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COST CALCULATIONS IN THE CONSTRUCTION SECTOR: EVIDENCE FROM THE SLOVAK REPUBLIC AND THE CZECH REPUBLIC

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Abstract. Ensuring the company's competitiveness in globalised economies requires a dynamic (flexible) costing system. The objective of this paper is to evaluate the use of costing methods in businesses in the construction industry, to identify the degree of use of the Activity Based Costing (ABC) method in practice, to evaluate the appropriateness of costing methods for use in businesses in the construction sector and to make recommendations. For analysis, we used the Chi-squared test, the Chi-squared data distribution test, the Wilcoxon paired test and the Mann-Whitney U-test. Using analysis, we found that 36.7% of all the studied businesses use the ABC method. We quantified the level of doubt among managers about the suitability of the ABC method for construction companies. Through analysis, we found that managers of construction companies are mainly concerned that project implementation would be highly time-consuming. Management's doubts about the project's contribution to the business are a less compelling reason for not using ABC in practice. Managers of companies operating in Slovakia are more convinced of the unsuitability of this method for their company than companies operating in the Czech Republic. In conclusion, we make a recommendation for practice in construction companies; we recommend implementing the ABC method, especially in medium-sized enterprises. The analysis was carried out in the Slovak and Czech Republics. However, the analytical conclusions can also be applied in other European countries, especially countries with a similar history, a similar type and state of the economy, and a similar mentality of managers and people.

Keywords: activity-based costing (ABC); margin-based costing; construction sector

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1. Introduction

The cost accounting system in a construction company must contribute to the most thorough analysis of operational data on costs, their structure and types, and classification by particular buildings, responsibilities, and places of origin (Gerasimova, 2020; Al Amri & Marey-Perez, 2020).

The construction industry needs innovative technologies due to its complex and dynamic nature (Demirkesen & Tezel, 2021). In construction, the prime concern of project organisations is how to strike a balance between the optimal level of quality and the associated costs (Shafiei et al., 2020). The lack of a standardised approach, expertise, and reliable data are considered to be the most significant obstacles (Manege & Kennedy, 2020).

However, it is essential to achieve sustainable competitive advantages in the construction industry (Tam et al., 2021). Sustainability in the construction sector can be seen in many areas. A sustainable supply chain and cost management are two aspects. Cost and supply chain management influence the overall success of

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construction projects. Sustainability is based on reducing costs and, thereby, material items. Information technology and promising management approaches can significantly help supply chain and cost management (Mandicak et al., 2021).

Based on the above, we decided to discover the rate of use of more accurate costing methods in the construction industry, the attitudes of managers towards cost calculation methods, evaluate the perception of doubt about the suitability of the activity-based costing (ABC) method for construction companies and then make recommendations and suggestions for practice.

2. Theoretical background

Given the high level of competition among companies in the market and the demand on the part of consumers for quality products, companies need to gain more control over production processes and the costs of these processes (Braga et al., 2021; Maâlej, 2022; Nguyen et al., 2024). Knowledge and use of appropriate costing methods can be an advantage over competitors. Small and medium-sized businesses face increasing pressure to keep going in a highly competitive environment. These businesses are primarily unable to adopt newer management accounting practices and adapt to the changing business scenario. Manufacturers must act as custodians of their assets, knowing the strengths and weaknesses in their production systems (Araujo et al., 2020). Costs and budget calculations in the construction industry are an ever-known and controversial topic (Shaikh et al., 2020). It is, therefore, essential to use cost control and reduction techniques effectively in the construction industry (Oyegoke et al., 2021).

The construction technology has several specifics that influence the organisation of analytical and synthetic accounting for business entities. The high level of competition and the search for reserves to reduce the cost of construction products and increase profitability require information on the actual levels of costs and the rationality of using different resources. The management of construction costs should form an essential part of the management system of a construction company (Bozgulova et al., 2019).

High competition in the industry forces companies to have a new cost calculation focusing on the company's profit. The problem in practice is that production costs are not calculated accurately. The study results show that in the traditional system, there is unused capacity and distortion of the cost of each product. A comparison of the actual and planned costs of goods manufactured shows an increase of 1%. Based on the projected costs of goods manufactured, the company can determine the offer price according to the required profit. Thus, the analysis of the actual and planned costs of goods sold using activity-based costing can be used both as a financial reporting tool and an effective management tool (Pratiwi et al., 2024).

The activity-based costing system (ABC) has emerged as a method of cost calculation that can overcome the limitations of traditional costing systems in light of economic and technological developments, eliminating the arbitrary and inaccurate allocation of indirect costs. In the current context, developing an adequate cost system in organisations is extremely important because they feel the need to properly manage the resources at their disposal and control their costs to achieve efficient and effective management (Quesado & Silva, 2021).

Volatility, uncertainty, complexity and ambiguity are four aspects that generally describe today's world and the unique challenges of manufacturing companies. Increasing volatility requires rapid innovation cycles, while uncertainty and ambiguity prevent companies from knowing what customers really want. Many products and product options are being developed and offered to the market to anticipate possible future requirements. Increasing complexity leads to increasing effort and, therefore, costs of product implementation, especially in indirect areas (overheads) that cannot be correctly attributed to the product that induced the overhead. This is mainly due to the shortcomings of commonly used costing systems (Riesener et al., 2021).

In practice, the potential of the cost strategy - activity-based costing (ABC) still needs to be addressed despite research demonstrating its importance for the competitiveness of businesses in the sector (Sorros et al., 2021).

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Among the main reasons for low operational efficiency (loss, low profit) are outdated management methods and low cost-effectiveness. Applying the ABC method improves business performance. If businesses use the ABC costing method, their performance will improve significantly (van Tran & Nguyen Thao, 2020).

Promoting ABC implementation can help manufacturing companies develop steadily and sustainably and continuously improve their position and company performance. Research recommends that business managers pay more attention to the application of modern management methods, especially ABC. In addition, business managers should pay greater attention to environmental uncertainties caused by suppliers, competitors, customers and other factors. All these factors influence company performance through their impact on implementing ABC, which impacts company performance (Pham et al., 2021).

For the system to be effective, managers must ensure the cooperation of departments and staff involved in the design and implementation of ABC (Vetchagool et al., 2021). It is essential to simultaneously involve accountants in the design of the product costing system. The involvement of accountants in the design of the costing system is vital to implementing ABC, thereby increasing the quality of the cost system created. In practice, there is a positive relationship between product diversity and the need to adopt Activity Based Costing. The ABC method significantly impacts the importance and accuracy of the product cost data collected. In addition, high product diversity has been identified as a significant negative predictor of ABC adoption (Mazbayeva et al., 2022).

