published and indexed in Scopus database between 2011 and 2024, with a generally positive growing trajectory along the years, as presented in the Figure 2 of the Results Discussions chapter.

The second question looked to find and quantify whether the European Green Deal moment - December 2019, had an impact to the scientific interest evolution in the field and if yes, to which extend. Our analysis showed that inflection points were observed in the years after 2011, 2013 and 2018 (Figure 2.. Linking those points to the milestones presented in the literature review chapter, besides the 2011 moment mentioned above, in 2013 - the "Clean power for transport: a European alternative fuels strategy" act was published by the European Commission. Even though the institution introduced the Strategy for low-emission mobility in 2016, the analysis showed a drop in number of documents published at that time, with the trend re-accelerating in 2018, a year before the European Green Deal was launched. A direct correlation between the year of re-acceleration of the trend (2018) and the year when European Green Deal was launched (2019) could not be made, however, the number of documents on the subject was the highest between 2018 and 2022. As stated in the Results Discussion chapter, the recent period between 2022 and 2024 marked another leg down in the number of publications. This dip in publication activity might reflect the field's gradual maturation. After a decade of rapid growth, many central questions may already be well explored, leaving fewer obvious gaps for novel studies. Bibliometric snapshots, for example, suggest that topics once at the forefront—such as "hybrid EVs"—now draw far less attention, implying that foundational issues could be largely clarified (Haghani et al., 2023). Policy and funding priorities may also be shifting. The geopolitical and energy turbulence of 2022–2023 appears to have steered resources toward urgent energy-security agendas, potentially nudging e-mobility lower on the research docket.

At the same time, the bibliometric evidence points to a clear West–East divide in EU e-mobility writtings. A handful of Western countries dominate the literature, while most Eastern members contribute only modestly.

Germany—buoyed by a strong automotive sector and high R &D spending—publishes the most by a substantial margin, and Italy and several other Western economies also post high output thanks to generous funding and active involvement in EU framework programmes. Central and Eastern European states, by contrast, typically add just a few papers to the corpus. This pattern mirrors wider discrepancies in research capacity: 2023 Eurostat data indicate that Sweden, Belgium, Austria and Germany each invested more than 3 % of GDP in R &D, whereas Romania and Hungary devoted roughly 1 % (Eurostat, 2024).

Another assumption was that the most scientific research was conducted in the very recent years, expecting a similarity in evolution and trend with the above-mentioned events in the field of Electric Mobility in the European area. Specifically, we chose the European Green Deal as the before and after point of analysis and found that in the first 8 years of the analysis there were 135 publications (between 2011 and 2018), compared to 178 publications between 2020 and 2024 (less than 5 years), registering a 31,8% increase.

The third research question looked to identify the trend of study in the field and the topics addressed. It was answered using the co-occurrence and density vision maps analysis generated from VOSviewer software based on the similar dataset exported from Scopus database. Out of 1064 words inserted, 49 were had more than 3 occurrences and strong links with the other Author's keywords. As seen in the Figure 8., the most occurrences appeared for public transport (21), followed by mobility (17), sustainability (15), charging infrastructure (11), battery electric vehicle (10) and sustainable mobility (9). Adding the density map from Figure 9. we could identify the following major keywords based areas of interest in regards of Electric Mobility development in the EU: public transport (blue), sustainable mobility (brown), infrastructure (rose), market development & energy efficiency (red), electrification (purple), renewable energy, recycling (light blue), air pollution and environment (orange), renewable energy (green), sustainable transport and city logistics (yellow) and "battery electric vehicle" cluster at the intersection of sustainable mobility, electrification, and environment.

Our analysis confirms some of the findings of Haghani et al. (2023) who through their general computational review on EV also found charging infrastructure as a main cluster and market development as a growing cluster. At the same time, their analysis found hybrid EV as a dominant keyword (though on a declining trend) which did not materialize in our bibliometric analysis.

The "mobility" cluster found to be linked and compatible with the European Green Deal strategic statements found by Szpilko & Ejdys (2022) in their systematic literature review and bibliometric analysis was also highlighted by our analysis. In their study, mobility was mostly linked to the accelerating the shift to sustainable and smart mobility. Those connections were also found by our analysis but the closes links in our case were to public transport, air pollution and environment, infrastructure (charging), or sustainable development.

Compared to Debnath et al. (2021)'s social network analysis and machine learning modelling algorithm on social media posts from the United States in regard to EVs, our findings were different. Their analysis found that political, economic, and legal posts on the technology policy of EVs in US had dense clusters. Besides the region chosen for the analysis, the differences come from the fact that they looked to the general population's reaction, rather than the academic world's contribution to the field, which was our focus in this study.

In conclusion, our analysis validates that the most publications in this field of study were completed after the accelerating of the framework by the European Commission, starting with 2011. A direct correlation between the European Green Deal moment and the re-acceleration of the trend which started one year earlier, could not be made, however, the period between 2018-2022 registered the highest number of publications compared to previous years. Our identified clusters of keywords in regards of Electric Mobility development in the European Union were centred on public transport, sustainable mobility, infrastructure, electrification, market development & energy efficiency, recycling, renewable energy, air pollution and environment, sustainable transport and city logistics.

Limiting factors of this study should be mentioned. First, the data was retrieved solely from Scopus database, while being extensive, publications indexed elsewhere were not included. Similarly, the document selection criteria (e.g. the specific query terms, the focus on EU-affiliated research, and the 2011–2024 timeframe) could be other limiting factors. Even with a carefully formulated search strategy, there is a risk that certain pertinent publications or emerging topics were not captured, especially if they fell outside the chosen filters. Since bibliometric results are highly sensitive to the keywords used in the search, keyword sensitivity and standardization is another limiting factor. Although the query was designed to encompass known synonyms, complete standardization is challenging. Broad set of terms were added (e.g., "electric mobility," "e-mobility,") but inconsistencies in terminology remain a concern.

The analysis predominantly covers publications in the languages from the EU. This language focus may underrepresent research published in other languages. Those contributions would be largely absent from our study due to the language and indexing bias.

In addition, electric mobility is a very wide and growing field of research, subject to permanent developments which requires similar constant updates also in the academic world. The presented analysis proposes to offer a basic framework for further possible analysis.

Acknowledgements

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A REVIEW OF ORGANIZATIONAL CULTURE APPROACHES: SYSTEMATIC LITERATURE REVIEW AND BIBLIOMETRIC ANALYSIS

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Abstract
In the era of technological advancement, organizational culture (OC) plays a significant role in facilitating or hindering industrial transformation like industrial revolution 5.0 (IR5.0). Prior OC literature has unexplored several lines of inquiries, especially from IR perspective. To fill this void, this study systematically reviews the literature on organizational culture from 2014 to 2024. To extract the data, the Web of Science (WOS) database is used. To achieve the study objectives, a two-step systematic literature network analysis (SLNA) approach is adopted. It consists of systematic literature review and bibliometric analysis. A corpus of 2398 documents has been examined to present the performance analysis and map the intellectual structure. The findings of the performance analysis indicate that OC has gained attention after 2020, driven by increased interest in resilience and environmental management. The intellectual structure highlights that human factors (leadership & employees) and technical factors are gaining attention. This indicates that a sociotechnical perspective is more relevant in OC, especially in IR5.0. In terms of contributions, this study offers nuanced theoretical and practical contributions.
KEY WORDS: organizational culture, industrial revolution 5.0, systematic literature review, bibliometric analysis.
JEL classification: M14, M54, L20

Introduction

In the age of digital transformation, the notion of organizational/corporate/firm culture has gained considerable attention (Truong et al. 2025). Contextually, this shift emphasizes the adoption of cutting-edge technologies but also necessitates a vital change in firm culture to facilitate successful digital transformation (Blomkvist et al. 2025). Organizational culture (OC) refers to a set of unique characteristics that differentiate a firm from any other and serve as a social glue holding the organization together (Foss et al. 2013; Blomkvist et al. 2025). OC serves as a foundation stone of beliefs shaped by the members of a firm through internal integration or external adaptation (Bogale and Debela 2024). Moreover, OC involves values, stories, symbols, and myths that are shared among existing employees and learned by new organizational members (Hofstede 1991). From a digital perspective, OC is a firm guided behaviour that can either hinder or facilitate the digital transformation (Romero et al. 2025). In the same vein, Leso et al. (2023) argued that a supportive OC helps to promote new technology adoption, whereas a resistant-to-change OC can impede the digital transformation (Isensee et al. 2023).

As the industrial world entered the fifth industrial revolution (IR 5.0), the concept of OC has gained more importance. The concept of IR5.0 was introduced by the European Commission (EC) in 2021. Fundamentally, IR5.0 is a holistic framework that consists of human-centric values, resilience, and sustainability (Ali and Johl, 2024). To implement these core aspects of IR5.0, organizations require to reassess their cultural frameworks. For instance, Saksena and Jha (2024) argued that to implement industry 5.0, there will be profound changes in OC. Moreover, Olsson et al. (2025) claimed that modification in OC requires new collaborative frameworks that integrate technology with human input. According to Reichental (2024), more than 87% of business leaders consider digital transformation as a leading factor of competitive advantage. However, more than 70% of businesses failed to adopt digital transformation. This is a serious disconnect between intentions and outcomes. The major reason for this failure is the positive data-driven OC (Reichental 2024). In the same vein, Doucette & Parsons (2020) claimed that culture (33%) is the most significant self-reported barrier to digital effectiveness.

To address the research gaps, this study aims to review the literature of OC performance (publications, authors, countries) and to examine the network structure of the OC from 2014 to 2024.

The research methodologies like a systematic literature review (SLR) and bibliometric analysis were used. Where the first one includes identification of the study scope and relevant database with selection & evaluation criteria and the second one quantitative techniques to evaluate the scholarly calibre of authors or journals by looking at citation rates to assess the performance and relationships of organizational culture research. (Ahamer et al. 2015).
This article consists of the following sections: Introduction, Research Methodology (SLR, Bibliometric Analysis, Results of this Research), Discussion and Conclusion.

Review of Organizational Culture Studies

Organizational culture review studies the concept of OC that gained significant attention from practitioners and academicians. For instance, the review study of Palumbo & Douglas (2024) examines the relationship between OC and quality management, spanning between 1993 and 2022 (see Table 1) by focusing on the joint optimization of OC and quality management. Likewise, Bogale & Debela

(2024) review the measurements, perspectives, and orientations of OC from 52 documents spanning between 2014 and 2022. In the same vein, Oliveira et al. (2023) review the OC with strategic management in public and educational sectors, covering 348 documents from 2011 to 2020. In spite of a considerable amount of review studies performed on OC, as indicated in (Table 1), there are still many lines of inquiries and research gaps that need to be addressed. For instance, past review studies on OC have predominantly focused on documents published up to 2022, leaving a significant gap in understanding the evolving dynamic of OC in the wake of IR5.0. Moreover, analyzed studies have relied on limited or no database, which may compromise the quality of input and output, like Bogale & Debela (2024), Baek et al. (2019), and Mueller (2012).

Table 1. Review of studies on organizational culture

Authors	Purpose/aim	Timeframe	Technique	Number of articles	Sources
Palumbo & Douglas (2024)	To review the effect of organisational culture on quality management	1993-2022	Scientific Procedures and Rationales for Systematic Literature Reviews (SPAR-4-SLR)	76	International Journal of Quality & Reliability Management
Bogale & Debela (2024)	To systematically analyse the measurements, perspectives and orientations of OC.	2014-2022	Systematic review	52	Cogent Business & Management
de Oliveira et al. (2023)	To systematically review the OC and strategic management in public sector and school management.	2011-2020	Bibliometric analysis	348	School Leadership & Management
Reader et al. (2020)	To systematically review the unobtrusive indicator of culture for the organisation.	2017	Systematic review	35	European Journal of Work and Organizational Psychology
Baek et al. (2019)	To review the fundamental premises (perspective) embodied in the literature on OC.	2000-2017	Integrative review	411	Journal of Organizational Change Management
Maitland and Rhind (2015)	To review the study of OC in sport	1995-2013	Systematic review	33	Sport management review

Research methodology

According to Tranfield et al. (2003), an SLR is a type of study that deals with previously published works and uses a methodical approach to synthesize data that has already been published. An SLR, according to Kraus (2020), is a review of an existing body of literature that employs an open and repeatable technique for finding, evaluating, and synthesizing it with a high degree of objectivity. SLRs have several drawbacks even if they are an effective method for analysing a lot of data. For example, a lot of SLRs ignore other viewpoints in favour of concentrating on only one kind of analysis. Furthermore, their search algorithms are not often clearly stated, and they frequently rely on a small database, which results in biased article selection (Dahabreh et al. 2012). To overcome these constraints, this study uses a brand-new methodology called Systematic Literature Network Analysis (SLNA). According to Inamdar et al. (2021), SLNA is a two-step process that combines a bibliometric analysis to examine the transmission and development of knowledge with a systematic literature review (SLR) to find pertinent publications. According to Colicchia and Strozzi (2012), this method should be broken down into two stages: SLR and bibliometric analysis.

Systematic literature review

A systematic literature review was carried out using a two-step process, which involved defining the study scope and selecting the relevant database with selection & evaluation criteria.

The scope of the study is set in the initial step of SLR following research objectives and questions. According to Denyer and Tranfield (2009), the scope should follow the CIMO logic, which includes context, intervention, mechanism, and outcomes. Thus, for this study, the scope is focused on “organizational culture”, “corporate culture”, “firm culture” and similar terms from 2014 to 2024, both years included.

The second step of the SLR involved selecting the appropriate search string and database. Based on prior literature, a combination of keywords with Boolean operators was used to identify the relevant documents. Keywords such as “"organi?ational culture" OR "corporate culture" OR "workplace culture" OR "company culture" OR "organi?ation culture" or "firm* culture" were used to identify relevant studies. For this study, the Web of Science (WoS) database was chosen to gather articles for analysis. The WoS is a reputable source for identifying high-quality journals worldwide (Elaish et al. 2023). Furthermore, the articles in this database are well-organised in terms of research quality (Elaish et al. 2023). The search was conducted at the end of Jan-2025, resulting in more than sixteen thousand documents. By limiting the search to journal articles and early access, approximately 2398 articles were deemed relevant for further selection, as shown in (Fig. 1).

The inclusion criteria were defined to select the primary documents. Studies that focused on the application of organizational culture were selected. Additionally, studies that investigate factors related to the above-mentioned context were also selected. The studies needed to be written in English and published between 2014 and 2024; both years were inclusive. Fig. 1 shows the PRISMA diagram in detail.

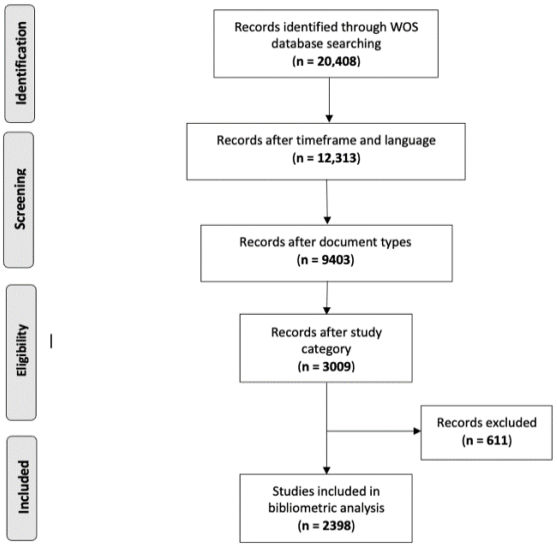

Fig. 1. PRISMA flow diagram

Bibliometric analysis

Bibliometric analysis, the second stage of the SLNA approach, uses quantitative techniques to evaluate the scholarly calibre of authors or journals by looking at citation rates (Ahamer et al. 2015). To prevent misinterpreting the term "quality," it is crucial to properly define the quality criteria for article selection before performing bibliometric analysis. According to Fonseca and Borges-Tiago (2021), bibliometric analysis examines co-authorship, references, citations, and publication contents using both quantitative and qualitative statistical techniques. Researchers can investigate citation patterns, author networks, knowledge bases, trends, reader usage, and the subject's importance and influence using this kind of analysis (Inamdar et al. 2021).

This study used bibliometric analysis to assess the performance and relationships of organizational culture research. The findings are organized into two categories: performance analysis and network analysis. Donthu et al. (2021) employed performance analysis approaches to determine the impact of research on a given field. Typically, this sort of study includes descriptive indicators such as the number of publications and citations per year, as well as contributions from authors, nations, organizations, and journals. These indicators are utilized because publication is a proxy for production, whereas citations indicate the research's influence and impact (Donthu et al. 2021).

Network analysis strategies focus on the structural linkages and intellectual exchanges between research elements. This sort of study employs a variety of methodologies, including citation and co-citation, co-word, co-authorship, and bibliographic coupling. These methodologies enable researchers to study the links and linkages within the area, resulting in a more comprehensive understanding of organizational culture research. Overall, bibliometric analysis is an effective method for assessing performance and relationships within a particular study topic (Donthu et al. 2021).

Results of this research

Performance analysis and publication trends as per the recommendations of Donthu et al. (2021), the 1st step in bibliometric analysis is to examine the overall progress in the research field through performance analysis (Kumar et al. 2022). It includes the most influential journals, authors, countries, and publication trends. From the WOS database, a corpus of 2398 documents from more than four hundred journals have been extracted, spanning a time frame of 2014-2024. In the corpus of 2398, more than 95% or 2268 documents are articles, and only 5% or 130 are early access articles.

In the performance analysis, firstly, it is necessary to highlight the publication trends between 2014 and 2024 because the corpus of 2398 indicated a gradual rise in firm culture research between these years. From 2014-2018, the number of publications was around a hundred with slight variations. This highlights that there was a consistent focus in firm/organizational culture research. In 2019, the number of publications slightly rose. From 2020 onward, there was a notable spike in the publication. In these years (2020-2024), the publications were more than double in comparison with preceding years. This surge highlighted the importance of corporate culture in remote work, resilience, and crisis management, especially after the COVID-19 pandemic. In the years 2021-2023, the publication trends remain stable, while in 2024, a significant rise was observed. This indicates that firm/corporate/organization culture has been gaining interest in the academic and practical world.

Most impactful journals and influential authors

From the corpus of 2398, table 2 highlights the 20 most impactful journals. From the table and figure, "*Journal of Business Research*" published 66 articles on firm culture (2.75%) followed by "*Cogent Business Management*" with 64 (2.67%) documents. From the corpus of the dataset, "*Journal of Organizational Change Management*" stands as the 3rd most impactful journal with 52 (2.17%) documents. Apart from the above three influential journals, "*Journal of Business Ethics*" (50, 2.09%) also plays a significant role in corporate culture research. In the firm culture research domain, other notable contributions are the "*International Journal of Organizational Analysis*" (42, 1.75%), "*Journal of Asian Finance Economics and Business*" (42, 1.75%), and "*Management Decision*" (37, 1.54%). Conclusively, these top 20 journals highlight the interdisciplinary nature of firm/organizational culture research, covering diverse domains like sustainability, ethics, organizational change, and performance management.

Table 2. Top 20 most impactful journals

Journal Name	Documents	% of 2398
Journal of Business Research	66	2.75%
Cogent Business Management	64	2.67%
Journal of Organizational Change Management	52	2.17%
Journal of Business Ethics	50	2.09%
International Journal of Organizational Analysis	42	1.75%
Journal of Asian Finance Economics and Business	42	1.75%
Management Decision	37	1.54%
International Journal Of Contemporary Hospitality Management	35	1.46%
Business Strategy and The Environment	34	1.42%
Business Horizons	33	1.38%
Business Process Management Journal	33	1.38%
Benchmarking an International Journal	32	1.33%
Employee Relations	32	1.33%
International Journal of Productivity and Performance Management	32	1.33%
Corporate Social Responsibility and Environmental Management	31	1.29%
Total Quality Management Business Excellence	31	1.29%
Administrative Sciences	30	1.25%
Industrial Marketing Management	30	1.25%
Journal of Business Industrial Marketing	28	1.17%
International Journal of Human Resource Management	26	1.08%

Apart from the impact journals, the performance analysis also highlights the most influential authors, as shown. From the corpus of 2398, the top 20 influential authors based on published documents were highlighted. In the organizational culture domain, the top 2 leading authors are Antony J. (9, 0.38%), and Kim S. (9, 0.38%). After that, three authors, Ali, Hitak and Le each published 7 (0.29%) documents. This highlights the researcher's interest in organizational culture research. Around 7 authors have published 6 documents (0.25%). Finally, around 8 authors have published 5 documents (0.21%). From the corpus of 2398, Fig. 2 highlights the top 20 most influential countries in organizational culture research from 2014 to 2024. Fig. 2 shows that most of the research in the firm culture domain has been conducted in developed countries like the USA, UK, Australia, Spain, and Germany. This highlights a significant research gap in terms of geography. Furthermore, the United States (US) is the leading country with 421 documents, which indicates its dominant role in the research domain. After that, England was the second most influential nation with 231 documents. According to Fig. 2, China, with 201 publications, ranked third in the most influential country, reflecting its growing influence in the research domain. As indicated above, most of the research in organizational culture was performed in developed countries, few developing/emerging countries like India (178), Indonesia (94), Vietnam (64), and Pakistan (62) were able to publish.

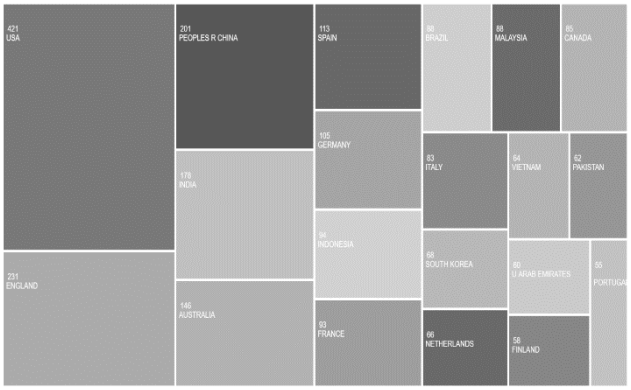

Fig. 2. Top countries in current research domain

Science mapping and Network analysis

As suggested by Donthu et al. (2021), the network analysis helps to understand the bibliographic linkages among published documents in terms of references, journals, and keywords. As recommended by Donthu et al. (2021), the network analysis consists of co-occurrence, co-citation, co-authorship, and bibliographic coupling, as explained below.

The analysis of co-occurrence in bibliometrics helps to understand the occurrence of certain keywords, terms, and phrases in the literature. It also helps to understand the intellectual structure, research trends and gaps of any research field (Donthu et al. 2021).

From the corpus of 2398 documents, the co-occurrence analysis was performed through VOS viewers. Fig. 3 and 4 show the co-occurrence analysis based on authors' keywords and all keywords, respectively. In both cases, the word "occur" was selected at least five times. Consequently, 386 items were extracted, as shown in Fig. 3, with a total of 15 clusters. The largest cluster is represented in red colour, having 44 items with prominent keywords being "*organizational culture*", "*innovation*", "*leadership*" and "*psychology*". The second cluster is presented as green colour having 41 words with prominent words being "*corporate social responsibility*", "green management", and "*business ethics*". The third cluster has 40 words, the 4th has 33, the 5th has 30, the 6th has 29 words, and the 15th cluster has 2 words.

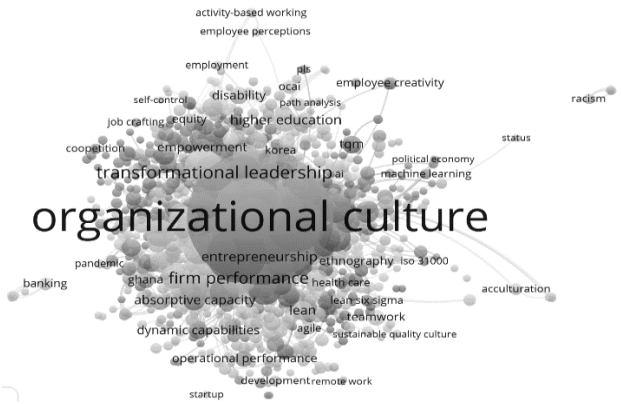

Fig. 3. Co-occurrence analysis based on authors' keywords

Similar to the above, Fig. 4 also highlights the co-occurrence analysis based on all keywords. The VOS viewer was used to complete the analysis. Again, a word with a minimum occurrence of five was selected for analysis. Consequently, a total of 896 words were extracted that formulate 9 clusters. From the analysis, the largest cluster is represented as green colour, consisting of 193 items. The most prominent keywords are "*organizational culture*", "*cultural change*", and "*leadership*". The second cluster is represented as red colour consisting 183 words, the third cluster has 137 words, and the fourth cluster has 102 keywords.

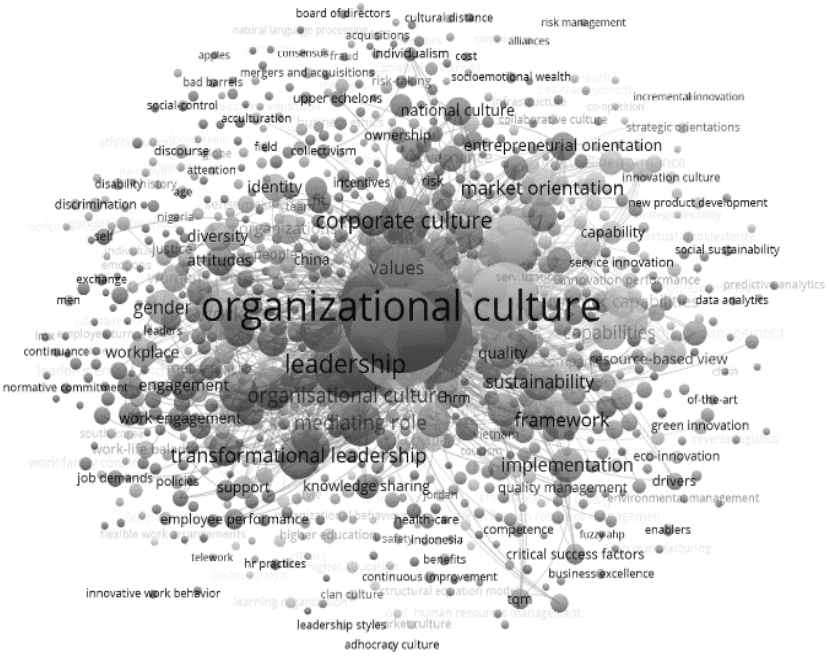

Fig. 4. Co-occurrence analysis based on all keywords

According to Donthu et al. (2021), co-citation analysis helps to understand the association among cited publications to develop the foundational themes in a specific research domain. In the current research, co-citation analysis is shown in Fig. 5. It highlights the co-citation analysis based on cited references. Through VOS Viewer software, references cited at least 15 times were selected for further analysis. From this threshold, 584 items with 7 clusters were formulated. The 1st cluster is represented in red, having 162 items. The prominent authors in this cluster are Schein (1985), and Oreilly (1991). The second cluster is represented in green colour having 116 items. The prominent authors are Fornell (1981), Podsakoff (2003), and Hair (2017). This cluster highlights the methodological references. This 3rd cluster is represented in blue colour having 88 items, yellow colour represents the 4th cluster having 75 items.

According to Donthu et al. (2021), co-authorship analyses the association and interactions among authors and their affiliations that impacts the development of the research field. Fig. 6 highlights the co-authorship analysis based on organization. An organization having a minimum of five documents and at least five citations were selected for analysis. Through this threshold, 210 out of 2867 organizations meet the thresholds. Furthermore, a total of 15 clusters was formulated. The 1st cluster has 22 items like "*Khalifa*", "*Cardiff*", and *"Kent"* universities and is represented in red. The second cluster consists of 21 items and is represented in green. The third cluster consists of 20 items and is represented in blue.

On the other hand, co-authorship analysis was performed based on a country with a threshold of 5 documents with five citations. Through this threshold, 81 items formulate 10 clusters. The 1st cluster has 14 countries of Central Europe followed by 13 items of the 2nd cluster. The majority of countries in the 2nd cluster represent the Middle East and UK.

Bibliographic coupling

In the bibliographic analysis, the bibliographic coupling highlights the association among cited publications to examine the present or periodical development in the research field (Donthu et al. 2021).

Fig. 7 shows the bibliographic coupling based on documents. To perform this, a minimum threshold is a document that has a minimum of 15 citations. With this threshold, 761 documents meet the criteria with 8 clusters. The 1st cluster consists of 246 items and is represented in red colour, followed by the 2nd cluster having 123 items and represented in green colour. This 3rd cluster has 117 items and is represented in blue colour.

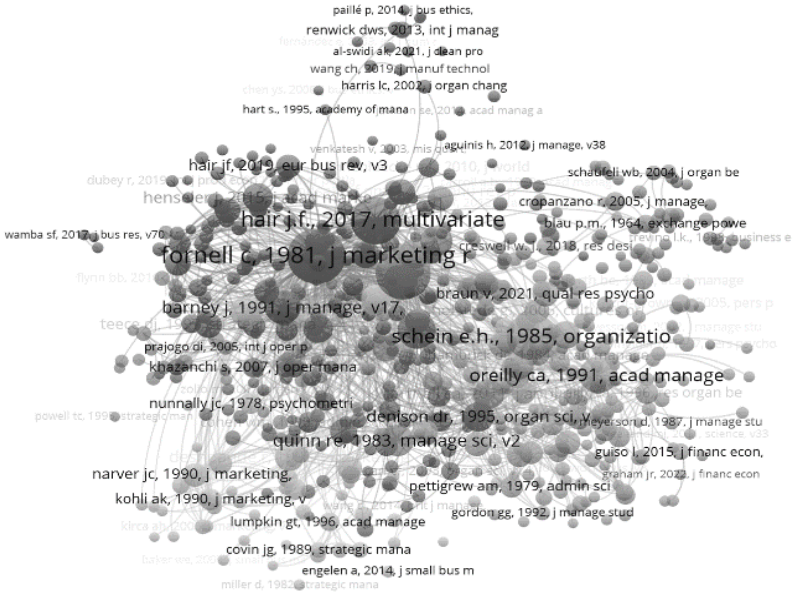

Fig. 5. Co-citation analysis based on cited references

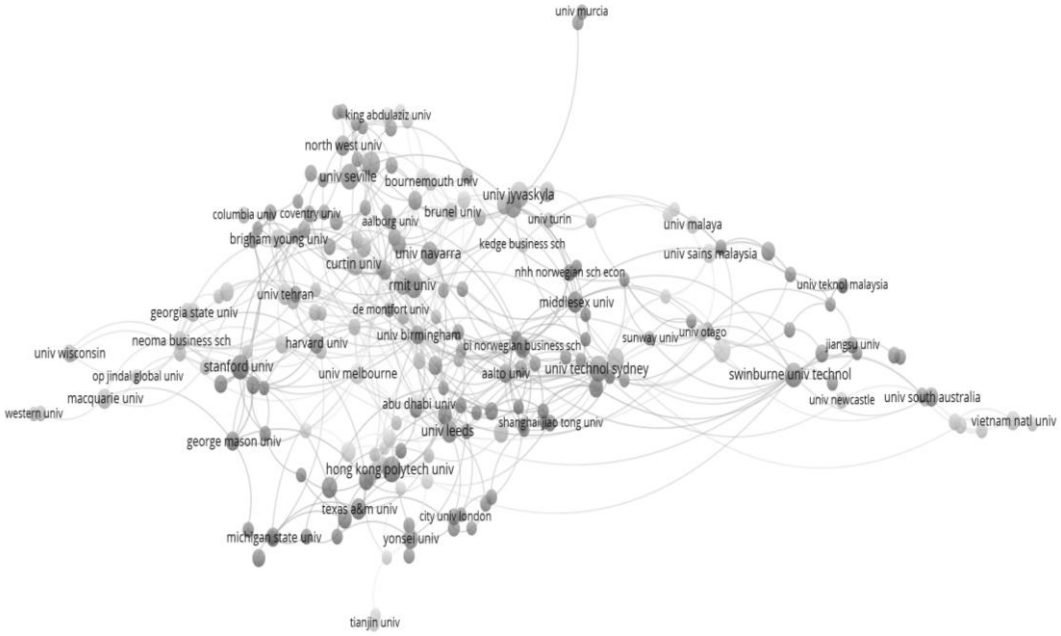

Fig. 6. Co-authorship based on organizations

Discussion

In the age of digital transformation, the notion of IR 5.0 has gained considerable research attention. Various factors help to implement IR5.0; the organizational culture is one of them. Past review studies systematically analyse the organizational culture; there are many lines of inquiries that need detailed analysis. To fill these voids, the purpose of this review study was to analyse the performance and network structure of organization culture from 2014 to 2024. To achieve the study objectives, the data was collected from WOS.

The bibliometric analysis was performed in two steps: performance analysis and science mapping & network analysis. In the performance analysis, the results highlight that the publication trend in the firm culture domain has been rising. For instance, more than 72% of documents published from 2020 to 2024. This indicates an upward trend in the organizational culture domain. This outcome is supported by past studies (de Oliveira et al. 2023; Bogale & Debela, 2024).

Furthermore, the analysis highlights that most documents are published in well-reputed journals. Table 2 indicates that more than 30% (760/2398) articles were published in top 20 journals. This outcome is supported by prior review work (Palumbo & Douglas 2023). Moreover, the performance analysis highlights the most impactful authors in the organizational culture domain. The most impactful authors published more than five documents, and the majority of authors are affiliated with developed countries like the US, UK, Australia, and Canada. In the same vein, most documents are published in developed countries. These outcomes are supported and in line with de Oliveira et al. (2023).

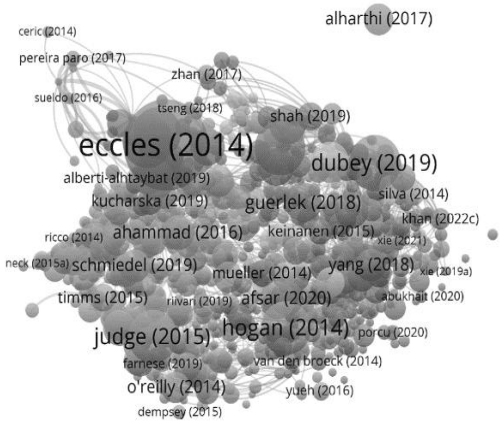

Fig. 7. Bibliographic coupling based on documents

Apart from performance analysis, the bibliometric analysis presents the science mapping and network analysis. These analyses highlight the conceptual structures among cited references, documents, and countries. As per the direction of past studies, co-occurrence, co-citation, co-authorship, and bibliographic coupling analyses were performed. The co-occurrence analysis indicates that the most dominating keywords are "organizational culture", "innovation", and "change management". In the IR5.0 perspective, these aspects gained central attention. Moreover, the co-citation analysis highlights the linkages among cited references. The outcomes depicted that the corpus of documents formulate various clusters like conceptual, methodological, and empirical clusters. Moreover, the co-authorship analysis reconfirms that most of the author's affiliations are from developed countries like the US, UK, and Australia. The co-authorship analysis also indicates that few researchers belong to developing/emerging countries like Malaysia, India, and Pakistan. Finally, the bibliographic coupling analysis indicates the periodical development in the organizational culture domain. All these outcomes are supported by past studies (Bogale and Debela 2024; de Oliveira et al. 2023; Palumbo 2024).

This study contributes to understanding how OC adapts in the different industrial revolutions, especially Industry 4.0 and IR5.0. Unlike the I4.0, which focuses on automation and data-driven outcomes, IR5.0 focuses on the synergy between humans and machines or sociotechnical systems. Secondly, this review study contributes to OC by conceptualizing the IR5.0 principle. This provides a nuanced framework for organizations to enhance their IR5.0 readiness. This perspective broadens IR5.0 research by integrating cultural dimensions into existing operational and technological frameworks. From a practical perspective, the review findings offer action insights into how the firm can cultivate a culture that aligns with current industry trends. By highlighting the importance of social factors like leadership, workforce commitment, and training & learning, the research offers a holistic roadmap for organizations seeking to foster their adaptability and resilience. Moreover, the practical aspects help firms to balance socio (human) and technical (technology) factors. This ensures that digital transformation is effectively integrated with strategic and cultural imperatives.

Conclusion

This research has endeavoured to provide a nuanced analysis of organizational culture (OC), spanning between 2014 and 2024 from the WOS database. Conclusively, the outcomes indicated that OC has gained considerable attention during and post COVID era. Specifically, an upward surge has been witnessed in year 2023 and 2024. In terms of intellectual structure, the corpus of 2398 articles indicated that most trending and prominent keywords are "organizational culture", "innovation", "environmental management" and "resilience". This highlights the future research avenues in the context of IR 5.0. Fundamentally, IR 5.0 consists of resilience, human-centric context and sustainability.

This systematic review has manifold limitations that pave the steps for future research. Firstly, the study relies on the WOS database. This limits the potential and relevant publications in other databases like Scopus. Thus, in the future, both databases can be used to ensure an in-depth literature synthesis. Secondly, the documents extracted and examined from a limited timeframe of 2014 - 2024, which may not fully capture the historical progress of OC or have a long-term effect on digital transformation. Thus, in future studies, a historical evolution of OC beyond 2014 can be conducted. Finally, the study employs bibliometric analysis through the SLNA technique. This technique is unable to provide in-depth insights into theoretical enhancements. Therefore, the future study will incorporate bibliometrics with other techniques like the TCCM framework or others.

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DIGITIZATION DEVELOPMENT ANALYSIS WITHIN THE SMART ECONOMY AND SOCIETY IN THE VISEGRAD 4 GROUP COUNTRIES

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Abstract
This research paper is devoted to analysis the circumstances of how the digitization process in economy and society will affect sustainable economic and social development in V4 countries to enhance their competitiveness in EU economy. The main objective of the research is to estimate the impact of digitization processes in the smart economy and society on sustainable economic and social development in V4 countries. The estimation is based on the World Bank, IMD, DESI, EIS data assessment approach. The main method used is the correlation a regress analysis conducted within the framework of the VEGA project output, from which data related to assessment were analyzed along with graphical explanation. The results have indicated that to fully benefit from digitization processes, V4 countries must strategically invest in digital tools, develop digital skills within their workforce. The ability to adapt to and leverage digital technologies will be a key determinant of success in the increasing digital business landscape to enhance their competitive advantage within the sustainable economic and social development in the EU.
KEYWORDS: digitization process, smart business, small and medium enterprises, international business, development sustainability, smart economy and society.
JEL: F66, F22, J62

Introduction

The objective of the study is to specify and analyze the factors that influence the quality of the business environment, digitization, and innovation within the V4 countries. The results of this analysis should then be compared between the V4 countries. The identification of these factors will be based on recognized indices developed by the World Bank (Doing Business), the International Institute for Management Development (IMD), and the European Commission (DESI, EIS). In the context of the findings, an effort will be made to demonstrate, through the application of correlation analysis, the extent to which the quality of the business environment exerts an influence on the growth of the number and value added of SMEs. Additionally, the role of innovation and digitization in promoting the growth of the number and value added of SMEs in high-tech sectors will be investigated. The research paper deals with the new phenomenon, namely the fact that the digitization process has a significant impact on the competitiveness of economies in V4 countries. This paper presents a framework for a new and so far, unexplored issue, where the novelty is how the implemented digitization process would affect the competitiveness of SMEs in V4 countries to enhance their sustainable economic and social development in the EU. This paper aims at filling this gap in literature by assessing the impact of digitization along with smart business entrepreneurship on competitiveness of SMEs in terms of the possibility to enhance their business being a significant pilar of national economies in V4 countries. The uniqueness of the paper lies in the exploration of the competitive advantage of V4 countries within their differentiation and faster adaptation to the EU economy. SMEs in V4 countries that leverage digital technologies can differentiate themselves from competitors by offering unique digital experiences, efficient services, or innovative products. Digitized economy and society are more agile and can quickly adapt to new technologies, regulations, or market shifts, maintaining their competitive edge to enhance their sustainable economic and social development within the EU. This paper is organized as follows. After the Introduction section in Section 2, essential theoretical background is proposed according to the description of the small and medium enterprises in their role in national and global economy along with the mutual parallels and synergies within the competitiveness issue found in the literature; in Section 3, the research methodology is described more in depth. In Section 4, the review results of empirical analysis have been proposed and in Section 5, discussions related to the contributions, advantages and recommendations of proposed findings are presented and significant insights are brought to light such as assessing the data analyzed by V4 countries and determining the impact on their economies. Finally, Conclusions at the end of the paper summer up the relevance of this study, along with the research limitations and future research directions.

Literature review

The notion of competitiveness finds its roots in classical economic theory and underwent significant development at the end of the 20th century, following the dissemination of the works of M. Porter. He was the first to identify the sources of sustainable prosperity in the modern global economy (Ahmedová 2015; Marchevská, Kravčáková-Vozárová 2019). Nevertheless, several authors (Stawasz 2019; Kaczmarek 2022) concur that the concept of competitiveness is not definitively defined. Due to the qualitative and quantitative nature of its factors, precise limits in the level of analysis and various measurement methodologies are lacking. Due to the

extensive scope of its significance, which encompasses the corporate, sectoral, national, and supranational levels, a consensus for its conceptual definition remains elusive. The concept of competitiveness can be examined across various geographical scales, including the European Union, individual countries, regions, and smaller geographical areas. Additionally, competitiveness can be studied within specific sectors, economic activities, and enterprise groups (Garcia-Martinez, et al. 2023).

According to Veber et al (2016), competitiveness is defined as "a set of institutions, policies, and factors that determine the level of productivity of a country." An increase in productivity has been shown to lead to an increase in a nation's income, thereby achieving greater prosperity for its citizens and enhancing their quality of life. As Kadárová and Janeková (2019) contend, the concept of competitiveness must first be understood at the macroeconomic level, where it is defined as the performance of a given economy in relation to another economy. Conversely, from a microeconomic perspective, it is defined as the level of education, productivity, utilization of natural resources, or advantageous government policy. Moreover, the concept of competitiveness encompasses elements such as competitive advantage, price competition, strategic management, and other historical and socio-cultural factors (Florek-Paszkowska 2021). The fundamental attribute of competitiveness is the comparative advantage of a given entity over another. A significant undertaking for small and medium-sized enterprises is the identification of a sustainable competitive advantage. This principle should serve as the foundational basis for the development of any business enterprise (Sariyev 2021).

The activities of enterprises are influenced by a multitude of factors, including economic, political, institutional, legal, technological, and cultural elements. These factors exert a significant influence on the environment in which enterprises operate. This concept is referred to as the business environment, which is considered a quantitative factor that exerts a fundamental influence on entrepreneurial activity within individual countries, as well as its outputs, results, and subsequent impacts (Pilková, et al. 2019). The business environment is defined as the external environment of an enterprise, comprising all phenomena, processes, and institutions that influence its exchange relations and developmental conditions. It signifies all phenomena that possess a spatiotemporal dimension, that are capable of exerting influence upon it, or that the enterprise has or will exert influence upon in the future (Rózsa, et al. 2023). In essence, the business environment encompasses all elements that are associated with the enterprise (Čabinová, et al. 2020). A salient feature of the environment is its variability, as well as the threats and opportunities that arise from the enterprise's operations. The business environment is a broad concept, and a considerable number of institutions and actors at the national and transnational levels participate in its formation. Specifically, the company exerts its influence on the specific environment formed by suppliers, customers, and competitors, as well as the general environment, which is represented primarily by the state. The contemporary corporation exerts a substantial influence on the global environment, a phenomenon that can be attributed, in part, to the processes of globalization. The business environment is influenced indirectly by social factors, which are considered relatively marginal. These values, opinions, and lifestyles are shaped by the environment, and the development of population, cultural, ecological, demographic, religious, and ethnic conditions is a contributing factor (Ključnikov 2016).

The quality of the business environment is frequently regarded as a pivotal element in the long-term economic competitiveness of small and medium-sized enterprises. A quality business environment is defined as a state that fosters entrepreneurship through the provision of adequate resources and the establishment of conditions conducive to long-term, sustainable economic growth. Additionally, it is characterized by a straightforward and accessible administrative framework, ensuring the effective operation of both the state and public administration (Mishchuk, et al. 2023). A quality business environment exerts its influence at two fundamental levels. The initial component of the legislative framework encompasses the establishment of overarching regulations, encompassing aspects such as the imposition of taxes and contributions, the extent of labor market regulation, prerequisites for the initiation of commercial activities, accounting regulations, and a plethora of other regulatory and administrative obligations pertinent to entrepreneurial endeavors. The second fundamental level, which gives shape to the business environment, comprises specific social and economic conditions in particular regions. These conditions include the development of transport infrastructure, the composition of local industry, and the availability of labor (SBA 2023). The seamless operation of the business environment is imperative for the optimal development and competitiveness of the business sector and nations. The process of globalization exerts significant pressure on national economies, compelling them to enhance their competitiveness at both the corporate and macroeconomic levels. This enhancement is a critical factor in fostering effective and competitive entrepreneurship (Galgánková 2020; Mura, et al. 2022).

The European Union acknowledges the necessity to provide support to small and medium-sized enterprises (SMEs), as they constitute the predominant and most significant European employers. Their prosperity is of considerable importance for the future of the European economy (Srpová 2020). At the EU level, the European Commission plays the most important role. It supports entrepreneurship and growth by reducing the administrative burden on small businesses and facilitating access to financing for small and medium-sized enterprises. The European Structural and Investment Funds (ESIF) finance operational programs in individual EU member states, and measures to support SMEs are also implemented within them. The Partnership Agreement on the use of the European Structural and Investment Funds in 2014-2020 between the Slovak Republic and the EC was concluded on June 20, 2014 (SBA 2023). The European Investment Bank (EIB), which prioritizes support in four key areas—innovation, small businesses, climate, and infrastructure—is also a prominent institution. During the period 2014-2020, 15,215 projects in Slovakia were supported through these funds, with a total of €8,740

million being drawn (ITMS2014+ 2022). The European Investment Bank also incorporates the European Investment Fund (EIF). The primary objective of the program is to provide financial support to micro, small, and medium-sized enterprises (MSMEs) in Europe by facilitating their access to financing (SBA 2023).

A comprehensive understanding of the external environment is a fundamental prerequisite for the formulation of a successful strategy in the face of evolving business conditions. A variety of indices are employed to assess the quality of the business environment at the international or global level, with different constructions and data sources (Belas, et al. 2023). The assessment of the business environment is conducted by agencies that utilize generally valid evaluation indicators. These criteria are subject to constant updating, expansion, and inclusion of current trends (Vyhnička, Žárska 2021). The factors to be considered include business conditions, government measures such as tax and levy policy, social policy, policy in the field of subsidies and grants, and the field of financing companies and capital (PAS 2021).

At present, several international organizations and institutions are engaged in the measurement and evaluation of economic entities on a global scale. These entities include national economies and the performance of business enterprises. Additionally, these entities assess the quality and competitiveness of the business environment. The most prominent compilers include the World Economic Forum, which annually compiles the Global Competitiveness Index (GCI). The Global Competitiveness Index is determined by evaluating 12 pillars: the quality of public institutions, infrastructure, macroeconomic environment, health and primary education, higher education and training, product market efficiency, labor market efficiency, financial market maturity, technological readiness, market size, business process maturity, and innovation (Herčko, et al. 2017; Svazas, et al. 2024).

Another major compiler is the World Competitiveness Center (IMD), which publishes a comprehensive annual yearbook, the World Competitiveness Rankings (WCY). The index is based on 333 competitiveness criteria selected based on comprehensive research, consisting of two-thirds statistical data and one-third survey data, and assesses 63 countries around the world (IMD 2022a). The ranking employs a multifaceted evaluation framework that encompasses economic performance, government effectiveness, business efficiency, and infrastructure (see Table 1). The company is also responsible for the publication of the World Digital Competitiveness Ranking, which has been conducted for the sixth consecutive year. This index serves to assess the capacity and readiness of individual world economies to adopt and explore digital technologies as a catalyst for economic transformation in the business sector. In 2021, a total of 54 criteria were employed, encompassing a combination of external hard data and the IMD Executive Opinion Survey. These criteria were subsequently grouped into three overarching categories: future-ready, knowledge, and technology. It is noteworthy that 63 countries worldwide are engaged in this assessment (IMD 2022b).

Table 1. WCY Competitiveness Criteria

Economic performance	Government effectiveness	Business efficiency	Infrastructure
• domestic trade • international trade • international investment • employment • prices	• public finance • tax policy • institutional framework • business legislation • social framework	• productivity and efficiency • labor market • finance • management practices • attitudes and values	• basic infrastructure • technological infrastructure • scientific infrastructure • health and environment • education

Source: own processing according to IMD, 2023

The World Bank's Doing Business survey is a comprehensive study that assesses regulations pertaining to the business environment in 190 global economies. The assessment was based on indicators during various stages of the life cycle of small and medium-sized enterprises, from company formation to obtaining a building permit, bank loans, to enforcing contracts and closing the business (Figure 1). The primary objective of the project was to establish an objective foundation for comprehending and enhancing the legal environment for business. Presently, the publication of this report is suspended. This is due to inconsistencies in the preparation. The report will be replaced by a new project, Business Enabling Environment - BEE (The World Bank 2022).

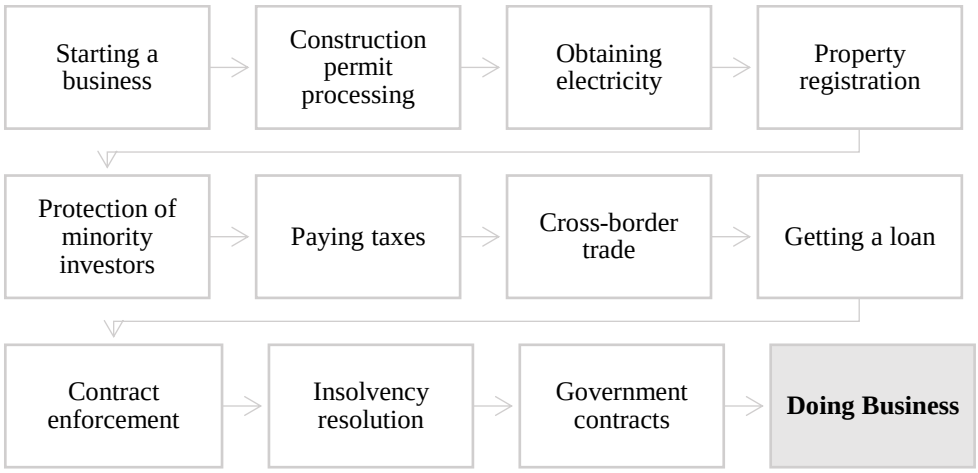

Fig. 1. Doing Business indicators
Source: Own processing based on The World Bank, 2022

In the contemporary business landscape, it has become imperative to assess innovation performance and the extent of digitalization, as these factors significantly influence a nation's or small and medium-sized enterprises' competitiveness. The European Commission employs the European Innovation Scoreboard (EIS) to evaluate the level of innovation on a regular annual basis. The evaluation of countries is conducted using a multifaceted approach, encompassing twelve primary categories of indicators. For instance, assessment encompasses a range of factors, including human resources, digital transformation, the innovative capacity of small and medium-sized enterprises (SMEs), and the support for scientific research and innovation. The objective of this study is to make a comparative analysis of the research and innovation performance of EU countries and a selection of third countries. The EIS contains an assessment of the strengths and weaknesses of national innovation systems and helps countries identify areas for improvement (SBA 2023). The European Commission also oversees the digital progress of EU countries in the Digital Economy and Society Index (DESI) reports. This index facilitates an evaluation of the aggregate degree of digitalization in individual EU countries and identifies problematic areas to which states should direct greater attention. Additionally, it facilitates a comparative analysis of EU member states. The assessment employs a composite indicator system, categorized into the following primary domains of measurement: human capital, connectivity, integration of digital technologies, and digital public services (MIRRI 2022).

Methodology

The goal of this paper is to identify the impact of digitization processes in the smart economy and society on sustainable economic and social development in V4 countries. The basic research method was the correlation a regress analysis conducted within the framework of the VEGA project output, from which data related to assessment were analyzed.

The paper used several combinations of research methods to achieve the stated primary objective. First, we searched for the necessary information and data related to the issues of SMEs and their competitiveness based on the literature review. Next, we elaborated the issues related to SMEs by abstracting and collecting secondary data and information. Then, by synthesizing the collected data, we described the relevant facts of this area. We applied mathematical methods in the calculations of the data obtained from Eurostat, which we then used in the time series analysis in the development of individual indicators of SMEs. We compared the obtained values of the SME indicators among the countries of the Visegrad Group. We also used analysis, synthesis and deduction in the assessment of the business environment, innovation and digitalization based on selected indices and rankings of renovated institutions and organizations. The data based on which we developed the analysis of SME development were obtained from the European statistical portal Eurostat. The advantage of using Eurostat data is that the statistics are harmonized and therefore more comparable between countries. We used the method of correlation and regression analysis to show the degree of dependence of individual EIS sub-indices on the overall EIS ranking and the dependence of the digitization of public services index on the overall DB ranking. Correlation is a measure of the relationship between two or more quantitative variables. The correlation coefficient is used to express the strength of the correlation, which can take values between -1 and 1. The closer the value is to 1, the stronger the linear dependence. Conversely, the closer it is to 0, the weaker the correlation. If the correlation coefficient is positive, there is a direct proportionality between the variables; if the correlation coefficient is negative, there is an indirect proportionality. If it is equal to zero, both variables are statistically independent (Grinčová, Petrillová 2019). The expression of correlation dependence is a correlation graph. Correlation was performed in MS Excel through data analysis. The calculation of the correlation coefficient is as follows:

$$r = \frac{\sum (x - \bar{x})(y - \bar{y})}{\sqrt{\sum (x - \bar{x})^2 \sum (y - \bar{y})^2}} \quad (1)$$

Results

Digitization is also linked to the development of innovation. A number of indices are used to monitor countries' progress in the use of digital technologies. One of these is the European Commission's Digital Economy and Society Index (DESI). Unlike the EIS assessment of digitization, which only looks at broadband coverage and individuals with high digital skills, the DESI tracks the state of digital technologies in EU countries more comprehensively using a number of indicators - human capital, connectivity, integration of digital technologies and the state of digitization of national public services. According to the DESI 2023 assessment, Poland has the lowest level of digitalization, ranking 24th out of 27 EU countries. Slovakia is one place ahead, while Hungary ranks 22nd. The Czech Republic is the best performing of the V4 countries, ranking 19th, but still below the EU average. Over the last few years, the countries have kept this position more or less the same, with no significant deterioration, but on the contrary, no improvement for any of the V4 countries. We can therefore say that the V4 countries are stagnating in the field of digitization. Figure 2 shows the positions of the countries in the individual indicators of the 2023 assessment in relation to the EU average results, as well as the weight of each assessed indicator for the final ranking. Based on the graph, we can conclude that the digitization of the public sector and its services has the highest weight on the overall digitization status, followed by connectivity and human capital. The lowest weight on the overall ranking is currently identified in the integration of digital technologies directly related to SMEs.

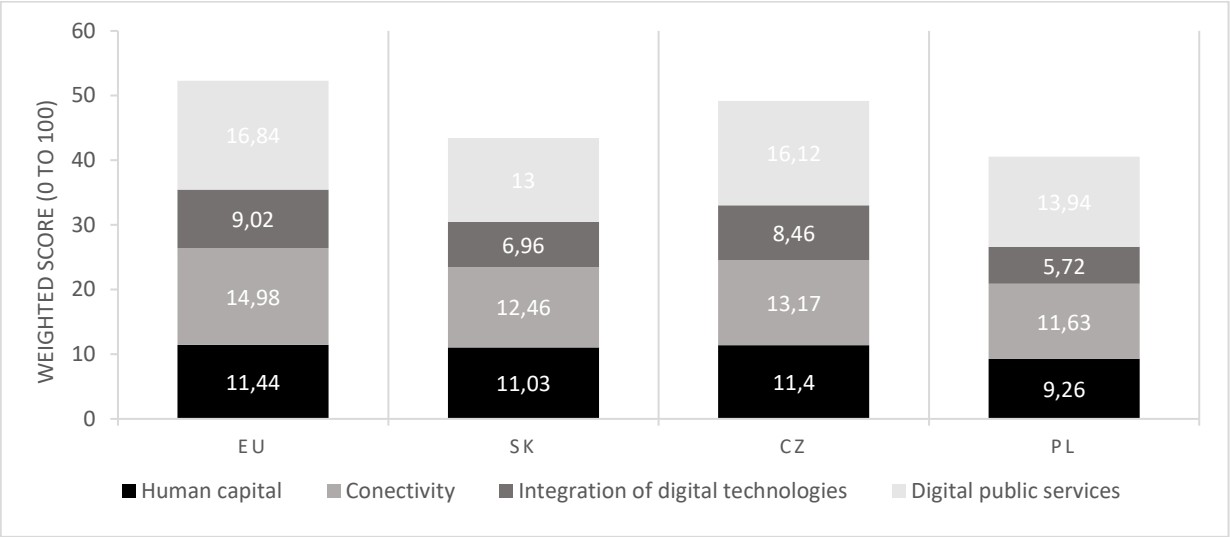

Fig. 2. Ranking of V4 countries according to the DESI Index in 2023
Source: Own processing based on DESI data, 2024

Based on the analysis, we can conclude that Slovakia and the Czech Republic are just below the EU average in human capital indicators, while Hungary and Poland are slightly worse off. For example, this indicator assesses basic digital skills, which 55% of Slovaks have in Slovakia, slightly above the EU average of 54%. For the advanced digital skills indicator, the percentage is significantly lower at 21%, compared to the EU average of 26%. According to the European Commission, this is due to the lack of a systematic approach to the implementation of adult digital literacy training. The Czech Republic is more successful in this indicator, with 60% of Czechs having at least basic digital skills and 24% having advanced digital skills. In Hungary, 49% of 16–74-year-olds have at least basic digital skills, compared to only 43% in Poland. In terms of connectivity, i.e. the availability, quality and coverage of the Internet network, all the countries surveyed are below the EU average. The best performer among the V4 countries on this indicator is Hungary, which ranks 13th overall; Poland also lags behind the other V4 countries on this indicator, making it one of the three worst performing EU countries on this indicator. It should be noted, however, that all V4 countries are showing significant growth in Internet connectivity, coverage and speed. The challenge for the countries remains the development of 5G networks, which will enable the use of the Internet of Things or autonomous vehicles, for example, and thus have a major impact on the future of the countries. From an SME perspective, an important category is Digital Technology Integration, which assesses SMEs based on their level of digitalization. Specifically, it focuses on indicators such as the basic level of digital intensity, electronic dissemination of information, big data, artificial intelligence, internet sales and turnover, cross-border internet turnover or the use of e-invoicing. Selected indicators for each V4 country are shown in Table 2.