Traditional management accounting practices include systems for costing, budgeting, performance measurement, and decision-making. The accounting practices of modern (strategic) management include activity-based management, competitive analysis, industry analysis, long-term forecasting, value chain analysis, target cost calculation, and overall quality management (Chandrarin & Zuhroh, 2021).

The ABC method is used as a cost allocation technique due to its better ability to determine the exact overheads based on the volume of resources consumed for each particular activity compared to the traditional costing method. It eliminates the inaccuracies and shortcomings of the traditional costing system. Compared to other costing methods, it significantly changes, in particular, how indirect costs are allocated to activities based on actual causes and, consequently, the allocation of activities to the cost items themselves according to the consumption intensity (Stopka et al., 2021).

The use of ABC, in combination with additional information from management accounting, enables verification of results for each stage of the production process and provides essential information for decision-making (Gonçalves & Moreira, 2021). It offers comprehensive information on every commercial level about all the attributes of the product, thereby contributing to cost management and optimal resource use (Azeez et al., 2020), assisting in decision-making (Ganorkar et al., 2020), and providing relevant information on costs for businesses (Sánchez et al., 2020).

A Greek study (Alexopoulou et al., 2024) examined the extent to which fundamental factors such as the structure, complexity and utility of a cost system influence the design of cost systems and the resulting satisfaction and help companies make the right decisions. The findings revealed that the structure and utility of a cost system, but not its complexity, significantly affect the satisfaction of users who are forced to make quick and correct decisions. The results show a positive correlation between user satisfaction with a cost system and the extent of information, the provision of accurate information, and the quality of information. The more competition affects a company's pricing policy, the more the company seeks systems that categorise costs based on behaviour (structure) and greater cost allocation (complexity). The larger the company, with a long (> 20 years) and international presence, the higher the likelihood that the company will have a system with a more detailed cost information structure.

Using the ABC method can reduce additional costs and has a solid and essential impact on decision-making on the product mix (Mohsin et al., 2021). ABC increases transparency in cost accounting (Schuh et al., 2021). A business can improve its decisions by allocating the indirect costs of its products more effectively, thereby eliminating the distortions present in the scheduling base when using the traditional method (Braga et al., 2021).

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Newer accounting and costing systems enable managers to track resource cost flows accurately. They provide accurate information on the use of resources and identify excess or unused capacities of such resources (Jassem, 2019).

ABC is an alternative method to overcome the limitations of traditional indirect cost systems, which distort actual cost accounting. The ABC system is adequate for determining actual costs and can bring more reasonable and competitive prices to the market. However, there is still resistance to its implementation due to human and technological ignorance (Escobar-Mamani et al., 2021).

Activity-based costing has advantages, including improving the management of activities, processes, and the chain of activities. As an important cost management tool in management accounting, ABC extends cost management across the entire value chain. In this way, the business will receive adequate assistance in establishing systematic cost management (Zhang & Li, 2021).

A study conducted in industrial (specifically foundry) production (Zavrbska & Besta, 2024) confirms that the main benefit of implementing the ABC method is the accurate allocation of costs to activities, which allows for a better understanding of the economic efficiency of processes. The ABC method opens up new possibilities for data automation and optimisation of production and logistics processes through digital technology, contributing to modernising production management.

Businesses make rational decisions about implementing ABC. In cases where the problems perceived during implementation are relatively small, the company will adopt ABC. Conversely, when a company perceives implementation problems as quite compelling, it rejects implementation (Pietrzak et al., 2020).

Managers are willing to use ABC as a costing strategy if they perceive it as providing accurate information for decision-making, indicating its potential to increase cost efficiency, competitiveness, performance, and firm survival. ABC is a proper costing technique for leveraging cost efficiency, competitiveness, and high performance, even for startups (Daowadueng, 2024).

Activity-based or process costing allocates costs to products, especially indirect costs and overheads. Because the required data for the cost model must be collected manually, existing approaches are significantly time-consuming and costly and do not represent the current state of costs. Increasing digitisation and increasing use of business information systems in businesses provide new opportunities for faster collection of cost-relevant data and improve the timeliness of costing (Riesener et al., 2019). The trend of information technology in construction requires automation and digitalisation of all activities, including cost optimisation, for a better level of work by construction professionals and the efficient implementation of contracts (Igwe et al., 2020).

The rapid development of production processes in industry requires systems capable of quickly adapting to dynamic market conditions and evolving customer needs. Manufacturing emphasises flexibility, adaptability, and real-time responsiveness, which poses challenges in analysing cost flows and production times. A two-stage approach using an activity-based costing mechanism addresses these challenges well. It enables real-time cost accounting and decision-making, unlike traditional methods that rely on historical data. The authors validated this approach in a study. The results demonstrate the effectiveness of the proposed method in providing a detailed overview of costs and production times, thereby increasing the efficiency and competitiveness of manufacturers (Javed et al., 2025).

3. Research methodology

This paper aims to assess the use of costing methods in companies in the construction sector in the Slovak Republic and the Czech Republic in comparison with each other and, based on the findings, to make recommendations, assess the level of use of the margin-based (traditional) costing method and the Activity Based Costing method, to evaluate managers' awareness of the advantages and disadvantages of both approaches and evaluate the suitability of the costing methods for practice in businesses in the construction

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sector. We chose the construction industry for the analysis because it is an essential sector of the economy; it is not dependent on the economic cycle, and in the event of a crisis, it could help stabilise the situation.

We performed the analysis on Slovak companies, and for comparison, we chose companies in the Czech Republic. The reason was the historical and cultural proximity of the countries, but especially the linguistic proximity, which is essential for data acquisition. However, the outputs can also be applied to other European countries, especially Eastern and Central Europe.

To meet the stated objective, we set out the following research questions and hypotheses:
Research questions:
RQ1: What costing methods do businesses operating in the construction sector use? How many companies use the ABC method?
RQ2: Are managers convinced of the suitability of the current costing method? Do they doubt the suitability of other methods?
RQ3: Why do some businesses consciously reject more modern, more accurate methods and remain with traditional cost calculations?