Table 2. Indicators of the category Integration of digital technologies in the V4 countries in 2023

	SK	CR	PL	HU	EU
Basic digital intensity level	43%	53%	40%	34%	55%
Electronic Invoice	16%	12%	13%	13%	32%
Online sales	13%	23%	14%	18%	18%
Internet turnover	8%	17%	n/a	11%	12%
Internet cross-border sales	7%	11%	5%	5%	9%

Source: Own processing based on DESI data, 2024

Looking at the overall category assessed, all V4 countries are below the EU average. The same is true when looking at the individual categories of the assessed indicator. SMEs do not make sufficient use of digitization to increase their competitiveness. Hungary ranks 25th in the EU in terms of the integration of digital technologies in the activities of enterprises. Despite an increase in several indicators in this area, most Hungarian enterprises still fail to make use of digital technologies. Only one third of SMEs have at least a basic level of digital intensity, and only 13% of companies use e-invoicing. More businesses are engaging in online trade, with internet sales up 5% and internet turnover up 2% compared to 2021. Cross-border online trade has been stagnant for several years, with Hungarian SMEs accounting for 5% of foreign online trade.

Poland ranks 24th in this indicator, reflecting the fact that only 40% of Polish SMEs have at least basic digital intensity, which is below the EU level. SMEs are more involved in e-commerce than in the previous period, with 14% of Polish SMEs using online sales and 13% using e-invoicing. Foreign online trading is below the EU average, with 5% of SMEs using this sales tool. Slovakia ranks 21st, with 43% of SMEs having at least a basic level of digital intensity, below the EU average of 55%. Only 16% of SMEs use e-invoicing, half the EU average. The e-commerce score is 13% and the share of online sales is also below the EU average at 8%. Slovak SMEs make only 7% of their cross-border sales online, compared to 9% in the EU. Negatively for the country, the individual indicators show a decline compared to last year. The Czech Republic ranks 19th among the 27 EU Member States in terms of digital technology integration, which is the best ranking among the V4 countries but still four places worse than in the previous period. More than half of SMEs have at least a basic level of digitization, which is just below the EU average. E-commerce indicators are higher than the EU average, with 23% of Czech SMEs selling online and accounting for 17% of turnover. Online foreign trade is also higher than the EU average at 11%.

The digitization of public administration is generally very important for all countries, as it has a major impact on the business environment, cutting red tape and speeding up processes. Governments should also support the digitization of SMEs by setting the right example and digitizing their operations and services, especially when dealing with small businesses. Recognizing this, digitization of the public sector is becoming a priority for V4 governments, but the countries rank below the EU average. It assesses the level of use of digital public services for citizens and businesses, open data, pre-populated forms or the percentage of e-government users. The Czech Republic is the best-performing country, at 17th place, while Slovakia is the worst-performing country, at 24th out of 27 EU countries and below average in all the indicators monitored. This is even though the country has, for example, significantly increased online filing of tax returns, eased the process of starting a business, and legislated for e-invoicing. Hungary has managed to significantly improve the digitization of its public administration, moving up to 4 places, while Poland underperforms in the availability of digital online services for citizens and businesses, ranking 22nd. E-government can have important demonstration effects for the economy, providing platforms, technologies and standards that facilitate transactions and create opportunities for SMEs.

Since we defined the need for digitization of public administration as a factor for improving the business environment in the results of the Doing Business ranking analysis, we investigated whether there is a dependency between these two variables. We examined this based on correlation and regression analysis. The coefficient value of the correlation analysis R= 0.54 shows a medium linear dependence between the variables of the overall DB ranking and the digitization of the public sector, as it is in the range of 0.3-0.8. The coefficient tells us that 54% of the data in the dataset behave in the same way as the overall Doing Business ranking. In Figure 3, it can be seen a positive linear dependence between the variables under study. The p-value = 0.013 is lower than the set significance level $\alpha = 0.05$ and therefore we can confirm hypothesis H1 that the correlation coefficient between the overall Doing Business score and the digitization of public services is statistically significant at the significance level $\alpha = 0.05$.

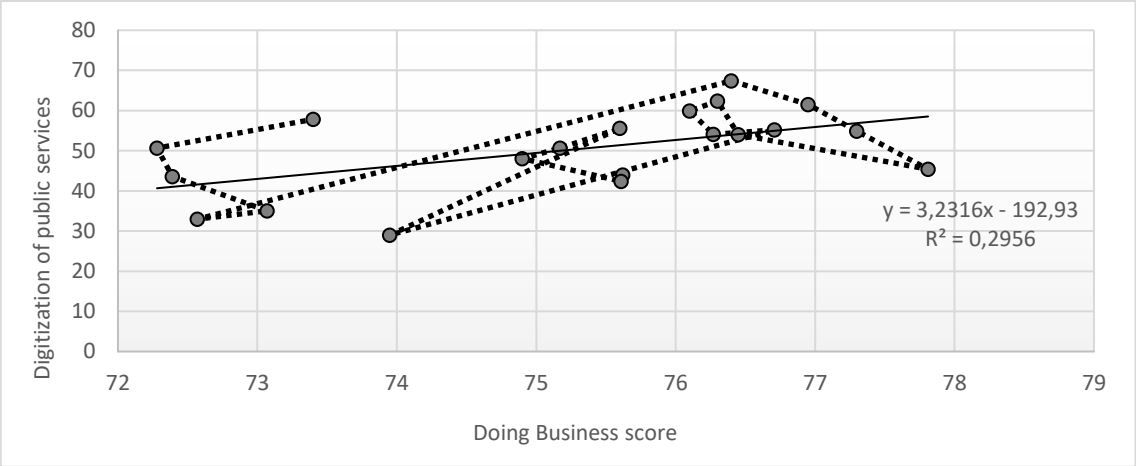

Fig. 3. Correlation between the overall Doing Business score and the digitization of public services
Source: Own processing

Countries with higher levels of digital transformation tend to be more competitive. The importance of digital transformation for countries to be more competitive is also highlighted by the IMD. In its assessment, it considers knowledge, technology and the future readiness of countries as the main factors affecting digital competitiveness. Based on these assessments, the ranking of the V4 countries is shown in Figure 4.

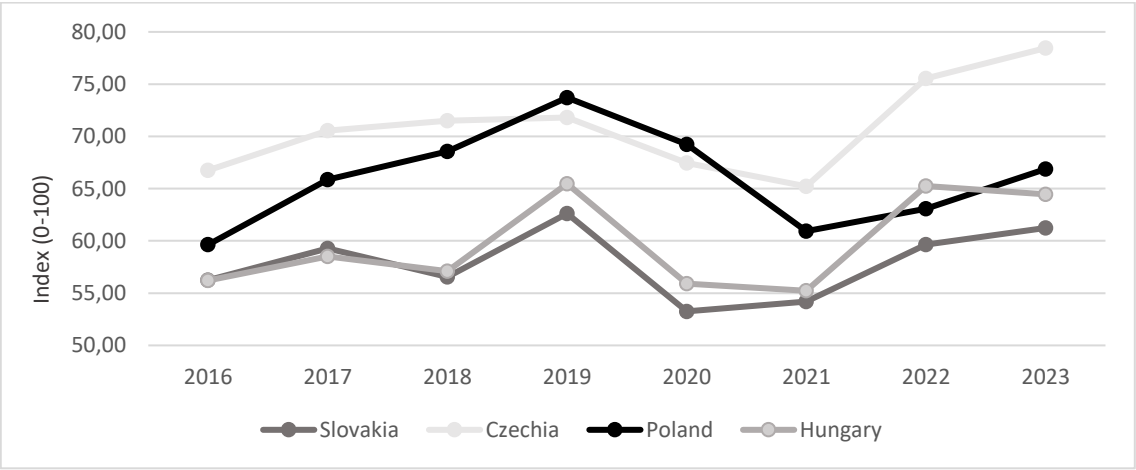

Fig. 4. Ranking of V4 countries in the WCY Digital ranking in 2016-2023
Source: Own processing based on data by IMD

Slovakia is the worst performer in this ranking at 47th place. The country's main problem is the indicators in the field of technology, such as starting a business, laws and legislation in the field of scientific research, capital and technical framework, such as Internet connection or export of the high-tech sector. In the IMD ranking, Poland is better placed than Slovakia (46th place). However, Poland is a country where conditions are gradually deteriorating. In 2019, it was the best-ranked V4 country in terms of digital competitiveness, but a significant decline was recorded in 2020 and 2021. A gradual deterioration was observed in all categories. Digital skills are underutilized in the country, and digital education of the workforce, public-private partnerships, or the development of technical applications are also lacking. Another country in the ranking is Hungary, which had similar results to Slovakia, but improved slightly in 2019 and even overtook Poland in 2022, finishing in 42nd place. Unlike Slovakia, Hungary has the best results in the technology category, while IMD rates it the worst in the area of future readiness, which includes areas such as the use of big data, threats and opportunities, or company skills. The most successful V4 country in this rating is also the Czech Republic, which ranks 33rd and is in the first half of the successful countries in the ranking. The results in all categories are similar, for example, the Czech Republic is the leader in mobile phone coverage or the provision of banking and financial services. The share of foreign university students and the use of robots in education and research are also positive.

Discussion

The research paper has been dealing with the complicated situation regarding digitization, its impact on competitiveness of SMEs in V4 countries. When identifying and analyzing the SMEs development factors given the prevalence of reports and assessments that consider innovation as a factor in SME development, the present study examined the innovation performance of the V4 countries using the European Innovation Scoreboard EIS Index from the European Commission. A comparison was made between the countries and the average of the EU 27 countries. The European Commission's evaluation is not particularly favorable, with the sole exception of the Czech Republic, which closely aligns with the EU average. The outcomes obtained by each nation vary across the spectrum of indicators that are subject to observation. For small and medium-sized businesses, the Innovators indicator is of particular importance. This indicator refers to SMEs that introduce innovations into their products and production processes. Consequently, it is primarily related to the high-tech sector. It is noteworthy that the Czech Republic is the sole country that attains results for this indicator that are commensurate with the EU average. Another crucial indicator for SMEs is the impact on employment and trade, in which Poland is particularly lagging. A prevalent challenge associated with the innovation performance rate pertains to human resources, a matter chiefly associated with educational attainment. In the evaluated countries, there is insufficient government and state support for financing and supporting innovation. Concurrently, individual companies do not provide sufficient funding for research and development.

When it comes to the quality of the business environment, it was assessed primarily based on the World Bank's Doing Business ranking. The overall ranking of countries within the index is found to be significantly influenced by the individual categories of the index, which are primarily related to various administrative tasks that entrepreneurs complete during their business life cycle. In general, it can be posited that the primary challenges confronting entrepreneurs in the countries under observation pertain to the superfluous administrative load and bureaucracy, protracted durations required for the execution of various tasks, the opacity of the fee system, onerous tax obligations, and the perpetual flux of legislation.

Next there was the estimation of the WCY ranking as a metric that evaluates countries based on their overall competitiveness. The analysis encompasses a more comprehensive evaluation of countries, incorporating macroeconomic indicators, government efficiency, business efficiency, and built infrastructure. According to the assessment of the ranking compiler, the most significant deficiencies in the V4 countries are deemed to be the gradual rate of digital transformation, the absence of financial resources for SMEs, inadequate support for innovation, the high cost of entrepreneurial initiation, and the dearth of qualified personnel. In the preceding year, energy supplies and migration to the V4 countries have become salient issues. It is evident that all the countries evaluated are confronted with these challenges to a varying degree. For instance, IMD offers a positive evaluation of the growth of real GDP, as well as the gradual improvement of the countries in administrative bureaucracy and the enhancement of the legal and regulatory framework.

Within the stated objective to determine the extent to which the implemented digitization process would affect sustainable economic and social development in the V4 countries, digitalization is also assessed within the EIS ranking; however, the European Commission addresses digitalization more extensively in the DESI ranking. This assessment indicates that the V4 countries are experiencing stagnation in the realm of digitalization. Their position at the lower echelons of the ranking, coupled with the absence of substantial advancement, substantiates this conclusion. The category of "Integration of digital technologies" has been identified as a primary concern for small and medium-sized enterprises. The countries exhibit deficiencies in nearly all of the evaluated criteria, including the fundamental level of digital intensity and the implementation of electronic invoicing. It has been demonstrated that businesses do not fully leverage online sales, consequently failing to attain the desired levels of online turnover. Furthermore, the realm of online cross-border trade holds untapped potential for enhancement. Digitalization of public services is an essential category that exerts a substantial influence on the quality of the business environment. The findings of the study indicate that the evaluated nations should prioritize the advancement of digital technologies, as the full potential of these countries has not been realized.

Conclusions

In this paper it has been shown that digitization has a fatal impact on the competitiveness of SMEs in V4 countries when enhancing the sustainable economic and social development in the EU. We have arrived at the conclusion that businesses in V4 countries are not leveraging digital technologies to the extent that they could be to enhance their operations. In order to ensure the continued competitiveness of small and medium-sized enterprises, it is imperative that improvements in this area be made in the future. Finally, to summarize the results of the research, digitization significantly enhances the competitiveness of SMEs by improving efficiency, reducing costs, expanding market reach, and enabling innovation. The ability to adapt to and leverage digital technologies will be a key determinant of success in the increasing digital business landscape in V4 countries to enhance sustainable economic and social development in the EU. As research limitations can be mentioned, issues such as: statistical data vary depending on the source being used; the brevity of the time series employed may have influenced the interpretation of the results. The period under analysis was influenced by the economic crisis resulting from the pandemic, as well as the utilization of solely quantitative indicators. By going deeper and making this explored issue coherent and compact further research will be devoted to exploring the issues such as the benefits of smart cities to social and economic sustainable development in V4 countries.

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THE BLUE ECONOMY IN EU COASTAL REGIONS: SECTORAL COMPOSITION AND STRUCTURAL CHALLENGES

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Abstract
The Blue Economy is becoming an increasingly vital component of regional development strategies, offering the potential to decouple economic growth from environmental degradation. It is viewed not only as a source of employment and value creation, but also as a platform for long-term environmental sustainability and innovation. While the Blue Economy integrates social, environmental, and economic dimensions, this study focuses on its contribution to regional economic development in EU coastal countries. Although coastal regions benefit from direct access to marine resources, the scale, structure, and effectiveness of Blue Economy contributions vary significantly across Member States. Acknowledging this heterogeneity, the study examines whether countries with different structural profiles exhibit signs of balanced or at-risk Blue Economies. The analysis draws on secondary data from the European Commission's Blue Indicators Tool for the period 2009–2021, focusing on gross value added (GVA) and employment. These indicators are used to calculate growth rates and structural indices, including the Herfindahl–Hirschman Index (HHI), Labour Intensity in Manufacturing Index (LIMI), and Relative Regional Specialization Index (RRSI). Using quartile thresholds and quadrant analysis, countries are classified according to their sectoral concentration, labour intensity, and regional advantages. Findings show that the Blue Economy has a divergent impact on regional development. Countries with labour-intensive, tourism-dominated economies—such as Bulgaria, Spain, Italy, Greece, and France—demonstrate declining trends in both GVA and employment. These at-risk economies are highly exposed to demand fluctuations and structural inefficiencies. Moreover, even where economic performance improves, labour involvement is declining due to the automation of services such as tourism. In contrast, balanced economies such as Latvia, the Netherlands, Slovenia, Lithuania, Romania, and Belgium show more diversified sectoral structures, lower labour intensity, and stronger regional advantages. Their Blue Economies are more resilient to shocks and better aligned with digital and innovation-driven transformation. Capital-intensive sectors like shipbuilding, maritime transport, and ocean energy are particularly associated with employment stability and productivity growth. Importantly, the analysis confirms that recent changes in employment dynamics are not directly linked to the COVID-19 crisis or its recovery phase. Instead, the underlying driver is the acceleration of automation and digitalization, which the pandemic only reinforced, particularly in labour-intensive service sectors. While this study is limited to the economic dimension, it acknowledges the crucial role of social and environmental aspects, such as wellbeing, inclusion, and the ecological health of marine and coastal ecosystems. These will be addressed in the subsequent phase of the research.
KEY WORDS: Blue Economy, Coastal Regions, Regional Resilience, Regional Development.
JEL classification: Q01, Q56, R11, J21

Introduction

The concept of the Blue Economy represents a major paradigm shift from the traditional linear model of natural resource exploitation, which has historically led to environmental degradation and resource depletion (Djoric, 2022). In contrast, the Blue Economy seeks to decouple economic development from ecological harm, promoting growth while preserving marine ecosystems and supporting long-term human well-being (Spalding, 2016). As noted by Elegbede et al. (2023), the Blue Economy is inherently multidisciplinary, encompassing economic, social, and environmental objectives through the sustainable use of ocean and coastal resources.

Although references to maritime economic activities such as port infrastructure, shipping, and coastal tourism can be traced back to the late 20th century (Leszczycki, 1979; Martínez-Vázquez et al., 2021), the interdependence between human settlements and aquatic ecosystems is deeply historical. Following the stabilization of sea levels after the last ice age, coastal zones became centres of human activity. Technological progress subsequently enabled more efficient exploitation of marine resources, fostering the emergence of global maritime trade (Griggs, 2017).

Today, the spatial importance of coastal proximity remains significant: approximately 70% of the global population lives within 5 km of a water body, and over 40% within 100 km of a coastline (Kummu et al., 2011; Barragán & De Andrés, 2015). This spatial distribution underlines the critical role of marine spaces in shaping socio-economic development.

In scholarly literature, the terms Blue Economy, ocean economy, and marine economy are often used interchangeably. However, as Martínez-Vázquez et al. (2021) observe, they differ in scope and emphasis—particularly regarding the balance between economic objectives and environmental sustainability. This conceptual ambiguity reflects an underlying tension between economic expansion and ecosystem protection, a tension that has real implications for policy and regional development strategies.

Nevertheless, the Blue Economy is increasingly recognized as a catalyst for regional economic growth, especially in coastal areas. It contributes directly through job creation and gross value added (GVA) in maritime sectors, and indirectly through value chains that also benefit inland regions (OECD, 2024; Mohyla et al., 2024).

These effects position the Blue Economy not only as a growth engine, but also as a framework for sustainable transformation at national and supranational levels.

Despite its growing relevance, the Blue Economy remains unevenly researched in terms of its economic structure, sectoral performance, and spatial implications, particularly at the subnational level. While numerous studies address specific sectors or environmental effects, few comprehensively assess how different configurations of Blue Economy activity influence regional development outcomes across the EU.

Accordingly, the object of this study is the Blue Economy of EU coastal countries, and its purpose is to evaluate how sectoral composition and structural features affect regional economic development. The central research question is: To what extent does the sectoral structure of the Blue Economy determine regional performance in terms of GVA and employment.

The study focuses on two core objectives:

(1) to analyse the economic contribution of the Blue Economy to coastal regions using gross value added and employment as key indicators;
(2) to assess whether countries with different structural profiles (e.g. labour intensity, specialization, regional advantage) exhibit different patterns of development.

To address these objectives, the study uses secondary statistical data from the European Commission's Blue Indicators Tool (2009–2021), and applies quantitative methods, including growth rate analysis, index-based classification (HHI, LIMI, RRSI), quartile thresholding, and quadrant mapping. This methodological framework enables the identification of countries with balanced or at-risk blue economies, thereby offering new insights into the relationship between structure and sustainability in the context of maritime-driven regional development.

Literature Review

The concept of the Blue Economy has emerged as a central theme in contemporary discussions on sustainable development, regional policy, and marine-driven economic transformation. It is widely understood as an integrated model that seeks to reconcile economic growth with environmental stewardship (Spalding, 2016; Djoric, 2022). Within this framework, Spalding (2016) emphasizes innovation, social inclusivity, and ecosystem preservation as core principles of blue growth, while Djoric (2022) analyses institutional strategies in the European Union, outlining policy instruments and governance mechanisms that facilitate sustainable marine development. Elegbede et al. (2023) further reinforce the multidisciplinary nature of the Blue Economy, highlighting its intersection across ecological, social, and economic dimensions.

This conceptual grounding has led scholars to focus increasingly on the measurement and evaluation of the Blue Economy's economic impact. A key area of inquiry concerns how specific sectors—such as shipping, fisheries, coastal tourism, and ocean energy—contribute to gross value added (GVA) and employment. Martínez-Vázquez et al. (2021, 2023) provide significant methodological insights by employing panel data models, correlation analysis, and causality testing to capture sectoral interdependencies. Their approach builds on earlier foundational work, including Leszczycki's (1979) recognition of maritime infrastructure as a key driver of regional economic integration.

Parallel to this, spatial and demographic analyses offer crucial context for understanding regional variations in Blue Economy performance. Studies by Kummu et al. (2011) and Barragán & De Andrés (2015) reveal that a significant share of the global population resides in close proximity to coastlines, underscoring both the economic potential and vulnerability of coastal zones. Griggs (2017) elaborates on this vulnerability, linking coastal urbanization and climate change to increasing socio-ecological risks—an important consideration for long-term Blue Economy planning.

To quantify the economic contributions of Blue Economy sectors, scholars frequently rely on GVA and employment metrics (Anda et al., 2020; Cai & Leung, 2020; Andreescu, 2021). These indicators enable cross-sectoral and cross-country comparisons, particularly when complemented by techniques such as data normalization and logarithmic transformation (Lütkepohl & Xu, 2012; Ogun, 2021). However, as Casler (2015) notes, the accurate measurement of growth trends remains a methodological challenge. National institutions, such as the UK Office for National Statistics (ONS, 2023), have developed practical tools to enhance the reliability of economic impact assessments.

Another important research stream investigates the structural characteristics that condition Blue Economy performance. Scholars such as Kaivo-oja et al. (2017, 2020) and Haukioja et al. (2018) explore how labour intensity, sectoral specialization, and regional resilience interact, applying indices like the Herfindahl-Hirschman Index (HHI), Relative Regional Specialization Index (RRSI), and Labour Intensity and Market Integration Index (LIMI). These indices help to identify the extent to which regional economies depend on specific sectors and how this affects their adaptability to economic shocks.

Technological advancement, particularly in the form of automation and digitalization, introduces further complexity to the Blue Economy's labour dynamics. Studies by Vermeulen et al. (2018) and Theotokas et al. (2024) warn that sectors characterized by high labour intensity—especially tourism and fisheries—are vulnerable to job displacement as technology substitutes for human labour. The COVID-19 pandemic further accelerated these trends, prompting widespread adoption of contactless technologies and remote service delivery, as shown by Rahimizhian & Irani (2021) and SAGE Publishing (2024).

Finally, spatial inequalities within the Blue Economy have drawn increasing attention. McCann (2020) and Filenta & Kydros (2022) advocate for regionally disaggregated analysis, employing quantitative and network-based approaches to detect economic asymmetries and map interregional spillover effects. This perspective reinforces the need for policy frameworks that account for the territorial diversity of the Blue Economy across the EU.

Taken together, this body of literature provides a comprehensive theoretical and methodological foundation for examining the Blue Economy. It not only informs the selection of analytical tools and indicators but also emphasizes the importance of sectoral structure, labour

dynamics, spatial proximity, and institutional context in shaping regional development outcomes. This review underpins the present study's goal of assessing how the structure and performance of the Blue Economy influence economic development in the coastal regions of the European Union.

Methodology

This study evaluates the Blue Economy at the national level, with regions defined according to the Nomenclature of Territorial Units for Statistics (NUTS) as major socio-economic territories. The analysis is based on two widely accepted macroeconomic indicators of regional development: gross value added (GVA) and employment. The selection of these indicators is supported by previous empirical research (McCann, 2020; Filenta & Kydros, 2022), as they capture both the output and labour market dimensions of economic activity. While GDP and GVA are commonly used to measure overall economic performance, sectoral disaggregation enables a more nuanced understanding of structural economic transformation by identifying key growth sectors and assessing regional economic specialization (Anda et al., 2020; Cai & Leung, 2020; Andreescu, 2021).

To enhance comparability across countries and regions, all data were normalized. In cases where variance heterogeneity or extreme values were observed, logarithmic transformations were applied to stabilize dispersion and minimize the impact of outliers (Lütkepohl & Xu, 2012; Ogun, 2021).

To capture temporal trends in the development of the Blue Economy and to distinguish between regions experiencing growth and those in decline, a longitudinal analysis was conducted. Specifically, two types of growth rate calculations were employed: the simple (arithmetic) growth rate and the logarithmic (continuous) growth rate, in accordance with the methodological recommendations of Casler (2015) and the UK Office for National Statistics (Measuring the Economy, 2023). The corresponding formulas are presented below (Formulas 1–2).

$$\text{Growth Rate} = \frac{(Y_{i,t} - Y_{i,t-1})}{Y_{i,t-1}}, \quad (1)$$

$$\text{Log Growth Rate} = ln\left(\frac{Y_{i,t}}{Y_{i,\,t-1}}\right) = \ln(Y_{i,t}) - \ln(Y_{i,\,t-1}); \quad (2)$$

where $Y_{i,t}$ is Gross Value Added for country i at time t.

To analyse local specialization within coastal regions, the Herfindahl–Hirschman Index (HHI) was employed to evaluate the degree of sectoral concentration within each country's Blue Economy. This index serves as a proxy for local specialization, indicating whether economic activity is broadly distributed across sectors or heavily concentrated in a few. To complement this, the Relative Regional Specialization Index (RRSI) was used to assess regional specialization, taking into account the presence of comparative advantages of an individual country in a specific Blue Economy sector relative to other studied countries.

To further classify countries based on the structural features of their Blue Economies, a quadrant analysis was conducted using two key indicators: the Labour Intensity in Manufacturing Index (LIMI) and the RRSI (Formulas 3–6). These metrics are particularly relevant for assessing the labour intensity of Blue Economy sectors and for identifying regional competitive advantages (Kaivo-oja et al., 2017; Haukioja et al., 2018; Kaivo-oja et al., 2020).

$$HHI = \sum s_i^2, \quad (3)$$

$$\text{RRSI}_c = \left[\sqrt{\sum (1-\text{BHI}_i)^2}\right]_c, \quad (4)$$

$$\text{BHI}_i = \frac{x_{c,i}/x_c}{x_c/x}, \quad (5)$$

$$LIMI_c = \frac{EMP_c}{EMP}; \quad (6)$$

where i – is sector, s – is the share of the sector i, c – country.

The combined application of these indices enabled a more comprehensive evaluation of the resilience or vulnerability of national Blue Economies. This approach facilitated a deeper understanding of the interaction between employment dynamics and value creation (GVA), helping to explain the underlying drivers of employment growth or decline in individual countries. Moreover, it allowed for the assessment of whether the presence of a Blue Economy sector in a given region genuinely contributes to job creation and economic activation, or whether structural limitations hinder its potential impact.

To identify vulnerable and resilient Blue Economies, a comparative analysis was conducted based on the values of the Herfindahl–Hirschman Index (HHI), the Relative Regional Specialization Index (RRSI), and the Labour Intensity in Manufacturing Index (LIMI). A quartile-based classification method was applied, whereby countries with indicator values in the upper quartile were categorized as "high," and those in the lower quartile as "low." This classification framework enabled the identification of economies exhibiting increased vulnerability—characterized by high specialization, high labour intensity, and a lack of regional advantages—as well as those demonstrating strong adaptive capacity and structural resilience in the face of economic transformation.

Data Sources and Processing

The study is based on secondary statistical data retrieved from the European Commission's Blue Economy Observatory and the Blue Indicators Tool. The primary indicators selected for analysis were gross value added (GVA) and employment, disaggregated across the key sectors of the Blue Economy.

The dataset spans the period 2009–2021 and is aggregated at the level of European Union Member States. Data were processed using Microsoft Excel for initial cleaning and organization, and further analysed using statistical software to implement regression modelling and index-based assessments, including transformations and quadrant analysis. The methodological approach ensures consistency and comparability across countries and over time, providing a robust basis for evaluating sectoral performance and structural differentiation within the Blue Economy.

Research Limitations

This study is subject to several important limitations, primarily related to the availability and consistency of data on Blue Economy activities across the European Union. The analysis relies predominantly on secondary data obtained from the European Commission's Blue Indicators Tool, which provides information on gross value added (GVA) and employment for the period 2009–2021. However, the dataset includes only seven sectors, excluding a range of emerging and innovative sectors—such as marine biotechnology, offshore renewable energy innovations, or digital marine services—which are increasingly relevant in the evolving Blue Economy landscape. As a result, the study may underestimate the full scope of the Blue Economy and fails to account for recent structural shifts, including those driven by the COVID-19 pandemic, the war in Ukraine, and related business redistributions or supply chain adjustments.

Another significant limitation concerns the territorial granularity of the data. Due to the unavailability of sufficiently disaggregated data, the analysis is conducted at the NUTS 1 level. This restricts the ability to examine regional heterogeneity within countries, particularly in Member States with diverse coastal geographies and substantial intra-national variation in Blue Economy activities. The lack of NUTS 2 or NUTS 3 level data limits the precision of spatial analysis and prevents a deeper understanding of localized development dynamics.

These limitations should be carefully considered when interpreting the study's findings. They underscore the urgent need for more detailed, sector-specific, and regionally disaggregated datasets to support future research and inform evidence-based policymaking in the field of Blue Economy development.

Results and discussion

According to the NUTS classification, 22 of the 27 European Union Member States (81.5%) are classified as coastal, while the remaining five — Austria, Czechia, Hungary, Slovakia, and Luxembourg — are landlocked, comprising 18.5% of Member States and lacking direct access to marine resources.

In these landlocked countries, the gross value added (GVA) generated by Blue Economy sectors remains limited, ranging from €69.17 million in Luxembourg to €479.6 million in Austria. These modest outputs reflect structural constraints on the development of marine-related industries. In contrast, even the smallest coastal economies perform more strongly. For instance, Slovenia, though the lowest among coastal countries in terms of Blue GVA, still outperforms all landlocked Member States, highlighting the spatial-economic advantage of coastal access.

The Blue Economy's share in national GDP is also significantly lower in landlocked countries (0.14%–0.42%), whereas coastal countries range from 0.6% in Romania to 7.16% in Croatia. In absolute terms, Germany leads in total Blue Economy output. In terms of employment, Cyprus stands out, with approximately 11% of the national workforce engaged in Blue Economy sectors.

A longitudinal analysis of GVA and employment growth (2009–2021) revealed pronounced disparities across Member States (Figure 1). Bulgaria experienced the sharpest decline in both indicators, indicating structural fragility. In contrast, Lithuania reported the highest GVA growth, while Poland led in employment expansion, demonstrating differing development trajectories and strategic sectoral choices.

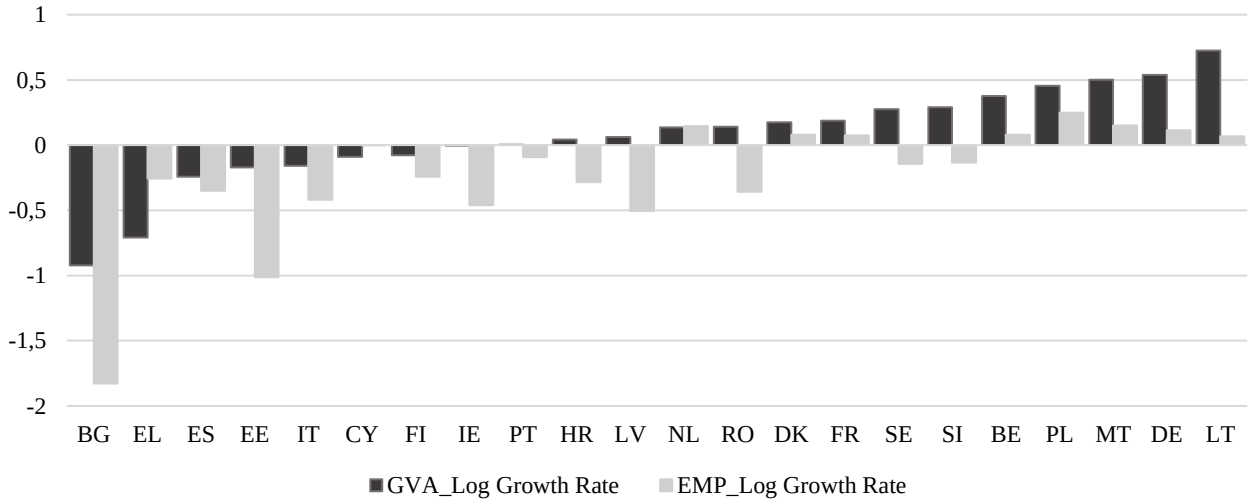

Fig. 1. Logarithmic Growth Rates of GVA and Employment in the Blue Economy by EU Member State (2009–2021)

To assess structural positioning, three indices were employed: the Herfindahl–Hirschman Index (HHI), the Relative Regional Specialization Index (RRSI), and the Labour Intensity in Manufacturing Index (LIMI). A quadrant analysis based on LIMI and RRSI (Fig. 1) identified that countries with high labour intensity and low regional advantage (Quadrant II) — including Bulgaria, Greece, and Spain — face structural disadvantages. In contrast, countries in Quadrant IV — such as Lithuania, Slovenia, and the Netherlands — exhibit both low labour intensity and strong regional advantages, suggesting higher capacity for sustainable development.

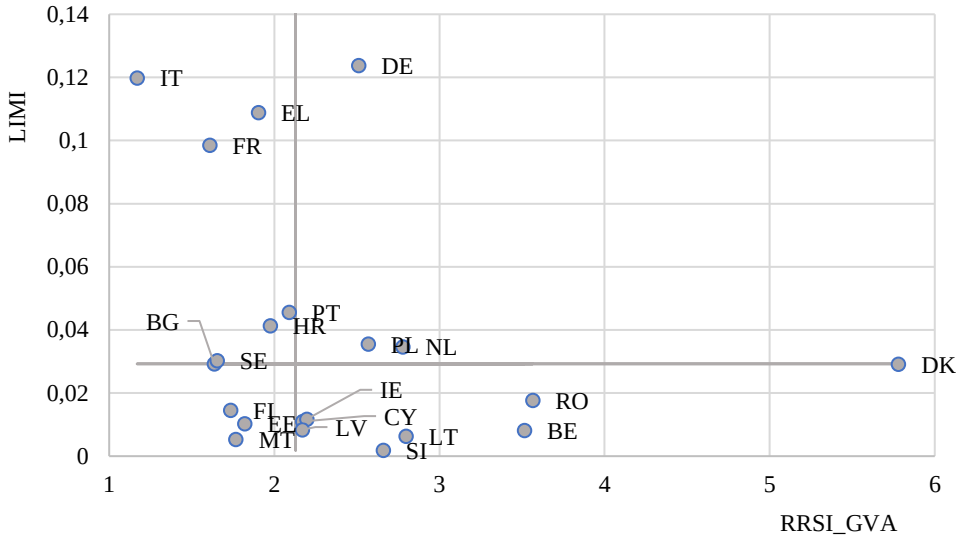

Fig. 2. Quadrant Classification of EU Blue Economies Based on Labour Intensity (LIMI) and Regional Specialization (RRSI)

To assess the structural positioning of national Blue Economies, this study applied a three-criterion classification framework (**Klaida! Nerastas nuorodos šaltinis.**) based on labour intensity (LIMI), sectoral concentration (HHI), and regional specialization (RRSI). Countries were assigned to either the at-risk or balanced category based on the presence of at least one structural condition associated with vulnerability or resilience.

Table 1. Classification Criteria for At-Risk and Balanced Blue Economies

	Criteria of At-Risk Blue Economies	Criteria of Balanced Blue Economies
1	high LIMI & high HHI	low LIMI & low HHI
2	high LIMI & low RRSI	low LIMI & high RRSI
3	high HHI & low RRSI	low HHI & high RRSI

Bulgaria, Greece, Spain, Italy, and France met one or more at-risk criteria, reflecting structural constraints in their Blue Economies. These economies are heavily reliant on coastal tourism, a sector that accounts for up to 66% of GVA and 74% of employment, and is both labour-intensive and highly cyclical, making them particularly sensitive to external shocks and demand fluctuations.

In contrast, Latvia, the Netherlands, Romania, Slovenia, Belgium, and Lithuania met at least one balanced economy criterion. Their Blue Economies are characterized by greater sectoral diversification, lower labour intensity, and stronger regional specialization advantages, making them less dependent on any single sector and better positioned for sustainable growth through technological advancement and structural adaptability.

The correlation analysis between GVA and employment across the EU Blue Economy revealed important trends (Table 2). At the aggregate level, a very strong positive correlation was observed ($r = 0.99$; $R^2 = 0.98$), indicating that in general, increases in value added are accompanied by proportional increases in employment. However, in living and non-living marine resource sectors, the relationship was not statistically significant (Das & Das, 2023), suggesting low labour productivity or structural inefficiencies.

Table 2. Regression Results: Relationship Between Employment and Gross Value Added (GVA) in Blue Economy Sectors

Sector	R	R^2	Beta	St. Error	t-stat	p-value	95% CL
BE $_{EMP\leftrightarrow GVA}$	0.99	0.98	0.735	0.010	74.613	0.000	[0.716; 0.755]
S1 $_{EMP\leftrightarrow GVA}$	0.77	0.593	0.476	0.088	5.396	0.000	[0.292; 0.660]
S2 $_{EMP\leftrightarrow GVA}$	0.09	0.008	-0.003	0.007	-0.401	0.693	[-0.017; 0.012]
S3 $_{EMP\leftrightarrow GVA}$	0.44	0.195	0.219	0.100	2.198	0.040	[0.011; 0.427]
S4 $_{EMP\leftrightarrow GVA}$	0.06	0.004	0.015	0.063	0.240	0.814	[-0.120; 0.150]
S5 $_{EMP\leftrightarrow GVA}$	0.99	0.992	0.734	0.047	15.647	0.004	[0.533; 0.936]
S6 $_{EMP\leftrightarrow GVA}$	0.77	0.596	0.630	0.116	5.435	0.000	[0.388; 0.872]
S7 $_{EMP\leftrightarrow GVA}$	0.99	0.983	0.718	0.021	34.133	0.000	[0.675; 0.762]
S3 $_{EMP\leftrightarrow S7GVA}$	0.50	0.253	-5.474	2.100	-2.607	0.017	[-9.854; -1.094]
S3 $_{EMP\leftrightarrow S7EMP}$	0.50	0.255	-3.98	1.520	-2.62	0.016	[-7.151; -0.811]

At the sectoral level, ocean energy and shipbuilding and repair exhibited the strongest correlation between employment and GVA, with beta coefficients near 0.7 and high R^2 values. These sectors demonstrate stable output-to-labour dynamics and appear better suited for long-term investment and sustainable development.

Interestingly, a negative beta coefficient was observed between maritime transport and shipbuilding and repair, possibly indicating intra-sectoral competition or labour reallocation. Nonetheless, the co-location of these sectors within the same regional ecosystems can still foster job creation through infrastructure development, value chain expansion, and industrial synergy.

Conclusions

The results of this study highlight the importance of understanding the structural composition of national Blue Economies when assessing their contribution to regional development. The classification of EU coastal countries into balanced and at-risk economies, based on the dimensions of labour intensity, sectoral specialization, and regional advantage, provides a useful analytical framework for identifying divergent development trajectories.

In particular, the findings suggest that countries with labour-intensive, tourism-dominated Blue Economies are more exposed to volatility, especially when these sectors lack regional competitiveness or technological upgrading. These structural profiles are associated with declining or stagnant GVA and employment, even in the absence of external shocks.

By contrast, countries with more diversified sectoral structures, lower labour intensity, and clear regional advantages are better positioned to sustain economic growth while maintaining employment stability. The presence of capital-intensive and innovation-driven sectors such as shipbuilding, ocean energy, and maritime transport appears to offer a more robust foundation for long-term development.

Importantly, the analysis reveals that employment dynamics in the Blue Economy do not follow GVA trends uniformly across sectors. In labour-intensive service sectors—particularly coastal tourism—increases in value added do not translate into proportional employment growth. This divergence is largely explained by structural shifts toward automation and digitalization, which reduce labour input requirements even under positive economic conditions. Consequently, the intensity of labour demand declines, limiting the capacity of these sectors to generate inclusive employment despite rising output.

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WASTE MANAGEMENT AS AN ELEMENT OF REVERSE LOGISTICS IN THE CIRCULAR ECONOMY

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Abstract
This article examines waste management and recycling as an element of reverse logistics in a circular economy. The concept of circular economy can be found very often in scientific and social environment. The aim of the article is to analyze the trends of waste management and recycling as a reverse logistics element in the conditions of circular economy in Europe and Lithuania. To achieve the goal were done: an analysis of theoretical sources to reveal the essence and connections of reverse logistics and circular economy, analysis of LR and EU legislation, development strategies of the environmental protection and waste management sector, analysis of EUROSTAT statistical data, monitoring, situation assessment and questionnaire survey. The main goals of the circular economy model are less raw materials, less waste, less emissions, managing such elements as raw materials, sustainable design, production, distribution, consumption, reuse, repair, collection, waste management, and residual waste. Direct logistics processes and reverse logistics play really important role in this concept. Logistics examines the movement of material, financial and information flows from the source of raw materials to the end user, reverse logistics examines the same flows, only in the opposite direction. Reuse, repair, collection, waste management are on responsibility of reverse logistics. For this reason, waste management in the terms of a circular economy cannot be seen only as the responsibility of the government and the end user (the resident sorting the waste). All participants in the supply chain, who were interested in bringing the material flow to the end user, and who created added value in the supply chain, according to the "polluter pays" principle, should take responsibility for the waste generated in the country, waste management and sorting, recycling. Because, for example, prevention of waste generation is a priority, and the cheapest solution is to avoid waste management and recycling. Thus, all participants in the supply chain must be interested and cooperate in the implementation of the circular economy. The general trends in the collection of the main sorted waste in Europe and Lithuania are not unambiguous, since waste management is regulated by different local laws of the countries. A general increase in the amount of sorted and collected waste is recorded, but not all countries demonstrate an increase, this may be related to the elements of the circular economy that have already been implemented, public awareness, declining consumerism, the economic situation in the country and other factors that lead to a generally more responsible approach to ecological aspects. EU newcomer countries are characterized by large increase in waste collection, regardless of waste types. Consumer opinion is quite favorable to the implementation of circular economy principles, but the main idea is that most of the responsibility for waste collection and management must be transferred to commercial participants in the supply chain.
KEY WORDS: reverse logistics, circular economy, waste management, supply chain.

Introduction

Modern society accepts quite favorably the changes that taking place in the last few years in the environmental protection and waste management sector. It is necessary to examine waste management from point of view of the reverse logistics, because this activity belongs to reverse logistics, as and collection, repair, utilization, recycling, etc. In principle, society is the end user of production, but giving full responsibility to the end-user for post-consumer waste is a wrong approach.

The relevance of the article is certainly understandable, the circular economy is already an inseparable part of business and public life today. Solutions are already being integrated and implemented. Reverse logistics plays a very important role in the circular economy, because the main elements are precisely the limits of responsibility of reverse logistics, including waste management.

The problem of the article is formulated from the position that the essential role of the end-user as a participant in the supply chain in the primary sorting of waste is insufficient for the consistent implementation of the circular economy.

The subject of this article is waste management and recycling as an element of reverse logistics.

The purpose of the article is to investigate the trends of waste management and recycling as a reverse logistics element in the conditions of the circular economy in Europe and Lithuania.

Tasks to achieve the goal:

- To present the theoretical aspects of waste management and recycling as a reverse logistics element in circular economy terms.
- To carry out an analysis of the current situation of waste management and recycling as an element of reverse logistics in the terms of a circular economy in Europe and Lithuania (observation, statistical analysis, questionnaire survey)
- Anticipate unused opportunities for reducing, collecting and sorting municipal waste in Lithuania to implement the principles of circular economy.

To analyze waste management as an element of reverse logistics in the circular economy, to determine the current situation, trends, perspectives and applicability, the following research methods were used:

- analysis of relevant literature sources, the latest scientific insights and legal acts,
- monitoring the current situation in the country and identifying trends
- overview of waste management practices and strategies
- analysis of statistical information on waste collection in the EU and in the country

• assessment of the public's attitude towards waste sorting in circular economy conditions by means of a questionnaire survey.

Theoretical framework

Essential assumptions of reverse logistics

In general, reverse logistics is the process of planning, realizing and controlling material flow that is suitable for reuse and recycling. The goal of reverse logistics is repair, recycling, redelivery or disposal. So far, society has not paid enough attention to reverse logistics. Reverse logistics is often viewed in a fragmentary ecological aspect, although reverse logistics can help companies reduce losses and increase revenues. The modern world is seriously concerned about the problems of nature protection, they are really very important. Companies must plan their supply chains, both direct and reverse, by assessing ecological requirements both in the purchase of raw materials and in production, and in the distribution of products to consumers.

There is more than one definition of the term "logistics", and there is no single definition of "reverse logistics".

The table shows the evolution of reverse logistics definitions.

Table 1. Evolution of the definition of reverse logistics

Year	Authors	Definition of reverse logistics
1993	R.J.Kopicki, M.J.Berg, L.L.Legg, V.Dasappa, C.Maggioni	Reverse logistics is a process by which companies can become greener by recycling, reusing and reducing number of raw materials used. In a narrow sense, reverse logistics can be understood as the reverse distribution of materials to channel members (Kopicki et al. from Carter, Ellram, 1993)
2004	J. Blackburn, D.Guide, G.Souza, L.Van Wassenhove	Reverse logistics is the transportation of products to the point of inspection, sorting and disposal (Blackburn et al. 2004)
2010	B.Beškovnik, L. Jakomin	Reverse logistics consists of reverse distribution and includes the transportation of used products and the movement of waste (Beškovnik, Jakomin, 2010)
2013	Council of Supply Chain Management Professionals	Reverse logistics is a specialized segment of logistics focused on product movement and resource management after sales and delivery to the customer. Includes product return for repair and/or credit (Council of Supply Chain Management Professionals, 2013).
2017	Supply Chain Management Association	Reverse logistics – the entire supply chain for the reverse flow of products and materials - return, repair, rework and/or recycling (APIS, 2017)
2018	Y.Wang, S.Peng, KAssogba, Y.Liu, H.Wang, M.Xu, Y.Wang	Reverse logistics - the reverse flow of unused and unusable products from customers to the point of origin for disposal or recycling. In general, reverse logistics is used to recycle used products when a company is concerned about environmental issues, or to collect goods from customers for a new distribution cycle. (Wang Y. et al., 2018)
2024	Anon, S.Y.; Amin, S.H.; Baki, F	Reverse logistics is an essential type of supply chain that can reduce a lot of waste generated from the disposition of products. Sustainable growth and reverse logistics help achieve efficient remanufacturing processes and play pivotal roles in having closed-loop supply chains, stimulating the recovery and recycling of products and reducing harmful wastes. (Anon, S.Y.; Amin, S.H.; Baki, F., 2024)

The concept of reverse logistics has been around for about three decades, and during that time it has developed very intensively. First, it is not reverse logistics, but the return of products. According to Starostka-Patryk and Nitkiewicz (2014), who studied the development of reverse logistics, some authors used the term "reverse distribution" instead of "reverse logistics", but with an equivalent meaning. According to authors Blackburn et al. (2004) reverse logistics includes only the transportation process. However, definition of reverse logistics has become more common in the last decade. Reverse logistics is understood as a strategy that involves a series of operations after products have completed their traditional life cycle. Logistics is called "reverse" because the informational, material and financial flows of the product are opposite to the traditional flow of the supply chain - that is, from the customer to the place of origin or processing (Banguera, et al. 2017; Beškovnik et. al., 2010). Beškovnik and Jakomin (2010) state that the entire process of reverse logistics can be divided into four main stages: collection, inspection, selection and sorting stage, processing and finally, redistribution.

Considering the aspiration to efficiently use natural resources and ensure their conservation for future generations, the term "green logistics" is often encountered. However, researchers do not consider reverse logistics to be the same as "green logistics". It is believed that reverse logistics is the starting point of development of "green logistics". Reverse logistics includes the movement of the returned product from the consumer to the producer, product sorting, recycling and disposal, while "green logistics" environmental issues such as pollution and environmental problems caused by inappropriate logistics processes and the use of old, environmentally unfriendly transport technologies (Beškovnik et. al 2010). Reverse logistics is used to solve various tasks – container returns, repairs, processing, utilization, etc. The price of material flow, sales volume, distribution channels are very important. Reverse logistics also provides economic benefits in terms of less raw material procurement, inventory control and landfill by setting strategic locations for collection centers, reprocessing centers, remanufacturing and transportation (Fernando, et al., 2022). Reverse logistics is a strategy that focuses on the appropriate use of resources to mitigate environmental effects, regulate processes, and generate commitment on the part of companies as to the use and final disposal of the products they manufacture or market.

Reverse logistics contributes to increased demand for products and services since they can be developed with lower cost and impact on the environment. (Salas-Navarro et al., 2024). Reverse logistics is necessary for the solution of many business tasks:

• refunded products for processing (seasonal, defective, cancelled, surplus, etc.),

- for ecological initiatives,
- for repair, recycling,
- outdated waste disposal,
- for the disposal of hazardous and electronic waste.

Of course, return rates vary greatly depending on the type of production. Reverse logistics is an essential type of supply chain that can reduce a lot of waste generated from the disposition of products. Sustainable growth and reverse logistics help achieve efficient remanufacturing processes and play pivotal roles in having closed-loop supply chains, stimulating the recovery and recycling of products and reducing harmful wastes. (Anon, et al., 2024). Ecology is another term that was introduced due to changing priorities. Ecology envisages the minimization of ecological consequences in the operation of logistic systems. For example, reducing energy consumption and minimizing the use of raw materials. In today's world, ecological aspects influence many decisions in logistics. A lot of produce can't just be thrown away, forcing companies to collect their unrealized, expired products. There are limited waste disposals.

The essential principles of the circular economy and the importance of waste management

The circular economy theory delineates a conceptual framework for global economic systems that prioritize developmental and restorative objectives (Feiferytė, Navickas, 2016; Yamoah et al., 2022). According to the report of the EU Parliament, about 2.2 billion tons of waste is generated annually in the European Union. The EU is currently updating waste management legislation to encourage member countries to move towards a more sustainable model known as the circular economy. In 2020 March, the European Commission unveiled a new Circular Economy Action Plan, which includes proposals for more sustainable product design, waste reduction and citizen empowerment (such as the "consumer right to product repair"). Special attention is paid to resource-intensive sectors related to electronics, plastics, textiles and construction. In contrast to the "take-make-throw" model established in society, the circular economy aims to reduce waste and resource use as much as possible through advanced product design, product reuse and repair, recycling, sustainable consumption and innovative business models that, for example, as an alternative to purchasing a product offers the service of renting, lending or sharing it. The main goals of the circular economy model are less raw materials, less waste, less waste, managing such elements as raw materials, sustainable design, production, distribution, consumption, reuse, repair, collection, waste management, residual waste. Reverse logistics plays a very important role in this concept. The success of designing for a circular economy is contingent upon the incorporation of diverse closed-loop system design methodologies (Seetharaman et al., 2022; Tan et al., 2022). Reusing and recycling products would slow down the use of natural resources, reduce the destruction of landscapes and habitats, and help limit the loss of biodiversity. Developing more efficient and sustainable products would help reduce energy and resource consumption, as it is estimated that more than 80% of a product's environmental impact is determined at the design stage. A shift to more reliable products that can be reused, refurbished and repaired would reduce waste. Packaging is also a growing problem and on average each European is responsible for nearly 180 kg of packaging waste per year. The aim is to combat the problem of excess packaging and improve its design to encourage reuse and recycling. The recycling of bio-waste from households is an essential factor in achieving the recycling quotas for municipal waste laid down by the EU. A major problem is posed by impurities in the bio-waste collected, such as plastics, metals and glass (Adam, et al., 2024).

As the world population grows, so does the demand for raw materials. However, the supply of basic raw materials is limited, and some EU countries are dependent on resources supplied by other countries. The extraction and use of raw materials has a significant impact on the environment. This increases energy consumption and CO2 emissions, and smarter use could reduce these numbers. Total value of trade in raw materials (imports and exports) between the EU and the rest of the world since 2002 has grown almost threefold, and exports are growing faster than imports. Despite this, the EU still imports more than it exports. For this reason, in 2021 the trade deficit amounted to 35.5 billion euros. Processing raw materials also reduces supply-side risks such as price volatility, availability and import dependency. This is especially true for key raw materials needed to produce technologies that are critical to meeting climate goals, such as batteries and electric motors (European Parliament, 2024).

Today, cities or municipalities consume close to two-third of the global energy, account for about 80 percent of the global greenhouse gas (GHG) emissions and produce more than 50 percent of the global waste. The rapid growth of the urban population has led to several environmental problems and challenges such as pollution, resource scarcity, and limiting aging infrastructure. Urban areas are often acknowledged as growth engines and are recognized as productive places for experimenting with alternative modes of service provision and public governance. (Heshmati, et al., 2021)

Repurposing materials and products for circular use would also stimulate innovation in various sectors of the economy. In 2021 The European Parliament approved the new circular economy action plan and called for the establishment of mandatory 2030 purposes of use and consumption of materials. In 2022 March the Commission has announced the first package of measures to accelerate the transition to a circular economy. The proposals include the promotion of sustainable products, a review of the Construction Products Regulation and a strategy for sustainable textiles (European Parliament).

The path of industrialization has been material and energy intensive. Profit maximization, fierce competition in the market, and a policy of a ‘race to the bottom’ combined with limited knowledge about environmental consequences have led to unsustainable development of production, distribution, and consumption. To solve this problem, sustainable development strategies, policies, and standards are being developing at the regional, national, and international levels. Their target is reducing the level of emissions to the 1990 level by 2030. Given the rapid population increases, biased fossil energy-based technology development, and a dominant focus on increased productivity, these goals are seen as coming late

and merely cosmetic aimed at only partially greening the market economy. (Heshmati, et al., 2021)

In 2022 November EU Commission has proposed new EU-wide packaging rules. They include suggestions for improving packaging design, such as clear labeling to encourage re-use and recycling. The rules also call for a shift to biodegradable and compostable plastics (European Parliament).

EU Circular Economy Action Plan

In keeping with the goal of the Green Deal by 2050 to neutralize climate impacts in 2022 March, the European Commission presented the first package, which also includes a circular economy action plan, which aims to accelerate the transition to a circular economy. In 2022 November, the European Commission published a second package, including a proposal for new EU-wide packaging rules and a proposal for EU carbon emissions certification. The third package was delivered in 2023 March, including a proposal to regulate corporate environmental claims and guarantee the right to repair. In 2023 July, the Commission proposed a revision of the Waste Directive to promote the sustainable management of textile and food waste, in 2022 October, during the plenary session, MEPs approved the revision of the regulations on persistent organic pollutants (POPs) (European Parliament).

The new rules will further reduce the amount of hazardous chemicals in waste and manufacturing processes by introducing stricter limits, removing pollutants from the recycling chain and banning certain chemicals. A circular economy has major benefits in four areas: environmental benefits, economic benefits, resource benefits, and social aspects. (Heshmati, et al., 2021)

To create an EU market for sustainable, climate-neutral and resource-saving products, the Commission proposes to extend the application of the Eco-design Directive to non-energy-related products and to create a digital product passport containing important information throughout the product's life cycle. It also supports improving the durability of products and the principle of "consumers' right to repair". Extended producer responsibility (EPR) is commonly implemented as a strategy in waste management. The core of the concept itself is a waste reverse logistics (WRL), which dictates how the collection, inspection and processing of end-of-life products are performed. Existing studies of EPR mainly focused on single products instead of using broader perspective on national level. Its contribution towards circular economy through slowing and closing the loops also has not been widely discussed. (Mayanti, et al. 2024)

The Parliament adopted the directive in 2024 April. The new rules should make it easier and cheaper to repair products than to buy new ones. In 2024 January, approved a temporary deal with the Council to update EU consumer rules that would stop "eco-manipulation" and provide consumers with more information about the durability of products. In 2024 March, the Parliament also adopted a position on the system for verifying companies' environmental claims. For a circular economy to be realized, sustainability must be integrated into all stages of the producer-consumer chain, from design to production and consumption (European Parliament, 2024).

The European Commission's plan aims to focus more on resource-intensive sectors with high circularity potential and calls for concrete action in areas such as plastics; textiles; electronic waste; food, water and nutrients; packaging; batteries and vehicles; buildings and construction.