Hypotheses:
H1: We expect that there are statistically significant differences between the two countries analysed in the types of costing methods used.
H2: The most common reason for not using the ABC method is doubt about the suitability of this method for construction companies.
H3: Levels of doubt about the suitability of the ABC costing method vary by country.

The material for the analysis is the data obtained by a questionnaire survey accompanied by data from relevant published materials from a sample of 150 companies operating in the construction sector, of which 80 are businesses operating in the Slovak Republic, and 70 are businesses operating in the Czech Republic.
In the questionnaire, we looked at:
The division of enterprises by size (micro, small, medium-sized, and large). In the selected sample of businesses, we included companies focused on building construction, civil engineering works, and specialised construction works, which must be part of the construction processes.

In particular, we looked at data on: the types of costing methods that are currently used by construction businesses in practice, the reason for not using the ABC method (for those construction companies that do not use or plan to introduce this method) – we offered reasons for the choice: we do not know the ABC method, the ABC method is not suitable for our company, the expectation that implementation of the ABC project would be highly time-consuming, management doubts about the contribution of the project to the company, the natural resistance of employees to change, benefits obtained by the introduction of the ABC method.

Given the established hypotheses and nature of the data, we used the Chi-squared Test, the Chi-squared Data Distribution Test, the Wilcoxon Paired Test, and the Mann-Whitney U-Test for two independent selections for statistical analysis. We used each of these tests for individual hypotheses based on the nature of the specific data appearing for the given hypothesis. We carried out statistical analysis in the programme SPSS 22.

4. Research results and discussion

The sample consisted of 150 respondents. Of these, 80 companies in Slovakia represented 53.3%, and 70 in the Czech Republic represented 46.7% of the entire sample.

The largest group in the sample regarding company size were medium-sized enterprises, which accounted for 43.3 % of the sample. Conversely, the most minor numerous groups were microenterprises, accounting for only 12.7% of the sample.

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Table 1. Distribution of the sample by country of operation

Country	Number	Percentage
Slovak Republic	80	53.3
Czech Republic	70	46.7
Total	150	100.0

Source: own research

Table 2. Distribution of the sample by size of the company

Size of the company	Number	Percentage
Micro enterprises	19	12.7
Small enterprises	44	29.3
Medium-sized enterprises	65	43.3
Large enterprises	22	14.7
Total	150	100.0

Source: own research

H1 We expect that there are statistically significant differences between the two countries analysed in the types of costing methods used.

Table 3. Costing methods used

Country	Costing method used			
	Margin based costing	**Variable costing method**	**Activity-based costing**	**Total**
Slovak Republic	49	3	28	80
Czech Republic	38	5	27	70
Total	87	8	55	150

Source: own research

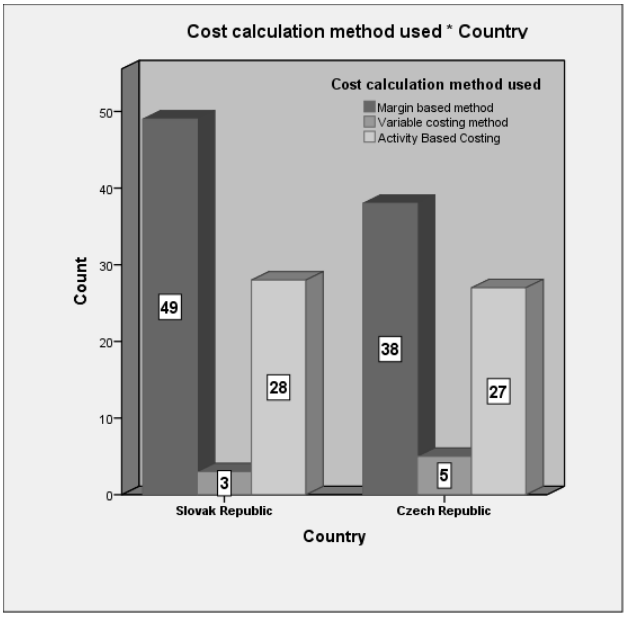


Fig. 1. The cost calculation method used
Source: own research

Based on the results in Table 3 and Figure 1, margin-based costing is the method used most often in both countries.

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For the correct selection of the test for hypothesis 1, it is necessary to test the normality of the distribution of the variables represented in the sample. This means whether the test data has a Gauss curve distribution or not. Due to the nature of the variables, we will use non-parametric tests to test hypothesis 1.

For hypothesis 1, we examined whether there was a statistically significant difference in using the costing method in the country of operation. After considering the variables' nature, we used the non-parametric Chi-squared test to analyse the hypothesis.

Table 4. Chi-squared test

Chi-squared test	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.248	2	0.536
Likelihood Ratio	1.251	2	0.535
Linear-by-Linear Association	0.457	1	0.499
N of Valid Cases	150		

Source: own research

If the value in the Pearson Chi-squared row in the Asymp Sig. Column (2-sided) is less than 0.05; we know that there is a statistically significant difference between the groups. In this case, the value is 0.536. Based on the results presented in Table 4, no statistically significant difference exists between businesses in Slovakia and the Czech Republic regarding using costing methods.
Hypothesis 1 was not confirmed.

H2 We expect that statistically significantly the most common reason for not using the ABC method is doubting the suitability of this method for construction companies.

Table 5. Reasons for not using the ABC method

Reason for not using the ABC method	Response	Number	Percentage
ABC method is not suitable for our company	Rather yes	30	46.2
	Certainly yes	35	53.8
	Total	65	100.0
Assumption of extended time for implementation of the entire project	Rather yes	27	41.5
	Certainly yes	38	58.5
	Total	65	100.0
Management doubts about the benefits of the project for the company	Rather yes	33	50.8
	Certainly yes	32	49.2
	Total	65	100.0
Natural resistance of employees to change	Definitely not	5	7.9
	Rather not	18	28.6
	Rather yes	40	63.5
	Total	63	100.0

Source: own research

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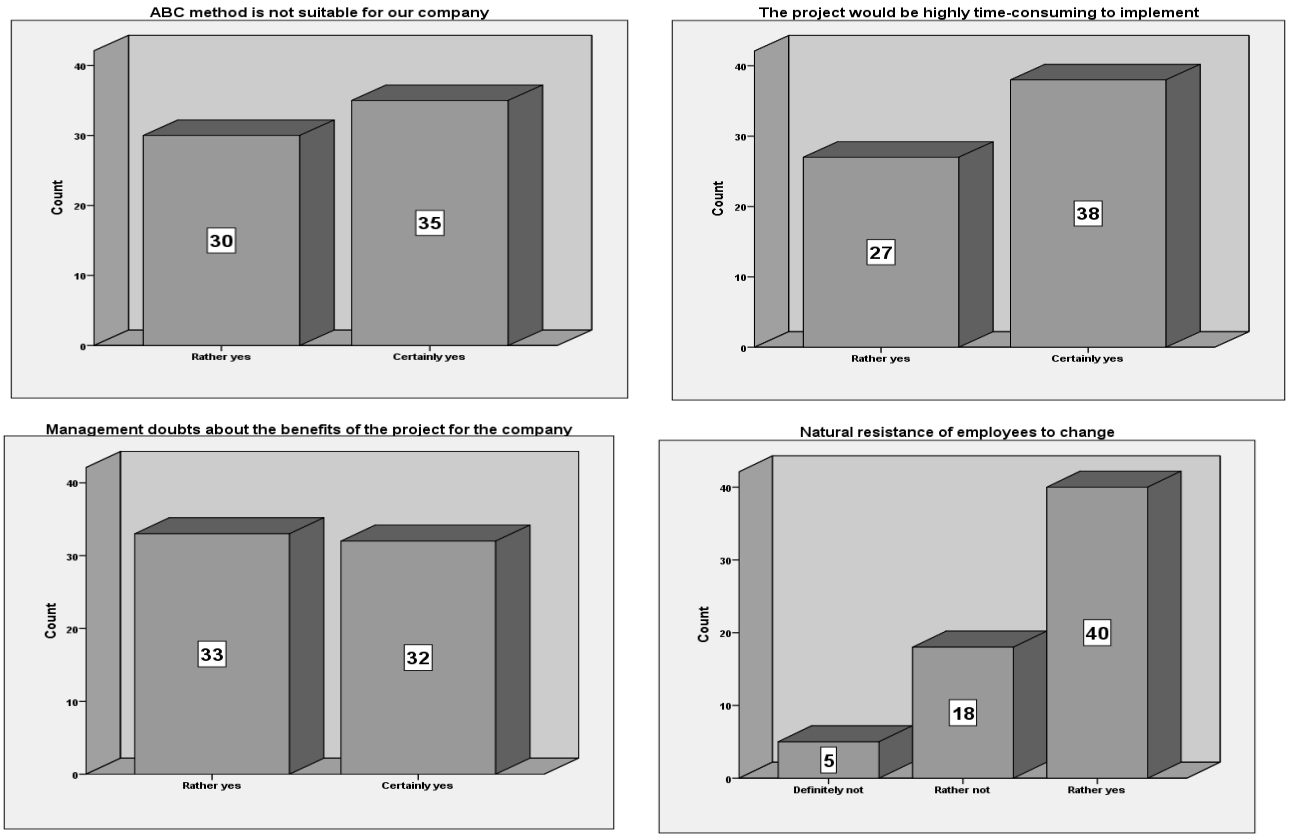


Figure 2. Reasons for not using the ABC method
Source: own research

Based on the results presented in Table 5 and Figure 2, the fewest respondents think that their most significant reason for not using the ABC method is the natural resistance of employees to change.

Based on the nature of the variables, we will use non-parametric tests to test hypothesis 2.

For hypothesis 2, we determine whether there is a statistically significant difference between the reasons for not using the ABC method. Considering the nature of the variables, we analysed the hypothesis using the non-parametric Wilcoxon paired test.

Table 6. Wilcoxon paired test

Wilcoxon paired test	Reasons for not using the ABC method	Pairs	Ranks	N	Mean Rank	Sum of Ranks
Z Asymp. Sig. (2-tailed)	-0.832 0.405	The project would be highly time-consuming to implement - ABC method is not suitable for our company	Negative Ranks	5	7.00	35.00
			Positive Ranks	8	7.00	56.00
			Ties	52		
			Total	65		
Z Asymp. Sig. (2-tailed)	-0.688 0.491	Management doubts about the benefits of the project for the company - ABC method is not suitable for our company	Negative Ranks	11	10.00	110.00
			Positive Ranks	8	10.00	80.00
			Ties	46		
			Total	65		
Z Asymp. Sig. (2-tailed)	-6.257 0.000	Natural resistance of employees to change - ABC method is not suitable for our company	Negative Ranks	47	24.00	1128.00
			Positive Ranks	0	0.00	0.00
			Ties	16		
			Total	63		
	-2.449		Negative Ranks	6	3.50	21.00

Z Asymp. Sig. (2-tailed)	0.014	Management doubts about the benefits of the project for the company - The project would be highly time-consuming to implement	Positive Ranks	0	0.00	0.00
			Ties	59		
			Total	65		
Z Asymp. Sig. (2-tailed)	-6.290 0.000	Natural resistance of employees to change - The project would be highly time-consuming to implement	Negative Ranks	48	24.50	1176.00
			Positive Ranks	0	0.00	0.00
			Ties	15		
			Total	63		
Z Asymp. Sig. (2-tailed	-6.132 0.000	Natural resistance of employees to change - Management doubts about the benefits of the project for the company	Negative Ranks	45	23.00	1035.00
			Positive Ranks	0	0.00	0.00
			Ties	18		
			Total	63		

Source: own research

Wilcoxon's pairing test created six pairs of tables. These represent the comparison between the pairs. First, we look at the table on the left and the value on the Asymp. Sig. Row (2-tailed) is less than 0.05, then there is a statistically significant difference between the different disadvantages in that pair of tables. Then, we find out which direction to go from the paired comparison. Based on the results presented in Table 6, employees' natural resistance to change is statistically the least compelling reason not to use the ABC method. Subsequently, we found that the expectation that the project would be highly time-consuming to implement is statistically significantly considered a more compelling reason for not using the ABC method than management doubts about the project's contribution to the company. For other comparisons, we did not find a statistically significant difference.

Hypothesis 2 was not confirmed.

H3 We expect that the levels of doubt about the suitability of the ABC costing method for the company vary statistically significantly between companies operating in Slovakia and the Czech Republic.