The EP supports the European strategy on the role of plastics in the circular economy, which aims to phase out the use of microplastics. Textile production uses a lot of raw materials and water, but less than 1% of clothing worldwide is recycled. In 2022 March EU sustainable and circular textile economy strategy presented by the Commission aims to ensure that by 2030 Textile products placed on the EU market would be durable and suitable for recycling, made from as many recycled fibers as possible and without hazardous substances. The amount of electrical and electronic waste is growing the fastest in the EU, but less than 40% of it is recycled. The governments as actors can impose and enforce official order in the form of specific instruments or regulations that affect multiple actors. They can mandate producers to arrange a free-of-charge collection system which will affect the producers that have to bear the economic responsibility of collection and the subsequent treatment; hence, added fee is included at the point of sale (advanced disposal fee). This set of regulations from the government will be translated into strategies by the producers to meet extended producer responsibility requirements and advocate for consumers to participate accordingly (Mayanti, et al. 2024)

In the EU, 10% of all available food is wasted every year. MEPs call for by 2030 to halve this number under the Farm-to-Fork strategy. The amount of packaging waste in Europe is growing. One person in the EU in 2021 generated an average of 189 kg of packaging waste. In 2024 April, the EP approved an agreement reached with the Council on EU rules on packaging and packaging waste to reduce and improve the situation. MEPs have approved new rules requiring that batteries and accumulators supplied to the EU market should be sustainable, efficient and safe throughout their life cycle, and that their production should meet human rights and social standards. The construction sector accounts for more than 35% of all waste in the EU. The Commission has announced a review of the Construction Products Regulation to update from 2011 applicable rules. MEPs aim to extend the service life of buildings, reduce the carbon footprint of materials and set minimum requirements for resource and energy efficiency. In 2024 March, the Parliament approved the updated rules for the energy efficiency of buildings, which aim at to create a climate-neutral building sector.

It can be inferred that the shifting global scenario is exerting an impact on the inclination toward transitioning to a circular economy via cohesive and comprehensive policy interventions (Chioatto et al., 2022; Awan et al. 2022).

Measures to reduce food waste

Food waste is one of the main obstacles to the implementation of the circular economy. It is estimated that around 10% of the food available to EU consumers is wasted, but there are more than 37 million in the EU people who cannot afford quality food every other day.

Reducing food waste and food loss are two of the EU's main goals to achieve by 2050 create a circular economy.

Standardized portions and overestimated number of guests are among the causes of food waste in restaurants and catering establishments. According to a study by the European Commission, food waste is also caused by date marking on food, such as "Best before". A better understanding of labels can help reduce food waste by up to 10%. Reducing food waste is essential to managing climate change. It accounts for around 16% of all greenhouse gas emissions from the EU food system. According to the UN's Food and Agriculture Organization (FAO), the production and transport of food, which is then wasted, accounts for 8% of the world's greenhouse gases. Households and businesses could save money by reducing food waste (European Parliament, 2024).

EU legislation on reducing food waste.

The goals of the Farm-to-Fork strategy include clearer date labeling and curbing their misuse in to reduce food waste. As part of this strategy, the Commission will also investigate food losses throughout the food supply chain. Donating food is another way to reduce unnecessary food waste. EU food donation guidelines were adopted in 2017 to facilitate the recovery and redistribution of safe, edible food to those in need. In 2019 EU methodology was adopted to measure food waste at each stage of the food supply chain. A common methodology facilitates the monitoring and reporting of food waste across the EU (European Parliament, 2024).

Sustainable waste management.

2.1 billion tons of waste are generated annually in the EU. The amount of waste and its management methods vary widely in EU countries, but there is a noticeable shift towards more waste recycling and less disposal in landfills. Waste management practices vary across EU countries. The EU wants to promote waste prevention and reuse of products. If this is not possible, priority is given to recycling (including composting) and then using the waste to generate energy. The most harmful option for the environment and human health is to simply dispose of the waste, for example in landfills, although this is also one of the cheapest options. Even though the amount of waste per capita has increased, waste management has also improved, with more recycling and composting, and fewer landfills. 60% of municipal waste collected and processed by municipalities, according to EU goals, must be reused or recycled by 2030. According to the Landfill Directive, EU countries also have until 2035 reduce the amount of municipal waste disposed of in landfills to 10% or less of the total municipal waste generated (European Parliament, 2024).

Export of waste outside the EU

Part of EU waste is also exported. In 2022 export of EU waste to non-EU countries amounted to 32.1 million tons. This indicator increased by 3% compared to 2021.

Most of the waste exported outside the EU (55%) consists of metal (iron and steel) waste, which is mostly exported to Turkey. The EU also exported a large amount of paper waste (15%), with India being the main destination. In 2022 39% of EU waste went to Turkey (12.4 million tons), followed by India (3.5 million tons), United Kingdom (2 million tons), Switzerland (1.6 million tons) and Norway (1 .6 million tons). The EU wants to fight illegal exports and ensure that waste is managed in an environmentally friendly way in destination countries. In February 2024, the Parliament approved stricter rules for transporting waste to third countries. The rules will ban the export of plastic waste to non-OECD countries and introduce stricter conditions for exports to OECD countries. Export of waste to another EU country will be possible only in exceptional circumstances (European Parliament, 2024).

Packaging waste

Online shopping, takeout, food delivery only add packaging waste. Packaging comes in various formats (bottles, containers, cans, boxes, bags), is made of various materials (paper, cardboard, plastic, glass, wood, metal) and is used in all stages of production - from raw materials to processed goods. Manufacturers, transporters, supermarkets, restaurants, households - they all need packaging and use it to protect and transport goods. In general, packaging is products used to store, protect, handle, deliver or present goods. Logistics and marketing packages should be distinguished. They perform sufficiently different functions, but both logistic and marketing packaging are waste that must be properly sorted and disposed of, packaging is not related to the use or functionality of the product. Packaging comes at an environmental cost. In 2021 each EU resident generated an average of 189 kg of packaging waste. This amount has increased by more than 20% in ten years. 1 figure presents the dynamics of packaging waste in the EU in 2012 – 2021.

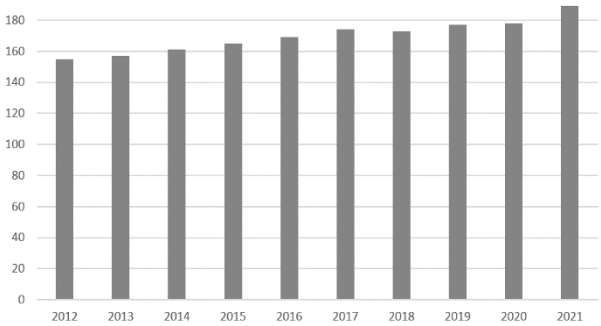

Fig. 1. Dynamics of packaging waste generated by each resident per year in the EU in 2012 – 2021, kg
Source: Eurostat database adapted by author

These numbers vary from country to country, from a minimum of 74 kg per person in Croatia to 246 kg per person in Ireland. On average, a Lithuanian resident generates 136.79 kg of packaging waste per year in 2021. In the EU, a total of 84.3 million tons packaging waste, i.e. 4.8 million tons more than a year ago. Paper and cardboard accounted for the majority (40.3%), followed by plastic (19%), glass (18.5%), wood (17.1%) and metal (4.9%). In 2021 about 64% of packaging waste was recycled and about 80% was used, i.e. the waste has been processed in one way or another so that it can be useful in the future (this also includes recycling). Recommended a transition to bio-based, biodegradable, and recyclable plastics to mitigate packaging waste and enhance package design (Feiferytė and Navickas, 2016).

EU rules on packaging and packaging waste

EU regulations on packaging and packaging waste cover both packaging design and packaging waste management. They aim to harmonize national measures, prevent waste generation and increase reuse and recycling. In addition, they set the minimum requirements that packaging sold on the EU market must meet. These rules began to be applied in 1994, and in 2018 were changed. In order to achieve by 2050 move to a circular economy, in 2022 November, the Commission proposed a new revision of the rules. Parliament and the Council reached an agreement and MEPs approved it in 2024 April (European Parliament, 2024).

The aim of the rules is to reduce, reuse and recycle packaging and increase its safety and sustainability. A lot of attention is paid to plastic packaging, because it is particularly harmful to the environment.

The new rules:

• set packaging reduction targets (5% by 2030, 10% by 2035, 15% by 2040);

• from 2030 January will ban various types of plastic packaging, such as: very light plastic bags, plastic packaging for fresh fruits and vegetables, etc.

• from 2030 in January will ban persistent pollutants (also known as "permanent chemicals") used in fireproof or waterproof food packaging, which can affect health;

• promote re-usability and re-filling by setting specific reusable packaging targets for alcoholic and non-alcoholic beverages (at least 10% by 2030) and enabling consumers to bring their own food and beverage takeaway containers;

• require member states to promote the provision of tap water in restaurants, canteens, bars, cafes and catering establishments;

• will introduce stricter recycling criteria (European Parliament, 2024).

The role of food packaging is being developed in light of changing market conditions. (Lingaitienė, et al., 2023)

Consumers are willing to correctly dispose of the bioplastics, the availability of correct (and uniform) sorting instructions is crucial to reduce this confusion. One possible way of doing this could be for manufacturers to include a note on their product stating: 'Biodegradability of this item does not imply a certain disposal route since this depends also on the existing waste treatment infrastructure and waste legislation. Please follow the waste sorting guidance in your region'. Additionally, having uniform sorting guidelines for a product throughout the country would also help in easing the confusion (Mhaddolkar, et al., 2024).

In general, a circular economy is considered as a development strategy which eases tensions between environmental concerns and economic development. Circular economy can also help consider pollution problems and resource scarcity and it enables green competitiveness (Heshmati, et al., 2021).

A cleaner and sustainable environment is becoming a topmost priority for both owners and stakeholders involved in businesses. It could be achieved by adopting better sustainable practices like reduction in waste through process of recycling, recovery and remanufacturing which helps to minimize both the cost and environmental losses (Dutta, et al., 2020)

Methodology

To analyze waste management as an element of reverse logistics in the conditions of circular economy, to determine the current situation, trends, perspectives and applicability, the following research methods were used:

• Monitoring the current situation in the country and identifying trends

• Overview of waste management practices and strategies

• Analysis of statistical information on waste collection in the EU and in the country

• Assessment of the public's attitude towards waste sorting in circular economy conditions with the questionnaire survey.

The monitoring of the current situation in the country and the identification of trends are carried out in accordance with the legal acts valid in the region, according to the publicly published information in the domain database of the ministry, according to the publicly available data of the institutions responsible for waste management in the country. Analysis of statistical information on waste collection (main types of waste, plastic, glass, paper and cardboard, directly related to end users) is performed according to Eurostat data, Lithuanian Statistics Department data, according to officially published and publicly available information.

The review of strategies is carried out according to the plans of the Ministry of Environment.

The assessment of public opinion is carried out with the help of a questionnaire survey, presenting 20 questionnaire and open questions to a random group of respondents (100 respondents/households), systematizing and summarizing the obtained data, clarifying the connections between variables.

Results

Monitoring the current situation in the country and identifying trends

It was decided to examine the current situation in the country according to the valid legislation and regulations, according to the activities and results carried out. Pursuant to the Law on Local Self-Government and Waste Management, the implementation of municipal waste management systems, the organization of the collection and processing of secondary raw materials, the installation and operation of landfills is an independent function of municipalities, and municipalities administer the provision of municipal waste management services. Municipal waste management service is a public service that includes municipal waste collection, transportation, use, disposal, organization of these activities, monitoring, and subsequent supervision of disposal sites. Pursuant to the Law on Waste Management, municipalities in Lithuania must ensure that the municipal waste management service is universal, of good quality, accessible (affordable) and meets environmental, technical-economic and public health safety requirements. The capacity of waste collection facilities and the frequency of waste collection from waste collection facilities are determined in such a way as to meet the need for the collection of municipal waste generated by the waste holder, and can be

determined individually, depending on whether the waste is sorted and composted at the place of its generation. The capacity of waste collection containers and the minimum frequency of waste collection (or emptying) are discussed in the contract between the waste manager and the municipality or administrator (hereinafter referred to as the contract). If there is no contract, the capacity of the collection facilities and the frequency of waste collection from the waste collection facilities shall be determined by the municipality in the waste management rules. Mixed municipal waste in Lithuania is collected in waste collection containers for mixed waste or by other means separately from other waste. The minimum collection of mixed municipal waste from waste collection facilities must be carried out at least once a month. Municipal waste management must be organized in such a way as to encourage the use and recycling of waste. Municipalities, applying various methods and measures of waste collection, must ensure that in the municipal waste management systems they manage, when individuals sort waste at the place of their generation, the following municipal waste is separately collected: hazardous waste; biodegradable waste (green waste and food/kitchen waste); secondary raw materials – paper and cardboard, glass, plastic, metal, including packaging waste; electrical and electronic equipment waste; used tires; bulky municipal waste (for example, furniture and others); construction and demolition waste; textile waste; mixed municipal waste (waste remaining after sorting).

Municipal waste and its management.

According to official sources, in Lithuania in 2022 a total waste was 6.8 million tons. 1.3 million tons was municipal waste generated in the household, i.e. average is about 475 kg per inhabitant of the country. Municipal waste is the type of waste that is generated in households. In 2022 of all generated municipal waste, was 718 thousand tons more than half was mixed municipal waste, i.e. the majority of which are not suitable for recycling or reuse. Municipal waste consists of waste that can be recycled and reused. These are secondary raw materials and packaging waste. Secondary raw materials are paper, glass, plastic and metal waste, which can be recycled into new products. Packaging waste is packaging made of various materials, intended for wrapping, protecting, transporting and presenting products to consumers. It should be remembered that there are logistic and marketing packages. About 15% of municipal waste in 2022 were removed to landfills, about 40% were recycled, and about 35% were burned for energy. The share of this waste disposed of in landfills would not exceed 5%, the share of waste prepared for reuse and recycled until 2035 would be at least 65%. For this, measures must be provided to encourage residents to reduce the generation of waste, to properly sort it, and after sorting, the remaining waste would be managed in accordance with the hierarchy (fig.2) of its management.

Fig. 2. Hierarchy of waste management
Source: European Parliament, 2024

The container system is primarily used to collect municipal waste from residents. Residents of apartment buildings throw mixed waste into mixed waste containers and sorted secondary raw materials and packaging waste into paper, plastic-metal and glass, and residents can also bring them to waste collection sites. In some municipalities, used clothes that are still suitable for use are collected in special closed containers. Containers for mixed waste are issued to residents of individual houses. At their request, containers can also be issued for green waste, glass, general containers for paper, plastic and metals.

Separately collected recyclable waste is additionally sorted before recycling, separating those parts that cannot be recycled. This waste is burned in power plants or disposed of in landfills. In most cases, waste suitable for recycling is only prepared (shredded, pressed) and then exported abroad according to EU practice. Such waste includes metal waste and textiles. Part of the waste is processed in Lithuania. Colored bottle glass shards are used as raw material. They are processed by the “Kauno stiklas” company. Paper waste is processed by the “Grigeo” company. Used electrical and electronic equipment is disassembled, shredded and separated into recyclable components. The most difficult situation is in the field of plastic waste recycling. Business representatives are usually only interested in recycling clean plastic production waste. Of the separately collected municipal plastic waste, only polyethylene film and PET bottles are recycled after additional sorting. A large part of food packaging made of polypropylene and polystyrene remains unrecycled. This is a big problem, and it's not just the end users who need to be concerned with solving it. Now the largest plastic waste processor in Lithuania is the company “Plasta”. Waste that is not suitable for disposal in the household waste container can be delivered free of charge to bulky waste collection sites. They can carry hazardous waste, dismantled furniture, wood, household appliances, electronics, construction, textiles, batteries and accumulators, metal, glass, paper, plastic, daylight lamps, mercury-containing waste, as well as tires (but only 4 pcs. per year).

Construction, repair and demolition waste, i.e. concrete, bricks, ceramic and stone mass tiles, ceramics, double-glazed windows, reinforced glass, mirrors, crystal, laminate, linoleum, plasterboard, glass wool, stone wool, carpets, mattresses, soft furniture parts cannot be thrown or left near household or other sorting containers. They must be brought to the waste collection sites or delivered to the waste handlers handling such waste after payment. Waste electrical and electronic equipment, i.e. all devices

that require an electrical network, batteries or electromagnetic fields to operate, as well as those devices that are designed to create, transmit, measure those currents and fields – must be taken to waste collection sites or electronic equipment distributors (electronic stores), if that waste have the same purpose as products sold by distributors. To remove bulky equipment, residents can call electrical and electronic equipment handlers to remove this waste from their homes. Small electronic waste can be disposed of in designated bins in many supermarkets and large stores.

Old portable batteries and accumulators can be taken to waste collection sites (bulky waste collection sites), battery collection buckets located at distribution points of such products, shopping centers, offices, educational institutions, as well as organizations. Scrap metal i.e. non-ferrous metal waste (aluminum, copper scrap, lead, brass), scrap metal from cars (batteries, starters, generators, gearboxes, aluminum turbine parts), copper wires and cables, car cables, ferrous metal must be delivered to waste collection sites or to official waste managers. Medical waste, i.e. human and animal health care and related research waste – can be collected, transported and processed by companies licensed for such activities. It is forbidden to throw medicines and medical waste into municipal waste containers. Citizens can return unused (expired) medicines that are no longer needed at any pharmacy throughout the country for free.

Mixed municipal waste is sent to mechanical-biological treatment facilities. Mixed municipal waste from households, i.e. those not sorted by residents are sent to mechanical-biological treatment facilities for secondary sorting. Those wastes that can be used as raw materials are mechanically separated, all others are diverted to cogeneration power plants as fuel to obtain energy, and non-burnable waste to landfills. The Ministry of the Environment informs that waste that cannot be used as secondary raw materials or to obtain energy is disposed of in landfills. The Ministry also emphasizes that disposal of waste in landfills is the lowest priority waste management method, therefore only those wastes that can no longer be processed or otherwise used must be disposed of. For a long time, the only waste management method in Lithuania was its disposal in landfills, and before the changes in the waste system began in 2000. more than 900 landfills operated in the country. Since 2007 11 regional modern non-hazardous waste landfills with gas collection and filtrate treatment systems have been put into operation in Lithuania. In 2009, the old district and municipal landfills were closed and recultivated. The amount of waste disposed of in landfills is decreasing. The State Audit Office informs that due to the mechanical and mechanical-biological treatment and new incineration facilities that started operating in the regions, the disposal of municipal waste in landfills from 2014 to 2021 decreased more than 3.5 times (from 58.85 to 15.36%). In turn, the ministry announces that by 2035 in Lithuania, no more than 5% of all generated waste can be disposed of in landfills. It is also emphasized that currently the development of landfills is not encouraged and supported with state funds. In the state audit report "Municipal Waste Management" prepared by the State Audit Office, it is emphasized that the municipal waste collection system in Lithuania needs to be improved.

Despite the fact that the share of the population sorting municipal waste increased from 40 % (2016) to 60 % (2021), and awareness in the field of waste management in 2015 – 2021 fluctuated around 74 % – 80 % during the period, due to poor waste sorting, the share of secondary raw materials included in the composition of mixed municipal waste did not change and is about 33 %. Without ensuring proper waste sorting at the place of their generation, the goals set for municipal waste recycling will not be achieved. Attention is also drawn to the fact that the mixed municipal waste collected in municipalities is not weighed or its quantity is not otherwise recorded at the time of collection, so that residents are assigned the actual amounts of waste to be managed, therefore it is not ensured that the fee for the management of this waste will encourage proper sorting of waste and thus reduce the amount of mixed municipal waste amount of waste. It is also emphasized that due to improper waste sorting, 33% of the waste in mixed municipal waste consists of packaging, the handling of which must be paid for by manufacturers or importers, in accordance with the requirements of legal acts. Therefore, the costs of handling packaging that ends up in mixed municipal waste are actually paid by the residents. It is also emphasized that the municipal waste management system would be more efficient if the residents were given the conditions and motivated to sort waste properly, and it would also be ensured that the collected waste was processed and organized in accordance with the hierarchy of their management.

Analysis of statistical information on waste collection in the EU and in the country

To comprehensively assess the dynamics, trends, dependencies, achievements, and effectiveness of waste collection in Europe in general and in the country under consideration, statistical data analysis is also carried out in the study, and reports are submitted according to EUROSTAT. Some data tables are very massive and are not presented due to the limited scope of the article, but the data are described. Waste collection data are provided in EUROSTAT for the period 2004-2020, the resource does not provide more recent data. The following types of waste were chosen for the study – paper and cardboard, glass and plastic, these are the wastes that are generated in households, if they are collected properly, they can be efficiently recycled, these wastes mainly make up packaging.

Paper and cardboard waste.

Analyzing the trends of paper and cardboard waste collection in Europe, the following important data have been collected. Total amount of paper and cardboard collected in Europe in 2004-2020 remained almost unchanged, i.e. the change was just 2%. Also, if the entire time interval is examined, clear downward trends are identified. 3 figure shows the total amount of paper and cardboard waste collected in European countries in 2004 – 2020.

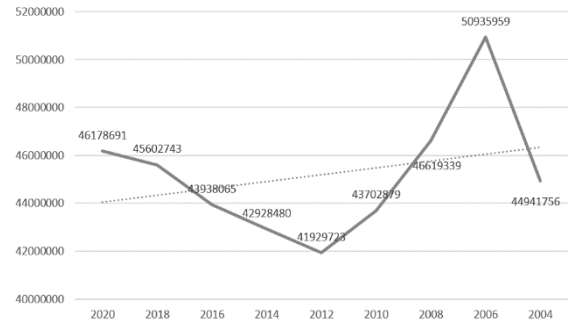

Fig. 3. Total amounts of paper and cardboard waste collected in European countries in 2004-2020, tons
Source: Eurostat database adapted by author, 2024

The countries where the largest amounts of paper and cardboard waste were collected in 2020 are Germany, France, Italy Spain, Belgium, these countries together collected 59% of the total amount of paper and cardboard waste collected in Europe. It is important to mention that changes in waste collection data need to be evaluated together with changes in the population in the country, political decisions made during the examined period, etc. In the analyzed dataset, countries that are not members of the EU, joined the EU in 2004 or later, in those countries the increases in the amount of waste collection during the considered period are the largest. For example, the amount of paper and cardboard waste collected in Slovakia increased by as much as 391% between 2004 and 2020. i.e. from 76080 to 373980 tons, in Bulgaria 353%, in Poland 315%, in Turkey 252%, in the Czech Republic 183%, in Lithuania 173%, in Iceland 169% and in Croatia 125%. Other countries also stand out with increases in their paper and cardboard waste management indicators, i.e. Malta 63%, Slovenia 49%, Portugal 38%, Italy 34%, Greece 28%, Belgium 26%, Austria 12%, Spain 2.6%. Romania's data did not change overall during the considered period, i.e. 0.49 %, but the year 2006 was marked by a large increase and a clear downward trend (fig. 4).

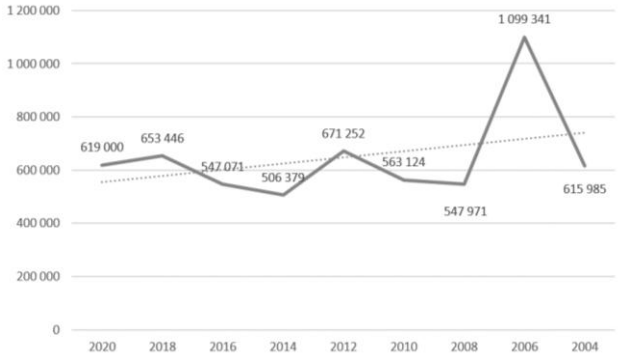

Fig. 4. Paper and cardboard waste collected in Romania in 2024-2020, tons
Source: Eurostat database adapted by author, 2024

Countries such as Serbia, North Macedonia, Bosnia and Herzegovina, Montenegro, and Liechtenstein are difficult to assess objectively, since Eurostat data are not available since 2004 and later, in 2008-2012.

Figure 5 shows the countries where the amount of collected paper and cardboard waste decreased from 2004 to 2020.

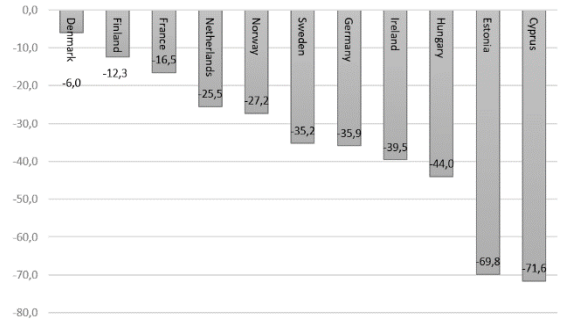

Fig. 5. Countries and the decrease in the amount of collected paper and cardboard waste 2004-2020, %
Source: Eurostat database adapted by author, 2024

As mentioned, the amount of paper and cardboard waste collected in Lithuania in 2004-2020 increased by 173%, i.e. from 74862 tons to 204991 tons. The diagram 6 presents the dynamics of paper and cardboard waste collection in Lithuania. A rhythmic growth dynamic is discernible.

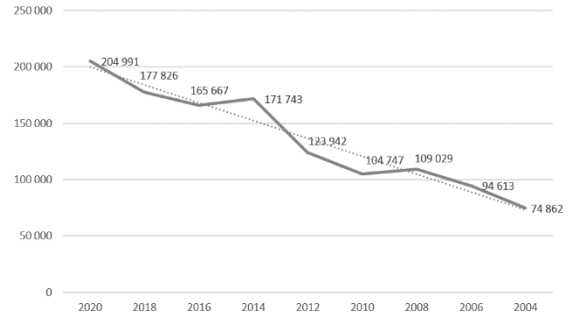

Fig. 6. Paper and cardboard waste collected in Lithuania in 2004-2020, tons
Source: Eurostat database adapted by author, 2024

Glass waste

Analyzing the trends of glass waste collection in Europe, the following important data are generally available.

Total amount increase of glass waste collected in Europe during 2004 – 2020 was 40%, i.e. from 12786476 tons to 18012473 tons. The dynamics of the increase are presented in 7 figure, clear increasing trends are visible.

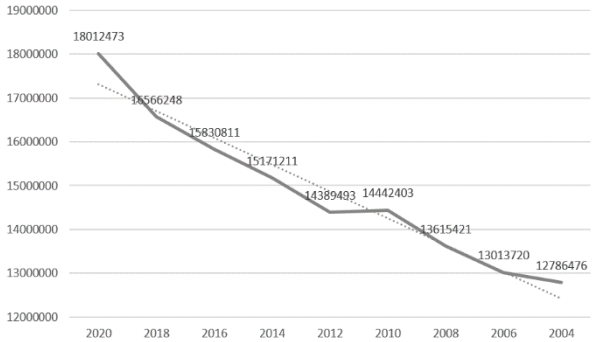

Fig. 7. Total amount of glass waste collected in Europe during 2004–2020, tons
Source: Eurostat database adapted by author, 2024

The countries where the largest amount of glass waste was collected in 2020 are Germany, Italy, France, Belgium, Poland, these countries together collected 40%

of the total amount of glass waste collected in Europe. The largest increases in the amount of glass waste collection during the considered period were achieved by Bulgaria 2307%, Malta 1874%, Slovakia 687%, Croatia 272%, Poland 254%, Belgium 206%, Latvia 160%, Italy 120%. Other countries also stand out with increases in their glass waste collection rates, where the percentage of increase is in the range of 100-0 %. These countries and indicators are shown in figure 8.

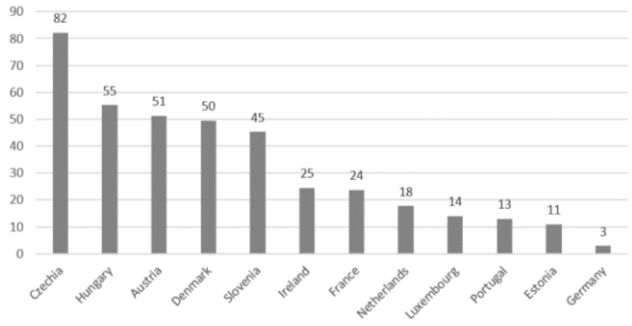

Fig. 8. Countries and percentage of increase in glass waste collection in 2004-2020
Source: Eurostat database adapted by author, 2024

The following figure 9 presents the dynamics of glass waste collection in Portugal in the years 2004-2020, as the increase in glass waste collection in this country in 2008 stands out among other countries in the entire analyzed data array. In general, according to the data, a decreasing trend can be seen.

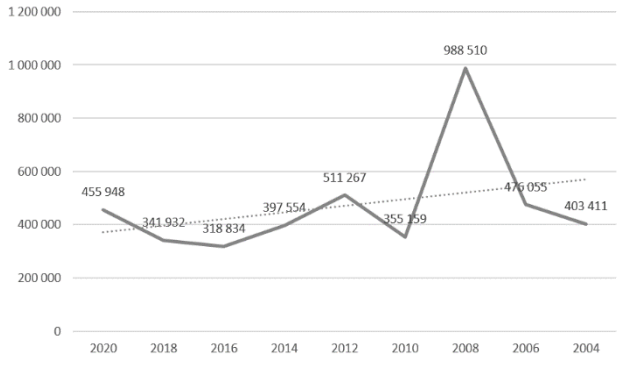

Fig. 9. Dynamics of glass waste collection in Portugal in 2004-2020, tons
Source: Eurostat database adapted by author, 2024

The figure 10 shows the countries where the amount of collected glass waste decreased between 2004 and 2020.