Table 7. Degree of doubt about the suitability of the ABC costing method for the company

Country	Response	Number	Percentage
Slovak Republic	Rather yes	8	21.1
	Definitely not	30	78.9
	Total	38	100.0
Czech Republic	Rather yes	22	81.5
	Definitely not	5	18.5
	Total	27	100.0

Source: own elaboration

Based on the results presented in Table 7, we can observe that in terms of the degree of doubt about the suitability of the ABC costing method for a company, companies operating in Slovakia are more convinced that this method is unsuitable for them than companies operating in the Czech Republic.

Based on the nature of the variables, we use non-parametric tests to test hypothesis 3.

With Hypothesis 3, we need to determine whether there is a statistically significant difference in the level of doubt about the suitability of the ABC costing method for the company in relation to the country of operation. Considering the nature of the variables, we analysed the hypothesis using the non-parametric Mann-Whitney U-test for two independent selections.

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Table 8. Mann-Whitney U-test

Country	N	Mean Rank	Mann-Whitney U-test	Degree of doubt about the suitability of the ABC calculation method for the company
Slovak Republic	38	41.16	Mann-Whitney U	203.000
Czech Republic	27	21.52	Wilcoxon W	581.000
Total	65		Z	-4.779
			Asymp. Sig. (2-tailed)	0.000

Source: own research

If Asymp. Sig. (2-tailed) is less than 0.05, then there is a statistically significant difference between the groups. Here, there is a value of 0.000, so we know that there is a statistically significant difference between the groups. The higher value for Mean Rank is the one for companies from Slovakia. Based on the results presented in Table 8, we can conclude that there is a statistically significant difference in the extent of doubt about the suitability of the ABC costing method for the company, namely that companies operating in Slovakia are statistically significantly more convinced than companies operating in the Czech Republic that this method is not suitable for their business.
Hypothesis 3 was confirmed.

From the theoretical perspective, we described the ABC method as a strategic tool important for the competitiveness of businesses in the industry. ABC is an alternative to traditional indirect cost calculation systems, which in some manner always distort the accounting of the actual costs. Although it has some limitations, the ABC system is adequate to determine actual indirect (overhead) costs and can enable the determination of more reasonable and competitive prices in the market. In practice, however, it remains neglected.

By analysis, we determined that 61.25% of companies in the construction industry in the Slovak Republic use the traditional margin-based costing method. 35% use the ABC method, and 3.75% use the variable costing method. Similarly, the most widely used costing method in the Czech Republic is the traditional margin-based method. It is used by 54.28% of businesses. The ABC method is used by 38.57% of companies (here, we include the businesses that currently use ABC in practice and the businesses that are putting this method into practice). The variable costing method is used by 7.14% of companies.

In practice, firms using ABC have defined the following as the most important advantages of the method implemented: more accurate cost identification, particularly for overhead type, and more efficient cost management. Conversely, optimising the portfolio of clients and products has been identified as the least important advantage of the ABC method.

The biggest reason for not using the ABC method would be doubt about its suitability for construction companies. This hypothesis was not confirmed. By analysis, the expectation that the implementation project would be highly time-consuming is considered to be statistically significantly a more compelling reason for not using the ABC method than management's doubts about the project's contribution to the company. The natural resistance of employees to change is statistically significantly the least compelling reason for not using the ABC method.

Next, we expected that the degree of doubt about the suitability of the ABC costing method for a company varies statistically significantly between companies operating in Slovakia and the Czech Republic. This hypothesis was confirmed. By analysis, we found that companies operating in Slovakia are more convinced of the method's unsuitability for a company than companies operating in the Czech Republic.

5. Conclusions and recommendations

We understand and describe ABC as a quality tool for determining overheads in construction companies. Through analysis, we find that in the practice of construction companies in the Slovak Republic and the Czech Republic, traditional costing methods prevail, precisely the margin-based cost calculation method. This method

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for determining the sum of overheads uses one stable scheduling base for all types of overheads, resulting in the inaccuracy of these costings. It allocates overheads per production unit based on workload or machine hours, often leading to incorrect unit costs.

The greater the share of business costs that overheads form, the more critical the allocation of overheads becomes more important. It is not rare that for construction companies, direct costs represent less than 50% of the total costs; the rest are overheads – they cannot be quantified directly with individual cost items of the price of construction works but are related to the whole preparation of construction, including taking the contract. These are costs related to the management of activities and the operation of the production process, the cost of shipping, customer service, research, product design, or quality control. They cannot be specified directly by a costing unit but only through the selected scheduling base and the percentage margin base. As a rule, these costs are recorded according to the chart of accounts used or according to the overhead catalogue if they are kept in the company to categorise them according to their place of origin.

In practice, overhead costs are considered the most challenging part of calculating unit prices for construction works. Research question RQ1 was: What calculation methods are used by companies operating in the construction sector? How many companies use the ABC method?

Our analysis confirmed that the margin-based method usually accounts for overhead costs. This is mainly because it is easy to use. The level of overhead costs per calculation unit is calculated using a percentage margin – a rate determined from internal company accounting – or taken from the indicative price of the works. The basis for calculating overhead costs may vary.

In the Slovak Republic, 61.25% of companies in the construction industry use the traditional margin calculation method. 35% use the ABC method. Similarly, in the Czech Republic, the traditional margin-based method, the most widely used calculation method, is used by 54.28% of companies. The ABC method is used by 38.57% of companies. Hypothesis H1 was thus not confirmed (H1: We expect that there are statistically significant differences in the types of costing methods used between the two analysed countries).

ABC helps eliminate the inaccuracy of the margin-based method by allocating overhead costs to products according to the extent to which these products contribute to the overhead costs incurred. In addition to overhead costs incurred directly in production, the ABC method also allocates non-production costs, such as customer service and support, product design or logistics costs. For example, the ABC method is suitable if some products require significantly more customer support and other activities related to orders and delivery.

In the second research question RQ2, we addressed whether: Are managers convinced of the suitability of the current costing method? Do they doubt the suitability of other methods?

100% of managers (46.2% rather yes, 53.8% definitely yes) using the traditional costing method are convinced that the ABC method is unsuitable for their company. Likewise, all 100% of managers (here: 41.5% rather yes, 58.5% definitely yes) are convinced that using the ABC method is time-consuming and unnecessary. All managers doubt the benefits of another method for their company. Employees' natural resistance to changes is the least significant reason for not using the ABC method.

This was also confirmed by statistical analysis. We found that the expectation that the project implementation will be highly time-consuming is statistically significantly considered a more compelling reason for not using the ABC method than management doubts about the project's benefits for the company. In other comparisons, we did not find a statistically significant difference.