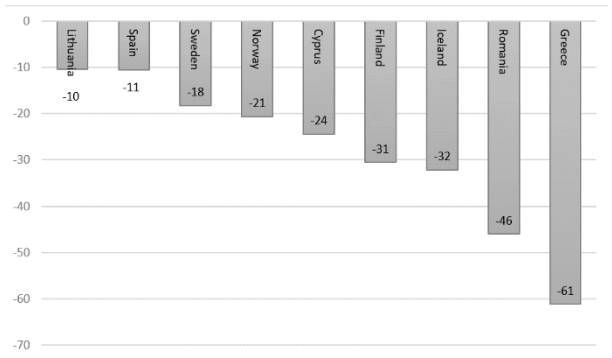

Fig. 10. Countries and percentage of glass waste reduction in 2004-2020, tons
Source: Eurostat database adapted by author, 2024

Countries such as Lithuania (-10%), Spain (-11%), Sweden (-18%), Norway (-21%), Cyprus (-24%), Finland (-31%) Iceland (-32%), Romania (-46%) and Greece (-61%) demonstrate a decrease in the amount of glass waste collection.

As mentioned, the amount of glass waste collected in Lithuania decreased by 10% between 2004 and 2020, i.e. from 105142 tons to 94129 tons. The diagram 11 presents the dynamics of glass waste collection in Lithuania. The chart also shows a general downward trend.

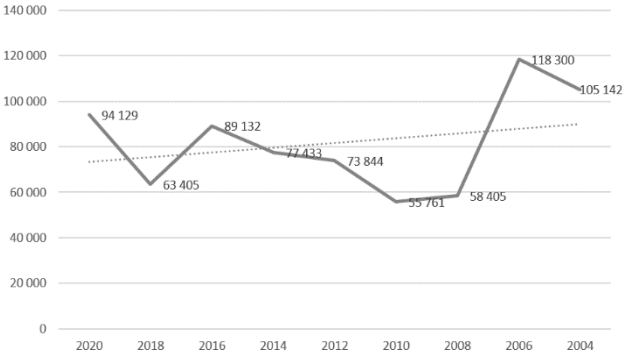

Fig. 11. The dynamics of glass waste collected in Lithuania 2004-2020, tons
Source: Eurostat database adapted by author, 2024

Plastic waste.

It is emphasized that the summarized table of plastic collection in Europe in 2004-2020 is not presented in this article due to its large volume. Analyzing the trends of plastic waste collection in Europe, the following important data are generally available. Total plastic collected in Europe increased by 105% between 2004 and 2020.

Figure 12 shows the total amount of plastic waste collected in European countries in 2004 - 2020. A clear upward trend is visible, the collected quantities only increased every year.

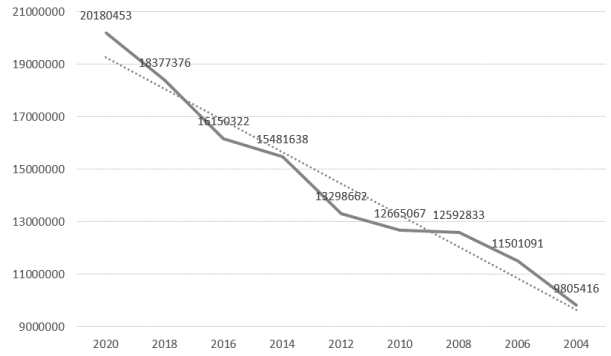

Fig. 12. The total amount of plastic waste collected in European countries in 2004–2020, tons
Source: Eurostat database adapted by author, 2024

The countries where the largest amount of plastic waste was collected in 2020 are Italy, Germany, France, Poland, Belgium, these countries together collected 67% of the total amount of plastic waste collected in Europe. It is important to mention that changes in waste collection data need to be evaluated together with changes in the population in the country, political decisions made during the examined period, etc. In the analyzed dataset, countries that are not members of the EU, joined the EU in 2004 or later, in those countries the increases in the amount of waste collection during the considered period are the largest. For example, the amount of waste collected in Poland increased by 1044% between 2004 and 2020. i.e. from 195685 to 2238779 tons, in Bulgaria 730%, in Lithuania 524%. Other countries also stand out with increases in their plastic waste management indicators, i.e. Slovakia 369%, Norway 350% Turkey 270%, Italy 247%, Czech Republic 229%, Germany 172%, Denmark 158%, Sweden 109% Iceland 102%

Countries such as Serbia, North Macedonia, Bosnia and Herzegovina, Montenegro, and Liechtenstein are difficult to assess objectively, since Eurostat data are not available since 2004. and later, in 2008-2012.

The figure 13 shows the countries where the amount of collected plastic waste increased to 100% between 2004 and 2020.

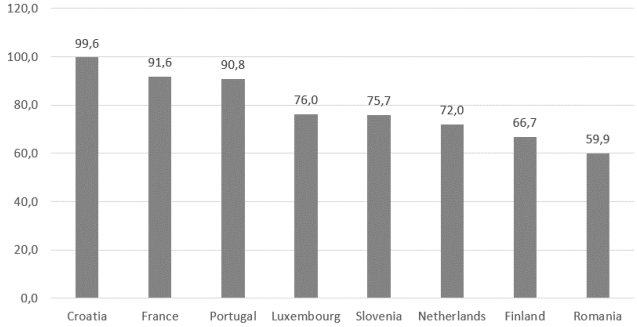

Fig. 13. Countries where the amount of collected plastic waste increased to 100% in 2004-2020.
Source: Eurostat database adapted by author, 2024

The decrease in the amount of plastic waste collection is demonstrated by countries such as Belgium (-25%), Spain (-27%), Austria (-32%), Ireland (-36%), Estonia (-41%), Greece (-51%) , Cyprus (-77%).

As mentioned, the amount of plastic waste collected in Lithuania in 2004-2020 increased by as much as 524%, i.e. from 17687 tons to 110399 tons. The diagram 14 presents the dynamics of plastic waste collection in Lithuania. Clear upward trends are visible, and the increase is recorded every year throughout the entire considered period.

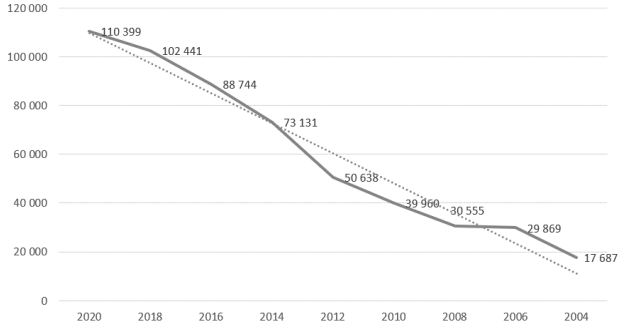

Fig. 14. Dynamics of plastic waste collection in Lithuania in 2004-2020, tons
Source: Eurostat database adapted by author, 2024

Evaluation of the public's attitude towards waste sorting in the conditions of a circular economy by the questionnaire survey

In general, it can be stated that society has a sufficiently favorable view of the principles of the circular economy and realizes its responsibility in the implementation of changes. The majority of respondents belongs to the age group of 35-45 years, women who raise children, have higher education, work, are socially active, have average and higher incomes, i.e. a part of society that is often responsible for household maintenance, takes care of food and other household supplies, makes basic purchases for the family, and is also responsible for waste management in the family.

During the research, the dependences between the income received and the benevolent involvement in the household waste sorting process become apparent. i.e. the higher-income part of society is more interested in sorting waste benevolently and free of charge.

Respondents (70%) consider fines for improper waste sorting to be an unfounded measure and deny the effectiveness of financial fines for improper disposal of stocks. Delivering waste to waste collection sites, according to 65% of respondents, can be a challenge, as well as the limited amount of waste per inhabitant, which can be delivered free of charge per year to waste collection sites, negatively affects the efficiency of such a scheme, according to 45% of respondents. The lower income segment of society tends to benefit financially from proper waste management. It can also become a source of small income by helping to sort waste.

The main reasons why there is no favorable attitude towards free waste sorting are as follows: lack of time, busyness, there is no organized waste sorting area in residential premises (home), waste sorting habits have not been formed, lack of information, it is physically inconvenient to reach the waste collection point (containers). Even 46% of the respondents claim that purchasing waste, even at minimal rates, is an untapped opportunity in waste management. Most of the respondents confirm that the participants of the supply

chain, first retail trade, must provide conditions and be interested in waste sorting, i.e. a greater variety of containers and packaging must be returned for recycling for a fee specifically at retail outlets, as is done with deposit plastic packaging that is suitable for beverages. It should be noted that not only plastic packages are used for drinks, but there are also other liquid products sold in small plastic containers. Respondents (78%) strongly support standardized deposit packaging in retail. Here, the responsibility of the manufacturer arises even before the product is placed on the market. Thus, it can be said that the regulation of production activities, indicating the standards for production packaging, has a sufficiently large contribution to the implementation of the circular economy. Respondents (64%) welcome the possibility to buy liquid and non-food products using their reusable containers. According to the respondents, the implementation of this measure is even delayed, it could have been implemented several years ago. The majority of those surveyed (82%) agree with the manufacturer regarding the tightening of measures to ensure product quality and durability. 94% of the respondents agree with the statement that the user must be fully enabled to carry out high-quality product repair. The interviewees emphasize that now, repairs and warranty service in retail are performed quite problematically (71%). 98% of respondents agree with the statement that repair should be more financially beneficial than purchasing a new product. According to the respondents, the textile waste collection system should also be improved (93%). Even 69% of respondents do not sort textile waste at all. This is a very undeniable sign. Solutions i.e. special containers for textiles and the possibility of delivery to retail clothing sellers at points of sale (for giving a corresponding discount on the next purchase) do not work. In this area, there is a clear lack of public information and promotion, according to 67% of respondents. The majority of respondents (86%) agree that end-user waste is not only the responsibility of end-users, but of the commercial intermediaries of the entire supply chain. The "polluter pays" principle must be directed at the intermediaries of the supply chain, not the end user, but the end user must be responsibly provided with favorable conditions, without coercive actions and restrictions. Waste management habits of society must be developed both in the family and in educational institutions, starting with preschool institutions. Here, decisions on solutions must be taken by education specialists, and a clear and consistent plan of actions and measures must be drawn up. All of them must reflect the importance of circular economy and waste sorting.

Conclusions

Waste management is important topic in the modern world, when resource conservation and ecological aspects become particularly important. The world's growing consumerism is becoming a negative phenomenon and must be managed in a way that conserves resources. The implementation of the circular economy aims at exactly such goals, i.e. less raw materials, less waste, less emissions by managing such elements as: raw materials, sustainable design, production, distribution, consumption, reuse, repair, collection, waste management, residual waste control. Reverse logistics plays a very important role in these aspirations, as reverse logistics is an entire supply chain dedicated to the reverse flow of products and materials - return, repair, rework and/or recycling. Waste management is also a reverse logistics task. Reverse logistics involves the movement of returned product from consumers to the manufacturer, product sorting, recycling and disposal. Often, reverse logistics is associated with the return of only low-quality material flow, but a truly unexploited opportunity in reverse logistics is the return of any product, whether it is a fragment of a product, whether it is parts, waste, etc. into the supply chain. Reuse, repair, collection, waste management are only the responsibility of reverse logistics. For this reason, waste management in circular economy conditions cannot be seen only as the responsibility of the government and the end-user (resident sorting waste). All participants of the supply chain, who were interested in bringing the material flow to the end-user and who created added value in the supply chain, according to the "polluter pays" principle, should take responsibility for waste generated in the country, waste management and sorting, recycling, as an extreme option. Because the prevention of waste generation is a priority, and the cheapest solution to avoid waste management and recycling. A shift to more reliable products that can be reused, refurbished and repaired would reduce waste. EU regulations on packaging and packaging waste cover both packaging design and packaging waste management. They aim to harmonize national measures, prevent waste generation and increase reuse and recycling. Food waste is one of the main obstacles to the implementation of the circular economy. In implementing the goals set by the EU circular economy regarding municipal waste management, Lithuania aims to have by 2030 the share of this waste disposed of in landfills would not exceed 5%, the share of waste prepared for reuse and recycled until 2035 would be at least 65%. For this, measures must be provided to encourage residents to reduce the generation of waste, to properly sort it, and after sorting, the remaining waste is managed in accordance with the hierarchy of its management, i.e. prevention, preparation for reuse, recycling, utilization (energy recovery), disposal. Certain conditions have been created for the society for the proper sorting of waste, but those measures are insufficient, as demonstrated by the household’s survey. Some measures are considered overdue, for some types of waste, e.g. favorable conditions for collection of textiles are not created, tools such as deposit packaging, which have proven to be excellent for plastic collection, are not used, proper waste sorting is encouraged by fines that do not materialize and do not cause internal motivation, waste weight restrictions are used, complex independent waste transportation, etc. In general, the topic of waste management is dynamic topic, new strategies, legal acts, rules are foreseen and approved in it, the monitoring of the situation should be continuous, assessing the public's reaction to the adopted changes.

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THE SIGNIFICANCE OF AFFORDANCES APPROACH IN GAMIFICATION RESEARCH FOR HUMAN RESOURCE MANAGEMENT

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Abstract
The contemporary organizational work landscape is becoming more and more digital and experiencing changes in workforce and work management. Productivity, flexibility and collaboration become the essence of the workplace. This leads to the consequence that motivation plays a pivotal role in the success and efficiency of many organizations. Moreover, organizations are facing challenges in how to inspire, energize and keep employees motivated. In response to this challenge, gamification, which is well-known as the application of game elements and principles for non-game purposes in a business context, emerges as a strategic instrument, to incentivize and motivate employees toward predetermined goals, objectives and behaviours. The goal of gamification applications is not only to enrich the usual work environment with game elements but also to create affordances that would serve as stimuli to promote employee motivation by satisfying psychological needs and encouraging employees to achieve goals. Hence, successful gamification application experiences in organizations have led to the fact that now gamification is one of the most common motivation tools in contemporary modern organisations. This study aims to explore the importance and relevance of the affordances approach in gamification research for Human Resource Management (HRM) as well as its implications in organisational contexts. To achieve this aim, the databases of Web of Science, Wiley online library, Scopus, and EBSCO host were searched for relevant articles for this systematic literature review. It includes 35 articles with empirical results, relevant to the field of business and management. This research focuses on peer-reviewed studies published in the English language from 2015 to 2023. Methods used for presenting and synthesizing results included conducting a systematic literature review based on PRISMA reporting guidelines. Furthermore, the systematic literature review was conducted using the digital qualitative data analysis tool MaxQDA and Mendeley reference manager for importing bibliographic data. For the contribution of the field, themes related to affordances theory have been identified and the findings have been structured to demonstrate the interrelationships between these concepts and their relevance in the HRM context. This study reveals that affordances can vary depending on the environment and can be influenced by social dynamics, contextual factors, organizational practices, or individual perceptions. The comparison of the studies allowed the identification of research gaps and areas for future research on gamification in HRM. Furthermore, the review emphasizes the significance of the affordances approach in understanding how gamification can influence employee psychological and behavioural outcomes in HRM contexts.
KEY WORDS: gamification, affordances approach, employee experience, HRM.
JEL classification: M12, M54, O15

Introduction

The contemporary organisational work landscape is becoming increasingly digital and experiencing rapid evolution and dynamic transformation. HRM practices are changing significantly through the lens of technology: E-HRM and self-service portals, user-friendly interfaces, personalized learning platforms, and mobile applications provide employees with easy access to HR services and resources. In response to these changes, gamification emerges as a strategic instrument, leveraging game elements within non-game contexts to incentivize employees toward predetermined objectives, behaviours, or initiatives within the corporate setting.

Researchers' interest in the application of gamification in work contexts is evident in studies exploring gamification potential, opportunities and challenges (Morschheuser and Hamari 2019), development of gamified assessment for employee recruitment and selection (Georgiou et al. 2019; Georgiou 2021), research on employee engagement (Hammedi et al. 2021, Gupta et al. 2021; Girdauskiene et al. 2022), the relationship between gamification and innovation (Patricio et al. 2018), gig-workers motivation and engagement (Pereira et al. 2022; Behl et al. 2022), employee creativity (Ikhide et al. 2022), gamification effectiveness in crowdsourcing (Morschheuser et al. 2017), motivation (Liu et al., 2018; Herranz et al. 2019; Miri and Macke 2021), gamification ethics and legitimisation in HRM (Kim 2018; Butler and Spoelstra 2024), to name a few. While gamification is widely used in organisations, it is explored in different fields of science but in HRM, it is less researched (Koivisto and Hamari 2019; Hammedi et al. 2021; Ikhide et al. 2022). Moreover, current studies have shown that gamification outcomes are highly context-dependent and user-dependent (Patricio et al. 2022; Bitrian et al. 2023; Chang et al. 2023). Furthermore, these research results are sometimes contradictory. Thus, further research in diverse contexts and business sectors is needed (Patricio et al. 2022; Wibisono et al. 2023).

A general overview of gamification studies reveals that the researchers are exploring gamification by selecting certain practical gamification design mechanisms (elements, mechanics etc.) or analysing gamification in terms of affordances. The affordances approach takes a research focus on the interaction between employees and gamification. Although the analysis of gamification research shows that the affordances approach is significantly less used in HRM, recent workplace gamification research shows the increasing popularity of this approach. Theoretical conceptual papers on the gamification of affordances approach in organisational contexts include gamification value in production and logistics (Warmelink et al. 2020), and gamification

affordance for creativity (Ikhide et al. 2022). Empirical studies include gamification contribution to knowledge management Suh and Wagner (2017), and engagement (Hammedi et al. 2021) but there are too few to see the big picture. In addition, researchers focusing on gamification affordances used the term motivational affordances, viewing them as a distinct type of gamification affordances linked to motivational needs (Huotari and Hamari 2017; Suh and Wagner 2017; Warmelink et al. 2020).

The embracing of the affordance approach to gamification studies in HRM helps improve insights into how gamification can be applied to enhance employee engagement, motivation, and performance by focusing on the interaction between employees and gamified environments, emphasising psychological outcomes and tailored experiences. There was an apparent contradiction in the empirical results of the existing studies. Researchers were discussing that gamification outcomes are highly context-dependent, so the possibility of focusing more on the gamification-employee interaction using the affordances approach may be an excellent opportunity to gain further insight into the phenomenon of gamification. Moreover, this can lead to an improved understanding of how gamification affects different individual, collective or organisational needs in the HRM context.

Although literature reviews on gamification in HRM have been conducted Mohanty and Christopher (2024), they have not highlighted and discussed the representation and importance of the affordances approach. Furthermore, it is not clear how the affordances approach is more advantageous than the game elements or mechanics approach to gamification in HRM. Also, the considerations behind the choice of this approach are vague. To improve understanding and application, more comprehensive reviews are needed to identify the potential of this approach in gamification HRM research and to identify directions for further studies. A literature review is needed to determine the prevalence, research specificities and progress of the affordances approach for researchers and practitioners to have a broader perspective in HRM. Thus, it is important to explore what is already known about the affordance approach in gamification in HRM and its potential in future studies. To answer this objective, the following research questions are raised:

1. What are the arguments for using the affordance approach in studying gamification in HRM contexts?
2. What theories and models are used to explore the affordances of gamification in HRM?
3. What is known about how gamification motivates looking through the lenses of affordances in the field of HRM?

The review's findings highlight areas where research knowledge is well-established, identify gaps requiring further investigation, and suggest future research directions to advance understanding of the topic.

Background of the study

Gamification

Gamification is “the enhancement of the context in which it is applied through the gamification to achieve greater overall value” (Huotari and Hamari 2012, p. 19). In addition, this definition is based on a human-centred approach that emphasizes prioritizing the needs, desires, and capabilities of employees to create value. The use of gamification in the management of organisations can work on two levels: interacting with the system, influencing employees, as well as managing data, and learning from the results of the interaction (Wanick and Bui 2019). Gamification can contribute to data collection, and governance, and thus support data-driven decision-making (Wanick and Bui 2019). Also, gamification is considered a method that makes work-related tasks more enjoyable and generates access to work-related performance information (Cardador et al. 2017, Gerdenitsch et al. 2020). Moreover, the goals of gamification in organisations are to encourage employee participation in activities and to increase the added value experienced by employees through the use of a specific system or tool (Huotari and Hamari 2017).

Gamification in the organisation is applied in many different ways and for different purposes, which allows it to have very different outcomes. Gamification solutions may be individual, but some of them are essentially social. Moreover, employees work in teams that unite them with common goals and joint efforts to achieve them, so gamification in the work environment rarely works as a solution affecting only at individual level. However, in existing studies, researchers have focused on assessing individuals' motives and actions to explain how to apply the appropriate gamification elements depending on the desired effect in a given context (Hamza et al. 2022).

Despite its popularity, gamification in other fields, such as marketing or education, is significantly more studied by researchers. Also, the analysis of scientific publications showed that there are studies based on the affordances approach in the HRM field (Wibisono et al. 2023, Ligorio et al. 2023, Benitez et al. 2022, Waizenegger et al. 2020, Holzer et al. 2020). These authors referred to the same widely used definitions of gamification which were primarily formulated in computing systems, business, and marketing fields (Deterding 2011; Werbach and Hunter 2012; Huotari and Hamari 2017). This suggests that the definitions are widespread in gamification studies, but are not specifically tailored to the characteristics of the HRM context. Also, there is no single definition which is used by researchers who follow the affordances approach.

Affordances Approach in Gamification

Gamification was researched based on two frameworks: game elements and affordances approach. The game elements or mechanics approach involves a choice where research is based on specific game elements or sets of game elements within a specific taxonomy. The affordance approach is more focused on the interaction between the employee and the gamified environment and the psychological outcomes arising from this interaction. To strengthen comprehension of the psychological impact of gamification, it is vitally important to study how individual game design elements influence motivation (Deterding 2011). This examination requires exploring the concept of affordance, which refers to the characteristics

of an object determining its capacity to fulfil and facilitate motivational requirements (Mekler et al. 2017).

The term gamification affordances refers to the specific features or characteristics of gamified systems that provide opportunities for motivation, engagement, and behaviour change (Xi and Hamari 2019). They can include various game-like elements such as points, rewards, leaderboards, badges, levels, progress tracking, narrative, clear goals, challenges, feedback and feedback loops (Hamari et al. 2014; Xi and Hamari 2019). Furthermore, affordances are intended to provide employees with opportunities and cues for action, enabling them to interact with the system or activity in a meaningful and engaging way (Treiblmaier and Putz 2020). Nevertheless, they are designed to tap into intrinsic motivation, enhance employee experience, and promote desired behaviours (Xi and Hamari 2019). The affordances are designed to enhance the employee experience and encourage desired behaviours (Hamari et al. 2014).

By leveraging these affordances effectively, gamification can create a more immersive and enjoyable experience for employees, leading to increased motivation, participation, and achievement (Xi and Hamari 2019). The effectiveness of gamification affordances can vary depending on the context in which they are implemented and the motivational needs of the employee (Hamari et al. 2014, Treiblmaier and Putz 2020). During the interaction of gamification and employees, possibilities for different actions, such as rewards, competition, altruism, and self-expression, can occur, supporting the satisfaction of employees' psychological needs like autonomy, competence, and relatedness (Patricio et al. 2022).

The affordance approach in gamification focuses on the interaction between employees and gamified environments, emphasizing the psychological outcomes of these interactions. It contrasts with the game elements or mechanics approach, which focuses on the game design components. Despite the recognized potential of gamification in HRM, there remains a research gap in understanding its full impact from the affordance perspective. Moreover, current studies often focus on individual motives and game elements without fully exploring the broader organisational context and the social and cultural dimensions of work environments that could benefit from an affordance approach.

Methodology

The research methodology consisted of a systematic literature review based on the PRISMA reporting guidelines (Fig. 1), which are renowned for their ability to produce reliable and unbiased results. The databases searched were Web of Science, Wiley online library, Scopus and EBSCO host. These databases were chosen to find a maximum amount of relevant articles to this systematic literature review. Also, these databases offer one of the greatest availability of studies in the field of management that address the application of gamification in the work environment. The search strategy aimed to collect relevant articles on the impact of gamification on HRM. The selection criteria were: relevance to the field of business and management, English language, peer-reviewed journal status, comprehensive articles with empirical results, primary literature and focus on gamification effects.

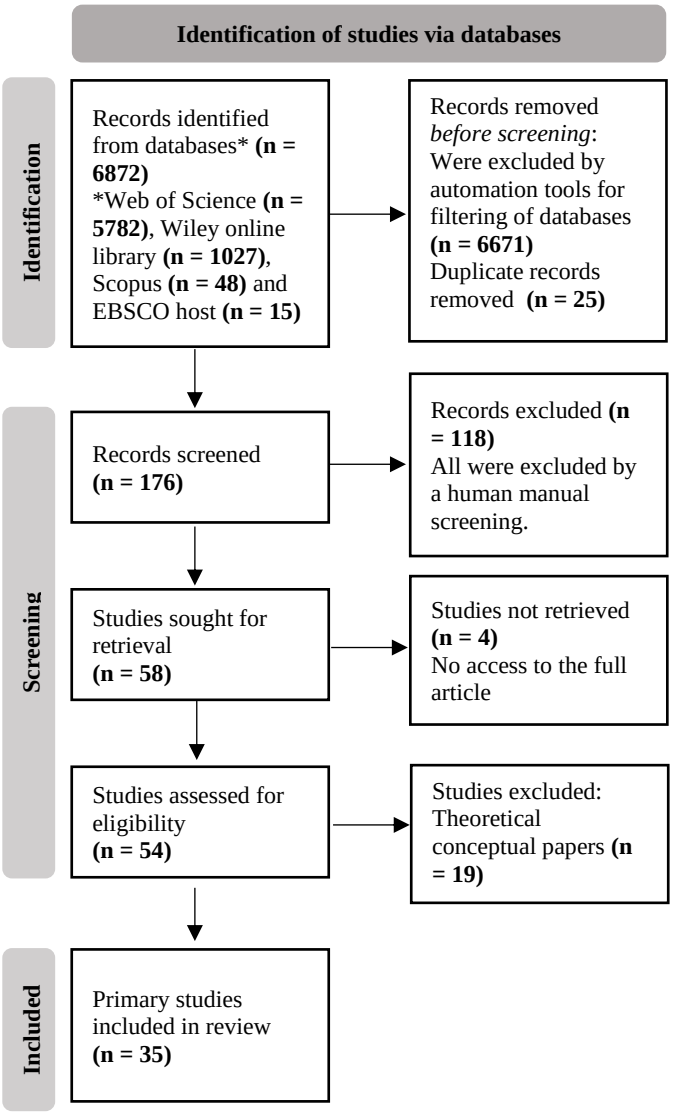

Fig. 1. Study selection procedure
Source: compiled by the authors

The primary search resulted in a set of 6872 articles across the four chosen databases. In the first step, after applying the above criteria, which were available as filtering tools in the database, the volume of articles decreased to 201. In the second step, duplicate records were removed before screening. In the third step, the titles, abstracts and keywords were manually reviewed (also after applying the above criteria). 67 % of articles were excluded in this step because the subject area was out of HRM. Most often, papers were rejected because they examined student teams in a gamified learning environment. In the fourth step, the full text was manually reviewed. Few article's sources do not have access to the full article. At last, 19 articles were excluded because they were theoretical conceptual papers without empirical results. As a result, the final pool of 35 articles remained for the current literature review. Articles were selected from the period 2015-2023 and analysed using the MaxQDA.

Results

What are the arguments for using the affordance approach in studying gamification in HRM contexts?

The analysis showed that the realisation of user-centred design is grounded on the fact that gamification satisfies basic psychological needs (autonomy, competence and relatedness), based on the Self-Determination Theory (SDT) (Behl et al. 2021; Patricio et al. 2022). By fulfilling the needs, gamification motivates amployee to engage in gameful experiences (Behl et al. 2021). Human motivators are integrated into user-centred design principles, resulting in a user-focused experience (Patricio et al. 2022). It might be hard to ignore the importance of meeting internal psychological needs to keep the employee as a core in the gamified HRM. Thus, the employee rarely acts as an isolated user when gamification is applied at the organisational level. There are influencing aspects of power, norms, roles, culture, and working practices (Wang et al. 2023). In other words, there are tangible norms that affect how employees act in response to game elements, which is not so relevant in the case of a single user.

An analysis of the definitions indicated that gamification in HRM is reactive, with employees responding to game elements, mechanics, features, and techniques. Gamification aims to create experience, response, and effectiveness by fostering engagement and enjoyment through game-like processes. To ensure a user-centred approach in HRM through gamification it is crucial to consider both the fulfilment of psychological needs and the influence of organisational norms and practices when implementing gamification in HRM where the affordances approach can be useful.