Hypothesis H2 was therefore not confirmed (H2: The most common reason for not using the ABC method is doubts about the suitability of this method for construction companies).

These are also the answers to the third research question, RQ3: Why do some companies consciously reject more modern, more accurate methods and remain with traditional cost calculations?

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Managers who still use traditional mark-up costing methods are convinced of their suitability and sufficiency for their company. Most of them are not interested in changing it. They want to avoid unnecessarily time-consuming calculation work that would lead, in their opinion, to the same or similar result.

There is a statistically significant difference in the level of doubt about the suitability of the ABC costing method for the company between countries. Companies operating in Slovakia are statistically significantly more convinced than those operating in the Czech Republic that this method is unsuitable for their business. Hypothesis H3 was confirmed (H3: The level of doubts about the suitability of the ABC costing method varies across countries).

In summary, our analysis found that 35% of construction companies in the Slovak Republic and more than 38% of companies in the Czech Republic already use the ABC calculation method. In practice, construction companies that already use ABC identified the most important benefits as more accurate identification of costs, especially the type of overhead costs, and more effective cost management. They consider optimising the client and product portfolio as the least important benefit. These findings correspond with the results of other studies, according to which newer costing methods allow for real-time cost accounting and decision-making; unlike traditional methods that rely on historical data, they focus on creating efficient production activities based on product requirements, which allows for detailed cost analysis, adapting products to customer requirements (Javed, 2025), the main benefit of implementing the ABC method is the accurate allocation of costs to sub-activities, which allows for a better understanding of the economic efficiency of production processes (Zavrbska & Besta, 2024), the results of the studies also indicate a positive correlation between user satisfaction with the ABC costing system and the extent of information obtained, the provision of accurate information, the quality of information and detailed cost information (Alexopoulou, 2024).

However, it is also necessary to bear in mind the limitations of the ABC method. Although the ABC method looks simple initially, its implementation and use are challenging and complex. It requires extensive preparatory work and analyses, information technologies that capture the measured parameters in operation, a qualified project team, and intensive support from company management. The method is demanding in data acquisition, and further problems may arise with allocating costs typical to several activities. Last but not least, there may be a problem with the relationship of the ABC module to other accounting methods used in financial accounting when pricing a product.

Through analysis, we found that construction company managers are mainly concerned that project implementation would be highly time-consuming. Management's doubts about the project's contribution to the business are a less compelling reason for not using ABC in practice. Managers of companies operating in Slovakia are more convinced of the unsuitability of this method for their company than companies operating in the Czech Republic.

In practice, the ABC method can be implemented in any company whose processes are sufficiently established to identify individual activities. However, companies must benefit sufficiently to compensate for the costs of its implementation and operation. Therefore, it is especially suitable for companies with a complex production process that produce more goods. If a company operates in a strong competitive environment that affects its pricing policy, it looks for systems and methods that categorise and allocate in more detail.

The analysis was conducted in the Slovak and Czech Republics, but the results can be applied to all countries with similar historical and economic backgrounds. Based on the above, we propose considering the introduction of the ABC costing method, especially in construction companies that meet the following conditions: when deciding to introduce the ABC method, a business should consider the structure of its costs. This is primarily the proportion of overheads within the company's total costs. The higher the proportion of overheads, the more inaccurate cost allocation using scheduling bases will be.

ABC is suitable for businesses whose production program is diversified - it contains multiple types of activities that differ from each other in their size, the size of production series or production technology. The more

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diversified the production programme, the greater the inaccuracies that arise when using traditional costing methods.

Another factor influencing the suitability of introducing the method is the characteristics of the competitive environment. Fierce competition in the sector means that incorrect pricing or an unsuitable range can negatively affect the business. With intense competition, there is a growing need for knowledge of the exact costs of individual products.

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INFLUENCER MARKETING: IMPACT OF AUTHENTICITY ON CUSTOMER PURCHASE INTENTIONS

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Abstract. Social Media Influencers (SMIs) are vital to the automotive sector by shaping consumer perceptions, increasing brand visibility, and driving purchase intentions through authentic and relatable content. Their ability to engage with specific audiences allows automotive brands to build trust and credibility, influencing the choices of prospective buyers. This study attempts to investigate the effect of SMI authenticity on consumer attitudes and purchasing intentions within the automobile sector in Pakistan. This study employs the Meaning Transfer Model of Celebrity Endorsement (McCracken, 1989) and the Authenticity Model of Computer-Mediated Communication (Lee, 2020) to investigate the impact of perceived authenticity on consumer attitudes and purchase intentions regarding automotive products. A quantitative approach was employed to collect data (N=385) from consumers in Pakistan who interact with SMIs in the automotive sector. The findings indicate that SMI authenticity significantly impacts consumer attitudes and purchase intentions, with consumer attitudes mediating between authenticity and purchase intentions. This study enhances the current literature on influencer marketing by highlighting the importance of authenticity in influencing consumer behaviour within high-involvement industries. The discourse encompasses ramifications for marketers and suggestions for subsequent research.

Keywords: social media influencers; perceived authenticity; consumer attitude toward SMI; consumer purchase intention

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JEL Classifications: M31, M37

1. Introduction

The automotive industry in Pakistan is a rapidly expanding sector that is making significant strides despite its relatively small size. Pakistan has established itself as an important player in the automobile industry, ranking 23rd in terms of production. This sector contributes around 3% to Pakistan's GDP and provides employment opportunities to over 3.5 million individuals annually. The automotive industry at large has faced challenges with no relief in sight. While the demand for cars has plummeted, the prices of products have increased due to the sharp fall in the value of Pakistan's rupee. Moreover, the Pakistan government has introduced high duties on the import of ancillary parts for the automotive industry to reduce the import bills, which has increased car prices. The sector has endured the most challenging financial year since the onset of the pandemic, which significantly impacted the economic performance and consumer demand. The provided data reveals that the

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overall volume of automobiles sold across all sectors in fiscal year 2023 was 13.48 lakh units, representing a 37.7% decrease from the 21.63 lakh units sold in fiscal year 2022 (PAMA, 2023).

The decline of the automotive sector in Pakistan can be attributed to numerous factors, including escalating input costs, pervasive inflation, diminishing demand resulting from a faltering economy, currency devaluation, changes in consumer behaviour, disruptions in the supply chain, and the application of elevated taxes on vehicle acquisition. Notwithstanding the problems, Pakistan's automotive sector exhibits resilience and is positioned for recovery in 2024. The industry's potential is highlighted by an anticipated increased demand of 350,000 units every five years, propelled by the increasing young population in the country.