The analysis of the papers revealed that gamification in HRM has been used from various perspectives in the areas of employee behavioural indicators, organisational development, recruitment and selection, employee training and development, employee relationships, types of employees, and organisational image (Fig. 2).

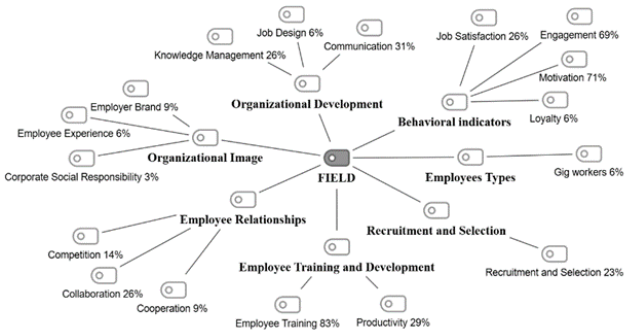

Fig. 2. Overview of studied gamification application contexts in the HRM field
Source: compiled by the authors

The literature analysis showed that gamification is mostly studied in the fields of training (83%), motivation (71%) and engagement (69%). Regardless of the fact that user-centred design is a guiding principle in gamification that focuses on organising the gamification design process to meet the needs and expectations of employees (Krath et al. 2021) and ensure the necessary elements to create an engaging and effective gamified experience for the employee (Patricio et al. 2022), the present literature analysis showed that employee experience (Behl et al. 2021; Wibisono et al. 2023; Bizzi 2023) is the newly explored contexts in the HRM field.

An analysis of the contexts of the gamification studies showed that the affordance approach was chosen to research engagement, basic need satisfaction and enjoyment (Wibisono et al. 2023), sustainable behaviour (Ligorio et al. 2023), employee performance and motivation (Benitez et al. 2022), team collaboration (Waizenegger et al. 2020), knowledge sharing and motivation (Holzer et al. 2020).Scholars who take the affordance approach mentioned some arguments as to why this approach is appropriate for studying gamification in the context of organisations. The synthesized argument for using the affordance approach to research gamification in HRM is provided in Fig. 3.

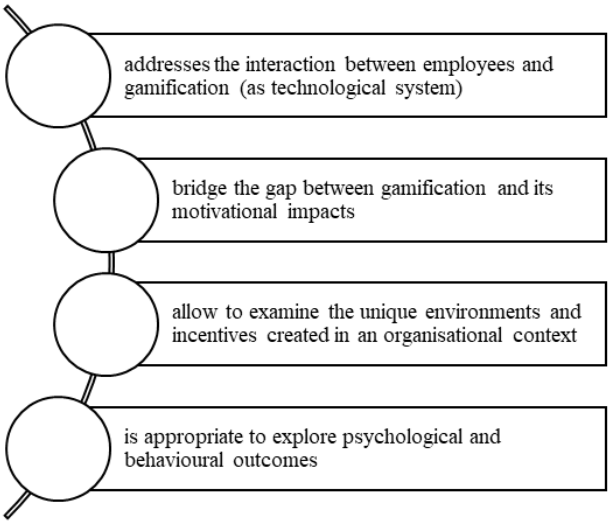

Fig. 3. Argument for using the affordance approach to research gamification in HRM
Source: compiled by the authors

First, the gamification phenomenon is deeply intertwined with technology and human interaction. The affordance approach is a useful way to understand how employees interact with gamification because it focuses on the opportunities for action that gamification provides and employees' commitment to these actions. According to Waizenegger et al. (2020), the affordance approach is useful for exploring the behaviours associated with IT objects and goal-oriented actors within workplace conditions (Waizenegger et al. 2020). Furthermore, the affordance approach is useful for examining previously unrecognized roles of technology and exploring how the affordances of achieving workplace goals have shifted to a new set of affordances to achieve the same goals (Waizenegger et al. 2020). Second, Wibisono et al. (2023) argued that previous studies have shown that game design elements utilize specific game design patterns and motivational affordances to create an environment that fosters pleasurable and engaging experiences. Third, this approach allows scholars to examine the unique environments and incentives created in an organisational

context. According to Benitez et al. (2022), this approach effectively highlights the unique affordances that make it an ideal resource for supporting and enabling gamification activities in an organisational context. Moreover, previous research revealed that the affordance approach is useful for exploring the behaviours and outcomes related to gamification in an organisational context (Wibisono et al. 2023). For example, gamification affordances support psychological ownership and behaviour (Ligorio et al. 2023). Still, previous studies have found a lack of strong empirical evidence and conclusive findings in this area in an organisational context (Holzer et al. 2020; Wibisono et al. 2023).

In addition to those already mentioned, there are further arguments. The use of gamification in a work context is unique in that the employee may feel incentivised, pressured or forced to participate (Hammedi et al. 2021). Concerns have been raised about employee exploitation by applying gamification (Kim and Werbach 2016; Kim 2018) and considerations of the ethical ambivalence of gamification in the workplace (Butler et al. 2024). The various negative effects associated with loss of employee autonomy, increased employer control, and reduced meaningfulness in performance can undermine employee well-being (Kim and Werbach 2016; Kim 2018; Butler et al. 2024). These considerations seem reasonable and worthy of further analysis from the HRM perspective. In a work environment, employees are bound by various hierarchical ties that can create a certain amount of power over each other. Moreover, the work environment is balanced between benefits, value for the employee and well-being, and benefits for the organisation and the achievement of its objectives. Employees represent different generations, cultures, experiences, and tech-savviness, so creating a playful experience and engagement that is valuable to the employee and the organisation can be a serious challenge. The affordances approach could influence these considerations or bring a different view of gamification in HRM considering that affordances are how employees perceive environments to support their needs. This may fundamentally change the approach to gamification, as gamification in this case is not something that is imperatively built into the system, something that might make the employee feel pressured or forced to participate.

To conclude, employee relationships and interactions applying various gamification solutions are getting more important. Close relationship with technology, examination of unique environments and incentives, exploration of behaviours and outcomes associated with gamification in organisational settings, and shedding light on the effects of unique affordances that support and enable gamification activities in organisational contexts are reasons to use the affordance approach in HRM. The affordance approach leads to understanding how employees interact with gamification and allows researchers to explore the psychological aspects of gamification and their overall experience within HRM contexts. It provides a comprehensive path for studying gamification by exploring behaviours, fostering engagement, supporting activities, promoting psychological aspects, examining technology roles, and addressing empirical evidence gaps within organisational contexts.

What are the theories and models used to explore gamification in HRM based on the affordance approach?

The literature review has shown that gamification research in HRM has applied various theories and models (Fig. 4). The most frequently used theories are SDT (42%) and Flow (38%), followed by Kahn's model of engagements (17%), Technology acceptance model (TAM) (13%) and Sak's model of engagement (13%). Also, gamification studies draw on social theories that seek to understand multiple social phenomena by applying gamification in HRM. Studies that have focused on motivation have also tended to apply SDT and Flow theory, followed by Herzberg's motivational theory, Goal-setting theory, and Self-efficacy theory. With the growth of gamification research in HRM, there is an increasing number of different theories that are being applied in research. Also, new theories are emerging which have not been applied before. For example, Social exchange, Social identity, Basic psychological needs satisfaction (BPNS) (a sub-theory within the broader framework of SDT) and others. It should be noted that some of these theories, which have already been applied in gamification studies in other fields, are still not very widespread and are rarely applied in the HRM field (for example, Goal-settings theory).

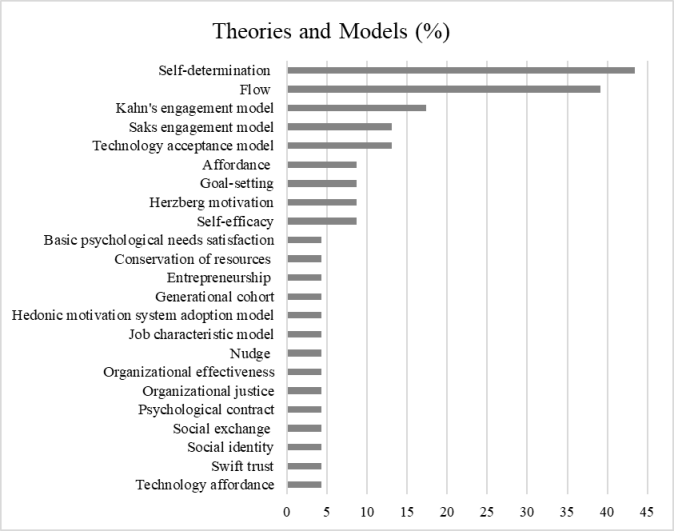

Fig. 4. Overview of the theories and models employed in the articles
Source: compiled by the authors

In a gamification context, the application of SDT and BPNS theories justifies the meaningfulness of gamification and the possibility of ensuring sustainable motivation in the HRM field (Behl et al. 2021; Norlander et al. 2023; Hidayat and Abdurachman 2022; Wibisono et al. 2023). This is argued by the fact that gamification has been shown to address not only extrinsic but also intrinsic motivation by satisfying basic psychological needs (Liu et al. 2018; Prasad et al. 2019; Girdauskiene et al. 2022).

The added value of applying Flow theory to the interpretation of gamification is also severalfold. First,

Flow theory also supports the meaningfulness of the gamification process in a work context (Silic et al. 2020; Sousa and Dinis-Carvalho 2021). Second, this theory explains how behavioural outcomes occur through gamification by providing an explanation of how flow is associated with an increased tendency to repeat intended behaviours related to performance (Behl et al. 2021). Process success is determined by the clarity of goals and the balance between challenges and skills (Jalili 2020; Silic et al. 2020; Bitrian et al. 2023; Gupta et al. 2021). Thus, this theory has contributed most to understanding how gamification inspires employees to engage their physical, emotional and mental efforts (Gupta et al. 2021).

Despite the positive results of gamification applications, studies have also found negative results for motivation and behavioural outcomes, so various other theories have been used to explore the reason for this difference. Some theories have helped to shed light on the necessary preconditions for gamification's positive impact on psychological and behavioural outcomes. Goal-setting theory allows the identification of factors that motivate employees to achieve goals in a gamification environment (Kulkarni et al. 2022). Nudge theory helps to reveal that employees behave well when they are better informed (Jalili 2020). Organisational justice theory added value by helping to reveal the feeling of fairness importance in gamified processes (Georgiou 2021). Also, Herzberg's motivation theory helps to reveal that there are hygiene factors (e.g. equality) that do not increase motivation, but their absence would decrease it (Sheiner 2015). Moreover, the TAM and the HMSAM models have been used to explain the relationship between gamification and attitudes towards specific technologies (beliefs in usage and usefulness) (Behl et al. 2021; Bitrian et al. 2023). Resource conservation theory, Technology affordance theory, Goal-setting theory, Social identity theory, Social exchange and Self-efficacy theory have added value in explaining the potential outcomes that may motivate an employee to engage in gamification at work (Sheiner et al. 2015; Behl et al. 2021; Benitez et al. 2022; Wibisono et al. 2023; Chang et al. 2023).

Analysis revealed that scientists have focused on engagement and applied theories to explain how gamification increases engagement. Swift's Trust Theory and Psychological Contract Theory provide perspectives on how gamification can engage digital employees (Pareira et al. 2022). Saks and Kahn's engagement models have added value by helping to uncover engagement factors and gamification relationship (Girdauskiene et al. 2022). Furthermore, scientists have focused on the gamification impact on employee behaviour outcomes. Job Characteristics Model, Generational cohort theory, Organisational effectiveness theory and Entrepreneurial theory have added value in understanding the relationship between gamification, employee behaviour and performance (Liu et al. 2018; Hidayat and Abdurachman 2022; Richards et al. 2023). In addition, the Affordance theory lens allows for a critical examination of gamification, exploring its barriers and constraints and its holistic impact on employee productivity and performance (Waizenegger et al. 2020), engagement and enjoyment (Wibisono et al. 2023).

Researchers who have adopted the affordance approach in their research have drawn on the following theories and models in their work: Basic psychological need theory, Conservation of resources theory (explains the motivation driving to both preserve existing resources and seek out new ones) (Wibisono et al. 2023), Technology affordance theory (the affordances provided by a technology influence its use, depending on individuals' perceptions and interactions with the technology) (Benitez et al. 2022), and Affordance theory (technological capabilities arise from the interaction between users and technological artefacts within a specific context, rather than being inherent to the technology itself, akin to the original definition of Gibson (1977) that affordances represent possible actions available to animals within their environment) (Waizenegger et al. 2020; Wibisono et al. 2023).

The term “affordances” has received much attention in the Human-Computer interaction field. Here the concept and theory have been developed and should not be treated in the narrow sense introduced by Gibson (Vyas et al. 2017). Furthermore, the affordance approach has recently been introduced into organisational and management literature (Wang et al. 2023). When an artefact or technology is used in a large organisation with multiple users, it is crucial to adopt a broader approach to affordances that includes the social and cultural dimensions of the workplace (Vyas et al. 2017). Despite the importance and potential of the affordances concept in the HRM field, very few researchers have paid more attention to this in the articles selected for this review. Only Waizenegger et al. (2020) have focused on the broader development of the understanding of affordance in gamification research. The authors have analysed several different types of affordances in their study and their research findings contribute to the theory of affordances by providing insights into the change in affordances of team collaboration. According to Waizenegger et al. (2020), affordances are frequently influenced by social contexts as well as by their historical and institutional applications. Affordances can be analysed by examining the design and usage, considering employee goals, community participation, and human reactions to changes in affordances (Waizenegger et al. 2020).

In summary, gamification research in HRM has mainly used self-determination theory and flow theory. This indicates a strong focus on intrinsic motivation. The application of different social theories highlights the importance of the multi-layered approach to understanding gamification's effect on the work environment. However, the limited application of motivational and social theories showed the potential for further research in this field. The concept of affordances has gained attention in the fields of gamification research, and organisational and management literature. While the concept of affordances has been developed beyond its original narrow sense, there is still a need for further exploration and understanding of affordances in the gamification and HRM field, which includes the social and cultural workplace aspects.

What is known about how gamification motivates looking through the lenses of affordances in the field of HRM?

In general, gamification is the integration of game elements into various other systems and tools. The context of HRM is no exception. Technologies, digital platforms, and systems provide opportunities for employees to enable or constrain certain actions and behaviours. The term affordances is used to refer to the various possibilities for action in a particular environment in gamification research. The systematic literature analysis showed that the concepts of environmental affordances, technological (or technology) affordances, social affordances, gamification affordances and motivational affordances were applied in 14% of the selected articles (n=5) or 17% of the articles focusing on motivation (Table 1).

Table 1. Overview of the affordances concept employed in the articles on motivation in the HRM field

Author	Research focus	Concept
Wibisono et al. (2023)	Engagement and Motivation	Gamification affordances
		Motivational affordances
Ligorio et al. (2023)	Sustainable behaviour	Gamification affordances
Benitez et al. (2022)	Employee performance and Motivation	Technological affordance
		Gamification affordances
Waizenegger et al. (2020)	Team collaboration	Gamification affordances
		Technological affordance
		Environmental affordances
		Social affordances
Holzer et al. (2020)	Knowledge sharing and Motivation	Motivational affordances

Source: compiled by the authors

This showed that the affordances approach is used in gamification research as well as in research that focuses on motivation. However, the analysis revealed that these concepts have only been started to be applied in gamification research in HRM since 2020. Moreover, the literature analysis revealed that researchers refer to slightly different concepts and definitions of affordances in their studies. Below (Table 2) the definitions of different affordances concepts are presented.

Based on Gibson (1977) environmental affordances describe how animals interact with their surroundings. Technology affordances refer to the interaction between people and technological artefacts (objects), emphasising the possible behaviours and actions enabled by these technologies which can be shaped by social environments, historical context, and institutional practices (Benitez et al. 2022). It is grounded in the idea that technologies have inherent properties that suggest how they can be used, and people perceive and actualize these affordances in different ways (Benitez et al. 2022; Waizenegger et al. 2020). Technology affordance theory was used to explain technological affordances and provides a useful conceptual framework to understand how the features and capabilities of technologies enable and constrain people's actions and behaviours in organisational contexts (Holzer et al. 2020). Social affordances can be considered the possibilities of action that people may provide as a social invitation for interaction with one another created by technological features within an environment (Waizenegger et al. 2020). Social affordances refer to a specific type of technological affordances when attention is paid to the social interaction that occurs due to the use of technology. These affordances can be a characteristic of all mentioned affordances. In this sense, even a point, badges or leaderboards can be social affordances because they can become a stimulus to compete.

Table 2. Definition of different affordances concepts

Concept	Definition	Authors
Affordances	Feasible and available actions provided by the environment that are practical and accessible for an employee to engage with.	Waizenegger et al. (2020)
Technological affordances	Potential uses and possibilities presented by a technology or platform, shaping what enable or constrain certain actions and behaviours	Benitez et al. (2022)
Gamification affordances	Actions that employees believe they can undertake within a gamified context.	Suh and Wagner (2017)
Motivational affordances	Designed triggers intended to address employees' motivational drivers and influence their psychological state.	Huotari and Hamari (2017)

Source: compiled by the authors

As an integral part of technology, gamification also enables or hinders certain specific actions and behaviours of employees in the work environment. In gamification, affordance theory proposes that technological capabilities are not embedded in technology but rather emerge from the relationship between employees and technological artefacts (objects) (Benitez et al. 2022; Waizenegger et al. 2020). Gamification affordance is an action that an employee perceives as possible when using a gamified system (Suh and Wagner 2017). Each element of the game used to design gamification can be understood as a practical mechanism that allows the affordances to manifest themselves. Also, they can be grouped according to certain common characteristics (Wibison et al. 2023).

Gamification can enhance the enjoyment of a task or activity by providing the employees with engaging and motivating gamification elements that encourage employee participation, motivation and engagement (Wibisono et al. 2023). When gamification is implemented effectively, it can increase motivation, leading to increased enjoyment for the employee (Liu et al. 2017). It is important to acknowledge that gamification design and employee perceptions can shape distinct affordances for different employees (Wibisono et al. 2023). Motivational affordance in gamification refers to how the activity is designed to motivate employees to engage, which includes rewards, challenges, and a sense of progress or accomplishment (Wibisono et al. 2023). Wibisono et al. (2023) study revealed that the relationship between motivational affordance and basic psychological needs

satisfaction is complex, as different employees may find different stimuli as motivating.

Summarising the analysis of the studies, it can be said that the studies focused on the single-user level. However, researchers studying affordances in the context of management have identified the existence of organisational and cultural or social levels in addition to the single user level. Vyas et al. (2017) argued that affordances need to be examined in the context of group dynamics, not just single users. Despite that from the design perspective, the affordances at the user level relate to its functionality, and representation, requiring an understanding of the one-to-one relationship between the user and the system (Vyas et al. 2017). However, when addressing affordances at the organisational level, it is necessary to take into account the cultural and social impact of interaction, rather than limiting it to the single-user relationship (Vyas et al. 2017). The analysis suggests that this aspect is still little explored and is an interesting new area of gamification research in the HRM field.

In summary, it can be concluded that studies refer to different concepts of affordances. However, all of these concepts are highly interrelated. Affordances (environmental affordances), technological affordances and gamification affordances refer to actions, while motivational affordances primarily refer to incentives to perform actions. Any element of gamification can be considered as information that the employee receives from the gamified environment. This information can be interpreted and this individual interpretation becomes a stimulus to effort and action. Affordances may differ across different environments and may be shaped by social environments, context, organisational practices, or employee perceptions. This is in line with Vyas et al. (2017) who argued that affordances should be examined in the context of group dynamics, not just individual employee and there is a growing recognition of the importance of considering affordances at the organisational and cultural or social levels.

Conclusions

Gamification is particularly relevant to the HRM field, but despite the large body of literature on gamification, it appears to be relatively under-researched in the HRM, even though it is a phenomenon applicable to HRM. Current studies often focus on individual motives and game elements without fully exploring the broader organisational context and the social and cultural dimensions of the work context. Affordances theory is gaining more attention in management and business, which is now much broader than it was introduced. It would be valuable to apply a broader understanding of it to gamification research and to carry out more research to uncover the context-depending and user-depending aspects of the application of gamification in HRM.

Affordances focus on the interaction between employees and gamified environments, emphasizing psychological outcomes. Also, affordances provide opportunities for motivation, engagement, and behaviour change tailored to enhance the employee experience and encourage desired behaviours. Leveraging these affordances effectively can create a more immersive and enjoyable experience for employees. Moreover, it offers a more holistic view of how employees interact with gamified systems, considering individual needs and preferences.

The affordance approach is useful for exploring behaviours associated with technology and goal-oriented actors within workplace conditions. The affordance approach effectively explores gamification in organisational contexts, although there is a need for more empirical evidence in this area. Future studies should explore how affordances operate at group or organisational levels and consider social and cultural dimensions in workplace environments.

Understanding affordances can lead to the design of more effective gamification strategies tailored to individual and organisational needs in HRM contexts. Future research should aim to address these gaps by investigating the broader applicability of gamification affordances, examining their long-term effects on employee behaviour and organisational outcomes, and developing a more nuanced understanding of how different organisational settings influence the success of gamification initiatives.

This research contributes to academic knowledge by providing a clear argument for using the affordance approach and identifying theories and models related to gamification affordances in gamification studies within HRM. The study identifies key concepts and definitions of affordances as applied in HRM gamification research and offers a more consistent understanding of how affordances impact employee behaviour and motivation. The study shows that most research on affordances in HRM gamification focuses on individual level, ignoring how it works at an organisational or team level. This opens the door for future research to consider teams, workplace practices and cultural influences.

Despite its strengths, the study has some limitations, such as focusing only on articles published in English and using a limited set of keywords in a limited number of databases, which may result in missing relevant studies that could have been identified. Future research should broaden the keyword set to include synonyms, and related terms to ensure a wider range of relevant studies are captured. Although some limitations, this study provides valuable insights for practitioners. These insights not only contribute to a more holistic understanding of gamification but also provide actionable insights to implement effective gamification strategies in organisations. It also helps practitioners to gain an understanding of how gamification can be applied to motivate employees by focusing on the affordances it provides.

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A COMPARATIVE ANALYSIS OF THE INNOVATION PERFORMANCE OF THE VISEGRAD COUNTRIES

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Abstract
This study conducts a comparative evaluation of the innovation performance of the Visegrad Group countries − Czechia, Hungary, Poland, and Slovakia − through a dual-framework analysis based on the European Innovation Scoreboard (EIS) 2024 and the Global Innovation Index (GII) 2024. To assess how efficiently each country transforms innovation-related inputs into outputs, the research employs Data Envelopment Analysis (DEA), a non-parametric method widely used for performance benchmarking. Both input-oriented and output-oriented DEA models are applied under the assumption of variable returns to scale, enabling the assessment of relative innovation efficiency and the identification of countries that operate close to or far from the efficiency frontier. Despite their shared historical and socio-economic characteristics, the findings reveal notable disparities in innovation efficiency among the Visegrad countries. Slovakia emerges as the most efficient, demonstrating strong performance in both input- and output-oriented models, which indicates a well-balanced and effectively managed innovation system. Poland follows with high input-oriented efficiency scores, suggesting prudent resource utilization, although there remains potential to enhance innovation output. Czechia, while achieving strong results in absolute innovation indicators, ranks lower in DEA-based efficiency due to relatively high output-oriented inefficiency, indicating underperformance in converting inputs into impactful results. Hungary consistently ranks at the bottom across both models, highlighting significant challenges in translating innovation investments into measurable outcomes and signaling the need for improvements in system effectiveness. These findings are placed in the context of previous studies on innovation performance in Central and Eastern Europe. Earlier research has often focused on input intensity or output volume, but few have combined efficiency analysis across multiple global indices. The findings of the study support prior conclusions that innovation systems in the Visegrad countries are unevenly developed, and that structural inefficiencies − such as limited innovation collaboration, low levels of venture capital investment, or weak commercialization processes − are central to the performance gaps. The results also provide actionable insights for policy design. Slovakia and Poland can serve as benchmarks within the region for balanced and efficient innovation systems. Czechia may benefit from targeted interventions to improve output transformation mechanisms, while Hungary requires a more comprehensive overhaul of its innovation ecosystem, with emphasis on fostering public-private cooperation and knowledge diffusion. By combining the strengths of two leading innovation measurement frameworks and the analytical power of DEA, this study contributes to a more nuanced understanding of innovation performance.
KEY WORDS: Global Innovation Index (GII), European Innovation Scoreboard (EIS), Data Envelopment Analysis (DEA).
JEL classification: O31, O32, O57, C67, R58

Introduction

International comparative analyses are essential for evaluating national innovation systems, as they help identify differences and performance gaps between countries. These analyses can support policy development and guide the identification of potential improvements. In global, multi-continent comparative analyses, the problem of different economic development and cultural factors may arise, which can limit the direct comparability of countries' performance. Therefore, analyses comparing areas with similar levels of economic development are better suited to supporting the development of countries' innovation ecosystems. In this study, we examine such a homogeneous group of countries, the Visegrad Group, whose member countries – Czechia, Hungary, Poland, Slovakia – share a history spanning several centuries and face similar challenges nowadays.

Innovation performance within the Visegrad Group countries has been the focus of numerous studies that explore various aspects of national and regional innovation systems. These analyses often underline the structural and contextual factors that shape innovation capacity and efficiency in Central and Eastern Europe.

Several scholars have emphasized the role of social and relational capital in fostering innovation. For instance, Będzik and Gołąb (2020, 2021) highlight the critical importance of trust, cooperation, and social capital as enablers of innovation activities. Their findings suggest that beyond quantitative inputs, the quality of institutional and collaborative environments plays a key role in shaping innovation outcomes.

Adding to this perspective, Kowalski, Kuberska, and Mackiewicz (2023) stress the role of collaboration and clustering, pointing out that cluster organizations can significantly enhance innovation performance through coordinated knowledge exchange and resource pooling, particularly in the Visegrad context.

In terms of quantitative performance assessment, Ivanová and Žárská (2023) examine the relationship between R&D expenditures and aggregate innovation index scores, concluding that there is a notable research gap in the analysis of how sub-indicators influence overall innovation indices. This insight underlines the need for more granular analyses that go beyond aggregate rankings.

Hudec and Procházdková (2015) contribute to the methodological discourse by employing a Cobb-Douglas production function with R&D costs as inputs and patent counts as outputs to evaluate regional innovation

efficiency in the Visegrad countries. Their findings suggest that, in addition to capital regions, several Polish and Czech regions exhibit high efficiency, supporting the idea that regional dynamics may diverge from national trends.

In a similar vein, Wibisono (2023) introduces the idea of R&D personnel as an additional category of knowledge input, advocating for more comprehensive models of innovation efficiency that account for human capital alongside financial inputs.

Despite the shared historical background and structural similarities of the Visegrad countries, their innovation trajectories differ significantly. Jabłońska (2020, p. 31) notes that while these countries share some institutional similarities, the structure and dynamics of R&D expenditures vary considerably, and their regional innovation potential remains below the EU average. These findings underscore the value of intra-regional comparisons, as pursued in the present study.

Moreover, Hintošová et al. (2020, p. 106), in their examination of the Summary Innovation Index (SII) and foreign direct investment (FDI), reveal that only outward FDI contributes significantly to innovation performance in the Visegrad countries. This suggests that domestic innovation ecosystems may not fully benefit from inward investment flows, pointing to systemic inefficiencies.

Kowalska et al. (2018) compare multiple composite indices—including the SII, GII, and Global Competitiveness Index—and observe that the Visegrad countries are increasingly diverging in innovation performance, with Czechia emerging as a clear frontrunner. They argue that these trends call for more complex and detailed analyses to understand the underlying efficiency differences and national innovation strategies.

Building on these contributions, the present study addresses a specific gap in the literature: the lack of integrated efficiency analysis using both the European Innovation Scoreboard (EIS) and the Global Innovation Index (GII) within a Data Envelopment Analysis (DEA) framework. While many of the previous studies offer valuable insights into innovation outputs, inputs, or contextual enablers, few examine how efficiently innovation systems convert resources into results across both regional and global benchmarking tools.

Most prior research has focused on individual indicators or innovation rankings, typically examining the European Innovation Scoreboard (EIS) or the Global Innovation Index (GII) separately. In contrast, comprehensive efficiency assessments that integrate both frameworks remain scarce. This study aims to fill this gap by employing a DEA-based dual-model approach that incorporates both EIS and GII data, thereby providing a more detailed and comparative perspective on the innovation efficiency of the Visegrad countries.