The automotive industry is currently characterized by intense competition among numerous brands worldwide. Each executes the latest and most innovative strategies to enhance their brands and engage with customers. The automotive industry is actively reaching out to potential customers through various channels alongside traditional media. Digital and social media are essential components of the marketing strategies employed by automobile brands (Rana & Lokhande, 2015). Social media as a marketing platform has emerged as a significant global trend within the automotive industry. An effectively formulated social media strategy is essential in the automotive sector. It empowers dealers to distribute premium information to potential customers and engage with them directly across various platforms, enhancing online visibility. The significance of viral impressions from widely used social media platforms like Facebook, Instagram, YouTube, and Twitter can help boost automotive industry sales (Balaban & Mustățea, 2019). Moreover, strong engagement on social networks cultivates a loyal customer base that continually chooses the same dealership. As a result, several car dealerships are utilizing social media management tools to sustain their competitive advantage in this progressively digital landscape (Oranim, 2023). Social media discussions can enhance awareness and sales; nevertheless, alterations in brand perceptions on these platforms may adversely impact sales.

The advent of digital media has significantly transformed the realm of communication and interpersonal connections. Digital media can replace traditional media in almost all aspects of human existence (Mahmood et al., 2023). The proliferation of technology, along with improved accessibility, has rendered the Internet pervasive across all domains. Social media has revolutionized communication, providing convenient, user-friendly, and cost-effective access (Kasumovic, 2024). Furthermore, the ever-evolving world of technology has brought about new opportunities for individuals, known as SMIs and influencer marketing (Garcia-de-Frutos & Ramon, 2021). Influencer marketing implies brands adeptly address the growing resistance to conventional marketing approaches. In influencer marketing, product placement or native advertising involves integrating a sponsoring brand's product or service within an influencer's content. Through collaboration with SMIs, brands can successfully present their products to a highly engaged audience.

Influencers are today's leading digital opinion leaders, influencing consumer attitudes and behaviours (Mahmood et al., 2022; Lee, 2021). Consumers are relying on these SMIs for genuine brand information. They also effectively engaged with consumers by disseminating brand-promoted messages through social media platforms. (Peltier et al., 2020). SMIs employ diverse authenticity management tactics to establish a close relationship with their followers and enhance their online visibility (Balaban & Szambolics, 2022; Lee & Eastin, 2021). This accessibility positions influencers as more authentic and fosters a sense of closeness, enhancing the credibility of their brand endorsements (Audrezet et al., 2020). To put it differently, the authenticity of influencer marketing is the foundation of its success, a quality that the source credibility construct has not yet fully incorporated.

Roth-Cohen et al. (2024) see perceived authenticity as a key driver of effective advertising content. Authenticity is favourably connected with the advertising activities of SMIs, as it is underpinned by their sincere aim to endorse items or services in exchange for external earnings (Kim & Kim, 2020). In contrast, Audrezet et al. (2020) have highlighted that SMIs who regularly disseminate paid content are regarded as less authentic. Influencer marketing represents a complex relationship, wherein SMIs are linked to both the brands they promote and their audience (Kim & Kim, 2020). Authenticity is a significant factor influencing the communication outcomes of SMIs and contributes to their source credibility (Djafarova & Trofimenko, 2019).

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However, different people participating in the communication process see it differently. Thus, the viewpoints of SMIs, their followers, and the brands they embody must be considered when discussing SMIs and authenticity (Poyry et al., 2019).

Efforts have been made to measure perceived authenticity, reality television personalities, and SMIs (Balaban & Szambolics, 2022; Lee & Eastin, 2021). In their seminal work, Lee and Eastin (2021) developed and validated a measurement scale for the perceived authenticity of social media influencers (PASMI). Exploratory factor analysis is performed to refine and establish an initial scale. This scale is then validated by confirming its structure and assessing convergent and discriminant validity. Additionally, the relationship between the underlying dimensions of PASMI and key consumer behaviour variables is examined as a measure of predictive validity. The findings indicated that perceived authenticity is a multifaceted construct comprising sincerity, truthful endorsements, visibility, knowledge, and originality. The five aspects influence customers' assessment of SMIs, their propensity to follow an SMI, and their desire to purchase things endorsed by SMIs (Balaban & Szambolics, 2022; Lee, 2020).

A substantial amount of study examines the increasing impact of social media on consumers' purchase decisions influenced by SMIs (Pop et al., 2022; Mahmood et al., 2023; Peltier et al., 2020). However, the perceived authenticity of SMIs in the context of the automotive industry has not yet been systematically explored.
This research seeks to evaluate the impact of the multidimensional construct of SMI authenticity, which includes sincerity, truthful endorsements, visibility, expertise, and uniqueness, on consumer attitudes and purchase intentions within the automobile industry of Pakistan. The findings are expected to guide current SMIs in effectively managing and presenting a genuine persona while offering brand managers improved criteria for evaluating the authenticity of influencers' authenticity before establishing potential collaborations. It will establish a foundational comprehension of perceived authenticity and augment the expanding literature on SMI authenticity.

2. Literature Review

Meaning Transferred Model of Celebrity Endorsement

The Meaning Transferred Model of Celebrity Endorsement (McCracken, 1989) asserts that meaning transfer occurs via a three-stage process and delineates how the images or meanings embodied by the celebrity endorser affect essential consumer behaviours, including attitudes toward the endorser, advertisement, brand, and purchase intention. Celebrities acquire many symbolic meanings in the preliminary stage through social media appearances. During the second stage, the brand endorsement phase, these significations are attributed to the brand as the celebrity associates with it. In the third stage, the importance shifts to the brand's consumers (Lee & Eastin, 2021).

Consumers primarily obtain the conveyed meaning rather than the actual product or service. In influencer marketing, the transfer of meanings must be observable when companies weave their messages into the everyday narratives of SMIs. Branded endorsements exemplify how SMIs incorporate specific products or services into their everyday routines, seamlessly integrating them into the posts they share daily. It enables individuals to improve a facet of their self-perception by emulating the activities of another person. Social media extends consumption beyond material goods to encompass content purchase in a broader sense. Followers engage with SMIs' content, emulate their style and behaviour, and incorporate their inspiring material into everyday routines (Ki & Kim, 2019; Lee & Eastin, 2021).