The primary aim of this study is to assess and compare the innovation performance and efficiency of the Visegrad Group countries – Czechia, Hungary, Poland, and Slovakia – within both regional and global contexts. Specifically, the research:

- Applies a dual-framework approach, using data from the European Innovation Scoreboard (EIS) 2024 and the Global Innovation Index (GII) 2024, to provide a comprehensive picture of national innovation systems in the Visegrad region.
- Evaluates the relative innovation efficiency of these countries through Data Envelopment Analysis (DEA), utilizing both input-oriented and output-oriented models under variable returns to scale, in order to identify efficiency gaps in the transformation of innovation inputs into outputs.
- Benchmarks the Visegrad countries against the EU-27 average, highlighting their position within the broader European innovation landscape and identifying best practices and underperforming areas.
- Explores structural factors and contextual differences that may explain variations in innovation efficiency among the Visegrad countries, drawing on previous empirical research and national innovation profiles.

Theoretical framework

The theoretical foundation of this study lies at the intersection of national innovation systems (NIS) theory and efficiency analysis in innovation performance measurement.

The concept of National Innovation Systems (Freeman, 1987; Lundvall, 1992) emphasizes the role of institutions, policies, and interactions among firms, universities, and government bodies in shaping a country's capacity to generate, diffuse, and apply innovations. Innovation performance is thus viewed as a systemic outcome resulting from the coordinated functioning of various components, including R&D investment, human capital, infrastructure, and institutional quality. The NIS framework provides a holistic lens through which the innovation capabilities of countries can be evaluated and compared.

To operationalize and assess innovation performance, international benchmarking tools such as the European Innovation Scoreboard (EIS) and the Global Innovation Index (GII) have been developed. These indices synthesize numerous indicators into composite scores that reflect both the input conditions (e.g., funding, education, research) and output results (e.g., patents, exports, firm innovation) of national innovation systems. While widely used in policy and academic circles, these indices typically provide descriptive rankings rather than analytical insights into how efficiently countries convert innovation inputs into outputs.

To bridge this gap, the present study adopts Data Envelopment Analysis (DEA)—a non-parametric, frontier-based method introduced by Charnes, Cooper, and Rhodes (1978)—as the analytical core of the theoretical framework. DEA is designed to evaluate the relative efficiency of decision-making units (DMUs)—in this case, countries—by comparing the ratio of multiple innovation outputs to multiple inputs. By applying both input-oriented and output-oriented DEA models under the assumption of variable returns to scale (VRS), the study is able to identify countries that lie on the innovation efficiency frontier, as well as those that underperform given their resource endowments.

This dual-framework approach enables a more nuanced interpretation of innovation performance than absolute scores alone. It integrates systemic thinking from NIS theory with methodological rigor from DEA-based efficiency analysis, thus offering a novel contribution to the literature on comparative innovation studies.

In the context of the Visegrad countries – Czechia, Hungary, Poland, and Slovakia – this framework allows for a comprehensive evaluation that accounts not only for their shared historical and institutional legacies but also for the divergence in how effectively each nation utilizes its innovation resources. By combining insights from innovation systems theory and efficiency measurement, the study provides an evidence-based foundation for policy recommendations aimed at improving innovation performance and competitiveness in the region.

Methodology

This study employs a comparative analysis of the innovation performance of the Visegrad Group countries (Czechia, Hungary, Poland, and Slovakia), using data from two internationally recognized innovation indices: the European Innovation Scoreboard (EIS) 2024 published by the European Commission, and the Global Innovation Index (GII) 2024 released by the World Intellectual Property Organization (WIPO). These indices provide harmonized, publicly accessible innovation input and output indicators that enable cross-country comparisons.

From the EIS, four main areas − Framework Conditions, Investments, Innovation Activities, and Impacts −were analyzed. These were further grouped into input and output categories based on the definitions of the GII. Specifically, the Framework Conditions and Investments dimensions were categorized as inputs, while Innovation Activities and Impacts were treated as outputs.

In the case of the GII, innovation performance is divided into two sub-indices: Innovation Inputs and Innovation Outputs, which include a broad set of indicators such as Institutions, Human Capital & Research, Infrastructure, Business Sophistication, Knowledge & Technology Outputs, and Creative Outputs. Country-level data for all EU Member States were extracted from the 2024 editions of the two indices.

To evaluate the efficiency of innovation systems, we applied Data Envelopment Analysis (DEA), a non-parametric linear programming technique widely used for performance benchmarking (Mason & Wagner, 1994). DEA is especially well-suited to evaluate the relative efficiency of decision-making units, which in this case are countries, based on multiple inputs and outputs (Bae et al., 2019).

Two DEA models were applied in the analysis:

1. Input-oriented efficiency model under Variable Returns to Scale (VRS): This model assesses the extent to which a country can reduce its innovation-related inputs while maintaining the current level of outputs (Kočišová, 2015). Efficiency scores in this model range from 0 to 1, where a score of 1 indicates full efficiency−meaning no further input reduction is possible without compromising output levels.
2. Output-oriented efficiency model under VRS: This model evaluates how much a country could potentially increase its innovation outputs using the same level of inputs. A score of 1 indicates full efficiency, whereas values above 1 reflect inefficiency, implying that the country could produce greater innovation outputs without increasing its current level of inputs. Therefore, an output-oriented efficiency score greater than 1 is commonly understood as an indication of inefficiency and can be interpreted as a measure of output-oriented inefficiency.

The efficiency scale is calculated as the ratio of input-oriented to output-oriented efficiency scores. A value <1 indicates that the country is not operating at an optimal scale.

This dual approach enhances the robustness of the analysis and provides nuanced insights into the specific strengths and weaknesses of each country's innovation system. By considering both input and output perspectives, policymakers can better understand the leverage points for improving innovation performance, whether by optimizing resource allocation or enhancing the impact of innovation activities.

The ability of DEA to simultaneously evaluate multiple inputs and outputs renders it a highly effective tool for capturing the complexity of innovation systems (Golany et al., 1990). Moreover, as a non-parametric method, DEA does not require the specification of a functional form between inputs and outputs, allowing the data itself to define the efficiency frontier (Park et al., 2017).

The DEA was conducted separately for the datasets derived from the EIS and the GII, providing two complementary views on the innovation efficiency of EU Member States. Additionally, a scale efficiency score was calculated as the ratio of input-oriented to output-oriented efficiency, highlighting whether countries operate at an optimal scale.

All DEA calculations were carried out using standard linear programming algorithms, and the results were interpreted in the context of the structural characteristics of national innovation systems.

The calculations were performed using the DEA package in R software.

Results and Discussion

In this chapter, the results of the countries are presented only at the level of the dimensions defined in the analyses, while specific indicators within each dimension are highlighted, as these may account for the performance differences between countries. Based on the results of the European Innovation Scoreboard (Table 1), Czechia clearly stands out among the examined countries, outperforming the other three in each of the four main measurement areas.

For the other three countries, the ranking is less straightforward. While Hungary's overall result is better than those of Poland and Slovakia, there are specific areas where it lags behind these countries. In field of Framework Conditions, Hungary surpasses Poland and Slovakia, primarily due to its strong performance in the Attractive Research System and digitalization development.

However, it falls behind in the Human Resources dimension, which is attributable to the poor performance in the Population with tertiary education indicator. For Poland and Slovakia, their performance in the Attractive Research System dimension drags their results down, largely due to weak scores in the Share of Foreign doctorate students indicator.

In the Investments dimension, Slovakia lags behind the other countries, particularly in Finance and support, which is driven by low public sector R&D expenditure, limited Venture Capital Expenditures, and low R&D support. In contrast, Czechia performs favourably in the Innovation activities field, although Poland also achieves strong results here, as reflected in the Intellectual Assets dimension. Poland's positive outcome in this area is largely attributed to its high Design applications value, and it also leads the group in the Trademark applications indicator. Hungary's heterogeneous performance is also notable. Although it performs well in the Linkages dimension − particularly in Public-private co-publications and Job-to-job mobility of HRST (Human Resources in Science and Technology) − its innovation performance among SMEs (notably in business process innovation) lags behind. Additionally, Hungary's low Design Applications value in the Intellectual assets dimension negatively impacts its overall result.

An interesting pattern emerges in the Impacts area, where Slovakia achieves a strong performance despite weaker results in other areas. Two indicators from the Sales impacts dimension (Exports of medium and high technology products and Sales of new-to-market and new-to-firm innovations) stand out, placing Slovakia ahead of the other three countries. In the field of Employment impacts, Czechia stands out among the countries, which is mainly due to the high value of Employment in innovative enterprises.

Table 1. Results of the Visegrad countries based on the dimensions of the European Innovation Scoreboard

	CZ	HU	PL	SK
Framework conditions	**0.413**	**0.344**	**0.313**	**0.327**
Human resources	0.366	0.232	0.351	0.382
Attractive research system	0.361	0.340	0.165	0.223
Digitalisation	0.562	0.518	0.477	0.398
Investments	**0.574**	**0.448**	**0.412**	**0.333**
Finance and support	0.513	0.495	0.376	0.285
Firm investments	0.678	0.414	0.366	0.346
Use of information technologies	0.511	0.428	0.535	0.385
Innovation activities	**0.380**	**0.291**	**0.336**	**0.240**
Innovators	0.497	0.236	0.237	0.237
Linkages	0.323	0.345	0.274	0.206
Intellectual assets	0.358	0.272	0.464	0.276
Impacts	**0.617**	**0.477**	**0.396**	**0.540**
Employment impacts	0.573	0.339	0.334	0.318
Sales impacts	0.667	0.601	0.448	0.648
Environmental sustainability	0.596	0.445	0.384	0.579

Note: The values for each dimension represent the unweighted arithmetic mean of the normalised indicator values. Similarly, the values of the four main areas (Framework conditions, Investments, Innovation activities, Impacts) are calculated as the unweighted arithmetic mean of the normalised dimension values.
Source: calculations based on data from European Commission (2024)

Based on the results of the Global Innovation Index on Innovation Input (Table 2), there is a slight difference between the countries studied. According to the Input Sub-Index, Czechia and Hungary scored better than Poland and Slovakia. One of the strengths of Czechia is its Institutional and Regulatory environment, but it also performs well in the field of Ecological sustainability, which belongs to the Infrastructure pillar. However, the results for Czechia in this Sub-Index are notably hindered by the Market sophistication area, particularly in the dimensions of Credit and Investment.

Hungary's strengths include, for example, the Business sophistication pillar. Within this, the Foreign Direct Investment (FDI) inflows indicator is particularly favourable, placing Hungary at the top among all countries. Additionally, Hungary ranks among the top 10 countries in the Public research-industry co-publications index. Despite these strengths, Hungary's performance in the Investment area under Market Sophistication, similar to Czechia, remains a weakness. This can be attributed to the moderate role of venture capital (VC) in the economy.

In the case of Poland, the standard deviation of values across the Input Sub-Index pillars is the smallest. However, its ranking position varies significantly depending on the pillar. The Institutions and Market sophistication areas are weaknesses for Poland, due to a lack of political stability and underperformance in credit access compared to other countries in the report.

Slovakia achieved the weakest performance in inputs. Its significant lag compared to other countries is apparent

in the fields of education and R&D. Additionally, Slovakia underperformed in the field of Innovation linkages within the Business sophistication pillar, mainly due to insufficient cooperation and joint initiatives among economic actors.

Based on the Innovation Output Sub-Index results, Czechia's advantage over the other countries becomes significant. This superiority is primarily due to its high level of Knowledge diffusion.

Table 2. Results of the Visegrad countries based on the dimensions of the Global Innovation Index

	CZ	HU	PL	SK
Innovation input	**47.56**	**45.31**	**40.98**	**39.04**
Institutions	67.46	52.18	44.92	47.84
Human capital and research	43.69	42.95	42.63	34.64
Infrastructure	54.04	51.05	45.77	47.94
Market sophistication	30.09	34.05	33.55	32.24
Business sophistication	42.52	46.30	38.01	32.52
Innovation output	**40.52**	**33.84**	**33.03**	**29.58**
Knowledge and technology outputs	42.71	35.58	28.01	31.40
Creative outputs	38.34	32.09	38.06	27.77

Note: The values of the two Sub-Indices (Innovation input, Innovation output) represent the unweighted arithmetic mean of their respective dimensions.
Source: WIPO (2024)

The DEA (Data Envelopment Analysis) results for EU countries, based on the European Innovation Scoreboard (EIS) 2024 and Global Innovation Index (GII) 2024, assess efficiency by analyzing innovation input and output scores.

Countries with a DEA efficiency score of 1.000−calculated as the ratio of input-oriented to output-oriented efficiency based on EIS 2024 data−serve as benchmarks, representing the optimal transformation of innovation inputs into outputs. These countries include Bulgaria, Cyprus, Denmark, Italy, and Romania (Table 3).

Countries with lower input-oriented efficiency scores demonstrate inefficient use of innovation inputs. Portugal (0.526) is the least efficient, indicating that its innovation investments yield disproportionately low outputs. Similarly, Spain (0.570), France (0.618), and Sweden (0.622) exhibit low efficiency, suggesting the need for improved resource utilization.

Countries with higher output-oriented efficiency scores (>1.0) exhibit greater inefficiencies in generating innovation output. Portugal (1.697) and Hungary (1.492) have the highest inefficiency, indicating that their innovation outputs are not proportional to their investments.

Some countries demonstrate moderate input efficiency and reasonable output efficiency, meaning they are neither fully efficient nor highly inefficient. Examples include Germany (0.829 input-, 1.046 output-oriented efficiency), Finland (0.662 input-, 1.057 output-oriented efficiency), and Ireland (0.764 input-, 1.075 output-oriented efficiency). These countries maintain a relatively balanced innovation ecosystem, where innovation inputs and outputs are more proportionally aligned.

Among the Visegrad countries, Slovakia performs the best in terms of DEA efficiency. With an input-oriented efficiency score of 0.806, it is closer to the efficient frontier compared to the other three. Although the output-oriented score of 1.227 still reflects inefficiencies in innovation output generation, Slovakia's relatively higher efficiency scale (0.657) indicates moderately balanced input-output relationships, making it the most efficient innovator within the group. Hungary and Poland face the greatest challenges, especially in converting innovation inputs into tangible outputs. Hungary has an input-oriented efficiency score of 0.656 and a high output-oriented inefficiency score of 1.492, while Poland scores 0.683 on input efficiency and 1.436 on output efficiency − both ranking among the lowest in the EU. Czechia performs slightly better, with an input-oriented efficiency of 0.696, but it also struggles with high output inefficiency, reflected in its output-oriented score of 1.356.

The Visegrad countries, as a group, underperform relative to the EU-27 average in innovation efficiency. Slovakia is the only country in the group approaching EU average efficiency, making it a regional benchmark.

Table 3. DEA Efficiency Results Based on Innovation Input and Output Scores from EIS 2024

Country	Input-oriented efficiency	Rank	Output-oriented efficiency	Rank	Efficiency scale	Rank
Austria	0.767	13	1.053	8	0.728	8
Belgium	0.688	18	1.061	10	0.649	13
Bulgaria	1.000	1	1.000	1	1.000	1
Croatia	0.791	11	1.250	19	0.633	14
Cyprus	1.000	1	1.000	1	1.000	1
Czechia	0.696	17	1.356	22	0.513	21
Denmark	1.000	1	1.000	1	1.000	1
Estonia	0.649	22	1.235	18	0.526	20
Finland	0.662	20	1.057	9	0.626	15
France	0.618	25	1.278	21	0.484	23
Germany	0.829	7	1.046	7	0.792	7
Greece	0.984	6	1.015	6	0.970	6
Hungary	0.656	21	1.492	25	0.440	25
Ireland	0.764	14	1.075	12	0.711	9
Italy	1.000	1	1.000	1	1.000	1
Latvia	0.774	12	1.272	20	0.608	17
Lithuania	0.698	16	1.373	23	0.508	22
Luxembourg	0.699	15	1.130	14	0.619	16
Malta	0.813	8	1.193	15	0.682	10
Netherlands	0.639	23	1.089	13	0.587	18
Poland	0.683	19	1.436	24	0.475	24
Portugal	0.526	27	1.697	27	0.310	27
Romania	1.000	1	1.000	1	1.000	1
Slovakia	0.806	9	1.227	17	0.657	12
Slovenia	0.800	10	1.201	16	0.666	11
Spain	0.570	26	1.520	26	0.375	26
Sweden	0.622	24	1.062	11	0.585	19

Source: authors' calculations based on innovation input and output scores from EIS 2024

Countries with an input-oriented efficiency of 1.000 and an output-oriented efficiency of 1.000 based on GII 2024 innovation input and output scores achieve an efficiency scale of 1.000, making them benchmark performers. These countries – Bulgaria, Cyprus, Germany, Romania, and Sweden – effectively convert innovation inputs into outputs and operate at an optimal scale (Table 4).

Countries with low input-oriented efficiency scores (below 0.8) demonstrate inefficient utilization of innovation inputs, indicating that they do not effectively leverage their innovation resources. Notable examples include Estonia (0.764, ranked 27th), Austria (0.772, ranked 26th), Luxembourg (0.774, ranked 25th), and Lithuania (0.777, ranked 24th). To enhance innovation performance, these countries should focus on optimizing resource allocation and improving input management to achieve better output conversion.

Countries with high output-oriented efficiency scores (>1.3) demonstrate significant inefficiencies in generating innovation outputs, indicating that their current innovation efforts do not fully translate into measurable results. Notable examples include Lithuania (1.525, ranked 27th), Latvia (1.504, ranked 26th), Slovenia (1.394, ranked 25th), and Hungary (1.312, ranked 24th). A higher output-oriented efficiency score suggests that these countries have the potential to increase innovation output without requiring additional inputs, highlighting inefficiencies in their innovation performance.

A moderate balance between input and output efficiency (scores around 0.8–0.9) reflects relatively effective innovation performance. Countries such as Italy (0.966 input-, 1.016 output-oriented efficiency), Netherlands (0.957 input-, 1.029 output-oriented efficiency), France (0.937 input-, 1.057 output-oriented efficiency), and Slovakia (0.966 input-, 1.176 output-oriented efficiency) demonstrate a well-structured innovation ecosystem, where innovation investments and outputs are proportionally aligned.

Table 4. DEA Efficiency Results Based on Innovation Input and Output Scores from GII 2024

Country	Input-oriented efficiency	Rank	Output-oriented efficiency	Rank	Efficiency scale	Rank
Austria	0.772	26	1.257	20	0.614	22
Belgium	0.784	23	1.262	22	0.621	21
Bulgaria	1.000	1	1.000	1	1.000	1
Croatia	0.925	11	1.251	18	0.739	13
Cyprus	1.000	1	1.000	1	1.000	1
Czechia	0.888	13	1.142	10	0.777	11
Denmark	0.832	20	1.150	11	0.723	16
Estonia	0.764	27	1.254	19	0.609	24
Finland	0.842	17	1.128	9	0.746	12
France	0.937	10	1.057	8	0.886	8
Germany	1.000	1	1.000	1	1.000	1
Greece	0.924	12	1.262	21	0.732	14
Hungary	0.856	15	1.312	24	0.653	20
Ireland	0.829	21	1.170	12	0.709	17
Italy	0.982	6	1.016	6	0.966	6
Latvia	0.851	16	1.504	26	0.566	26
Lithuania	0.777	24	1.525	27	0.510	27
Luxembourg	0.774	25	1.264	23	0.612	23
Malta	0.833	18	1.214	16	0.687	18
Netherlands	0.957	8	1.029	7	0.930	7
Poland	0.942	9	1.179	15	0.799	10
Portugal	0.832	19	1.229	17	0.677	19
Romania	1.000	1	1.000	1	1.000	1
Slovakia	0.966	7	1.176	14	0.821	9
Slovenia	0.816	22	1.394	25	0.585	25
Spain	0.858	14	1.175	13	0.730	15
Sweden	1.000	1	1.000	1	1.000	1

Source: authors' calculations based on innovation input and output scores from GII 2024

Based on the GII, Slovakia and Poland lead the Visegrad group in terms of DEA-measured innovation efficiency, indicating that their systems effectively utilize resources and maintain a good balance between input and output. Slovakia achieved an input-oriented efficiency score of 0.966, an output-oriented score of 1.176, and an efficiency scale of 0.821, the highest among the Visegrad countries. Similarly, Poland recorded a strong input efficiency of 0.942, with an output efficiency of 1.179 and a scale efficiency of 0.799, reflecting a stable and relatively efficient innovation system.

Czechia follows closely, with an input efficiency of 0.888, output efficiency of 1.142, and efficiency scale of 0.777, suggesting good performance overall but still some room for improving output generation, particularly in turning inputs into high-impact innovation results.

Hungary, on the other hand, lags behind its Visegrad peers, with an input-oriented efficiency of 0.856, a notably high output-oriented inefficiency score of 1.312, and a low efficiency scale of 0.653. This highlights significant shortcomings in converting innovation investments into measurable outputs and signals the need for targeted policy interventions to enhance commercialization, knowledge transfer, and innovation productivity.

Slovakia and Poland lead the Visegrad region in DEA-based innovation efficiency and both exceed the EU average in input utilization. Czechia remains a moderately efficient innovator, with good input efficiency but modest output performance, suggesting opportunities for enhancement in innovation impact and diffusion. Hungary underperforms in both models, indicating structural inefficiencies and a need for policy reforms to strengthen the conversion of innovation efforts into tangible results.

There is a general positive correlation between efficiency scores in EIS 2024 and GII 2024 (Fig. 1), meaning that countries efficient within the EU tend to perform well globally. However, some discrepancies exist, where certain countries are more efficient within the EU framework (EIS) but less efficient in a global comparison (GII), and vice versa.

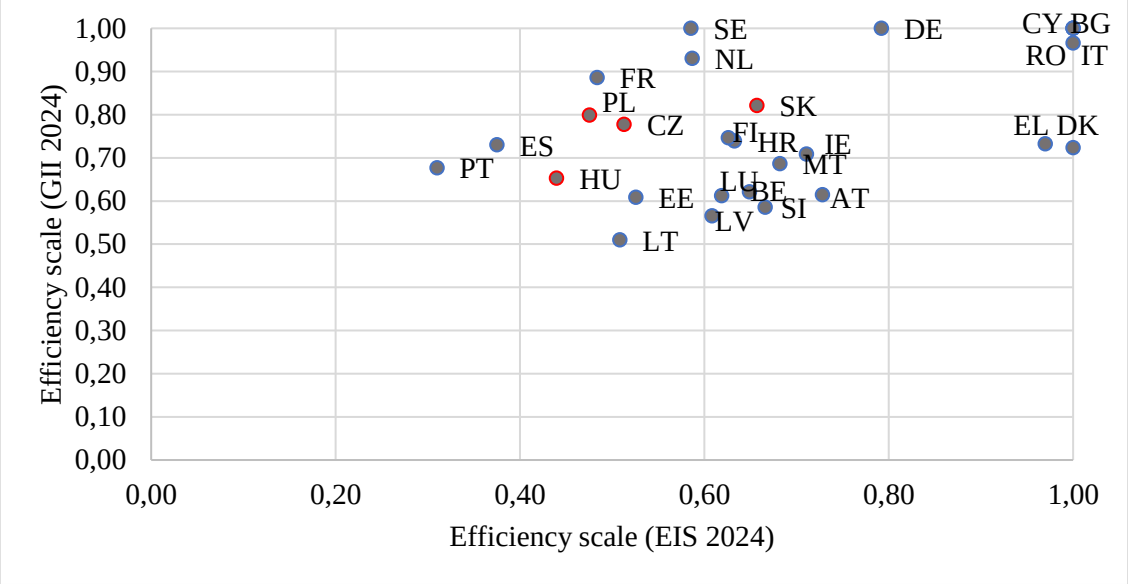

Fig. 1. Relationship Between Efficiency Scores Based on EIS 2024 and GII 2024
Source: authors' calculations based on innovation input and output scores from EIS 2024 and GII 2024

Benchmark Countries (Top-Right Quadrant) such as Cyprus (CY), Bulgaria (BG), Romania (RO), and Italy (IT) achieved an efficiency scale of 1.00 in both EIS 2024 and GII 2024. These countries are considered fully efficient in both models, meaning they optimally convert innovation inputs into outputs across both innovation measurement frameworks.

Denmark (DK) and Greece (EL) have a high-efficiency scale in EIS 2024 (close to 1.00) but a lower efficiency scale in GII 2024. This suggests that while these countries perform well in innovation efficiency according to EIS 2024, they exhibit lower efficiency in the global innovation context as per GII 2024.

Germany (DE), Sweden (SE), and the Netherlands (NL) have high-efficiency scores in GII 2024 but moderate efficiency in EIS 2024. This implies that these countries are efficient from a global innovation perspective but face some inefficiencies when measured within the EU framework.

Slovakia is the best-performing Visegrad country in terms of combined innovation efficiency. Its high efficiency score based on the GII (0.821) indicates that Slovakia is highly effective at converting innovation inputs into outputs on a global scale. While its EIS efficiency score is somewhat lower (0.657), it still surpasses the other Visegrad countries, reflecting strong innovation efficiency in both regional and international contexts.

Poland shows stronger innovation efficiency globally than within the EU. This may suggest that Poland's innovation outputs are better recognized or measured in the broader global context, possibly due to structural differences in the GII methodology. However, the lower EIS efficiency indicates potential weaknesses in how innovation policies function within the EU framework.

Conclusions

The DEA results reveal significant disparities in innovation efficiency across EU countries. Some countries (Bulgaria, Cyprus, Germany, Italy, Romania, and Sweden) efficiently utilize innovation inputs, while others exhibit inefficiencies in resource allocation or output generation.

Certain countries (Croatia, Latvia, Lithuania, Slovakia, Slovenia) perform well in input-oriented efficiency but lag in output efficiency, indicating a need to enhance the effectiveness of innovation investments. Conversely, countries with high output inefficiencies have untapped potential to increase innovation output without additional resources.

The comparison of DEA results based on EIS 2024 and GII 2024 highlights that some countries (Denmark, Greece) are efficient in an EU context but less competitive globally, while others (Germany, Sweden, and the Netherlands) perform well on a global scale despite inefficiencies within the EU framework.

The DEA analysis provides valuable insights into the efficiency of national innovation systems. Policymakers should leverage these findings to enhance innovation performance, close efficiency gaps, and strengthen competitiveness both within the EU and globally.

The DEA-based analysis of innovation performance, using input and output data from both the European Innovation Scoreboard (EIS) 2024 and the Global Innovation Index (GII) 2024, reveals significant differences in innovation efficiency among the Visegrad Group countries – Czechia, Hungary, Poland, and Slovakia.

Slovakia emerges as the most efficient innovator in the group. It demonstrates strong input-oriented efficiency in both indices (0.806 in EIS and 0.966 in GII), coupled with

relatively moderate output inefficiency, resulting in the highest efficiency scale among the four countries (0.657 in EIS and 0.821 in GII). These findings indicate that Slovakia not only utilizes its innovation inputs effectively but also operates at a near-optimal scale. This aligns with earlier findings by Hudec & Prochádzková (2015), who also identified high regional efficiency in several Slovak and Polish regions, particularly in terms of patent outputs relative to R&D expenditures.

Poland shows a mixed profile: while it lags in terms of raw innovation output (as seen in the GII and EIS rankings), it ranks second in DEA efficiency among the V4, with strong input-oriented scores (0.683 in EIS and 0.942 in GII). This suggests that Poland manages its innovation resources efficiently, though the quality or economic impact of its outputs may be lower. This corresponds with the findings of Kowalski et al. (2023), who emphasized the importance of improving the linkages between business and science to enhance innovation effectiveness in Poland.

Czechia performs well in absolute innovation rankings and shows balanced but moderate efficiency in DEA results (0.696 input efficiency in EIS, 0.888 in GII). However, it exhibits noticeable output inefficiency (1.356 in EIS and 1.142 in GII), indicating that despite having a solid innovation infrastructure, the country is not fully translating inputs into high-impact results. Previous research, including Ivanová and Žárská (2023), highlights that sub-indicator dynamics – such as R&D spending efficiency – are often underexplored, and Czechia might benefit from such micro-level adjustments to enhance performance.

Hungary consistently ranks as the least efficient Visegrad country in both DEA models. It shows low input efficiency (0.656 in EIS, 0.856 in GII) and very high output inefficiency (1.492 in EIS, 1.312 in GII), resulting in the lowest efficiency scale scores (0.440 and 0.653). These findings suggest serious structural inefficiencies in Hungary's innovation system, particularly in converting inputs (e.g., funding, infrastructure) into outputs such as patents, high-tech exports, or innovation-driven growth. This is consistent with Jabłońska (2020), who reported low innovation potential in Hungarian regions despite moderate levels of investment, and with Hintošová et al. (2020), who found that only outward foreign direct investment showed a meaningful contribution to innovation performance, suggesting limited domestic innovation dynamics

Limitations

The DEA results are highly sensitive to the chosen innovation input and output indicators from GII 2024 and EIS 2024. Alternative input-output combinations could lead to different efficiency rankings. Aggregated innovation input and output scores mask variations within individual components, making it difficult to identify which specific factors (e.g., R&D expenditure, human capital, patents) drive efficiency or inefficiency. Countries with different innovation structures, industries, or policy frameworks are evaluated on a single efficiency scale, which may not fully capture the nuances of their innovation ecosystems.

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