The efficacy of perceived SMI authenticity can be elucidated using these theoretical perspectives. Emulating the practices of authentic SMIs and engaging with the products they promote enables customers to align themselves with authenticity (Wang & Weng, 2024). Research has demonstrated that perceptions of authenticity regarding an SMI foster a stronger emotional connection, thereby increasing consumers' propensity to purchase the brand supported by the SMI (Ki et al., 2020). Furthermore, considering that authenticity is an essential aspect of consumers' daily experiences, it is logical that they are attracted to authentic SMIs.

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The Authenticity Model of Computer-Mediated Communication

Lee's (2020) Authenticity Model of Computer-Mediated Communication includes ideas like message credibility, perceived realism, and para-social relationships to give a complete picture of authenticity in digital interactions. The model consists of three key subcomponents: source authenticity, message authenticity, and interaction authenticity; each plays a crucial role in shaping perceptions of credibility and trust.

Source authenticity refers to the genuineness of a communicator's identity, emphasizing credibility, trustworthiness, and expertise. In an era of AI-driven communication, maintaining source authenticity is increasingly complex. Message authenticity pertains to the accuracy and alignment of content with audience expectations, values, and beliefs. Studies suggest that authentic messages from SMIs significantly impact followers' purchase intentions (Balaban & Szambolics, 2022; Mahmood et al., 2023; Pöyry et al., 2019). Lastly, interaction authenticity reflects the perceived genuineness of digital engagements, shaped by reciprocity and spontaneity. SMIs cultivate authenticity by fostering meaningful connections with their audience, reinforcing trust and emotional attachment (Farrell & Campbell, 2020; Kowalczyk & Pounders, 2016; Ki et al., 2019). These interrelated dimensions contribute to authenticity perceptions, influencing consumer attitudes and behaviours. This study further explores how authenticity through sincerity, truthful endorsements, visibility, expertise, and uniqueness shapes consumer trust and purchase intentions toward SMIs.

Perceived Authenticity and SMIs

The perceived authenticity of SMIs is a key determinant of their ability to shape consumer purchasing decisions. As digital communication evolves, authenticity has become a central concept in marketing and branding, representing the genuine and truthful portrayal of oneself (Shoenberger & Kim, 2023). In the context of SMIs, authenticity involves aligning one's self-presentation with personal values and beliefs, fostering credibility and trust among followers (Ebben & Bull, 2023). Beyond trustworthiness, authenticity also encompasses relational and emotional dynamics that strengthen audience engagement (Lee & Eastin, 2021).

Defining authenticity presents theoretical and practical challenges, as it involves ethical considerations, value congruence, and transparency in online interactions. Scholars argue that authenticity is subjective and socially constructed, shaped by environmental and ideological influences (Ebster & Guist, 2005). However, it remains a fundamental aspect of online identity, influencing self-perception and audience perception. Social media platforms provide various visual tools that enable SMIs to construct their digital personas and engage in meaningful, reciprocal connections with followers.

Research highlights the significance of authenticity in influencer advertising (Audrezet et al., 2020; Lee & Eastin, 2021). Followers are likelier to engage with SMIs they perceive as accurate, directly impacting their emotional and behavioural responses to influencer content (Lou, 2022). Pöyry et al. (2019) emphasize the importance of the "aura of authenticity," arguing that sponsored content aligned with an influencer's values enhances advertising effectiveness and positively influences consumer behaviour.

The effectiveness of SMIs depends on balancing authenticity with commercial endeavours (Balaban & Mustațea, 2019). Audrezet et al. (2020) propose two key strategies for maintaining authenticity: passionate authenticity, where influencers create content that is personally fulfilling, and transparent authenticity, where they openly disclose brand collaborations and share fact-based product information. Transparent authenticity is reinforced by sharing unfiltered content and providing clear disclosures about partnerships (Ebben & Bull, 2023). Lee and Eastin (2021) extend this to SMIs, identifying five key dimensions of authenticity: sincerity, truthful endorsements, visibility, expertise, and uniqueness. These elements are critical in shaping influencer credibility and effectiveness in digital marketing. While building on this seminal literature, the present study adopts these five dimensions of authenticity as a framework for analysis. A detailed discussion of each of these aspects, supported by relevant literature, is provided in the subsequent section.

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Relationship of SMIs Authenticity, Consumer Attitudes, and Purchase Intentions

Authenticity of media influencers plays a critical role in shaping consumer attitudes and purchase intentions. Authentic influencers, perceived as genuine, relatable, and transparent, foster stronger emotional connections with their audiences, which can lead to greater trust (Erdoğmuş & Çiçek, 2012). Consumers often see these influencers as more reputable sources of information, improving favourable sentiments toward the items or services they promote. As a result, these favourable attitudes can increase purchase intentions, as consumers are more likely to buy from recommendations given by the influencers they trust (Mahmood et al., 2023). However, when influencers are perceived as inauthentic or overly commercial, their credibility and influence on purchase decisions can diminish. Studies suggest that authenticity in influencer marketing is a key determinant of consumer engagement and long-term brand loyalty (Audrezet et al., 2020).

Cabeza-Ramírez and Sánchez-Cañizares (2022) found that perceived authenticity significantly impacts consumer attitudes and purchase intentions, with message authenticity being the strongest determinant. Authentic influencers create content that aligns with their audience's expectations, beliefs, and personal experiences, fostering a sense of trust and credibility. Similarly, Balaban & Szambolics (2022) introduced a model highlighting the self-perceived authenticity of SMIs as a key factor in consumer engagement. The study suggests authenticity goes beyond mere credibility since it involves emotional and relational components that enhance consumer-brand connections. This implies that brands collaborating with SMIs should prioritize influencers who resonate with their target audiences.

Several studies establish a direct correlation between influencer authenticity and consumer purchase intentions. Agnihotri et al. (2023) explored how para-social interactions mediate the relationship between SMI authenticity and purchase behaviour. Findings indicate that consumers are likelier to purchase products promoted by influencers they perceive as authentic, relatable, and knowledgeable. Similarly, Al Doghan and Arshad (2023) found that authenticity influences attitudes and predicts purchase intent. Their research suggests that influencers who engage in genuine interactions with their followers create a stronger sense of community, further reinforcing purchasing decisions. Based on the reviewed literature, this study proposes the following hypotheses:

H_1: Consumers' attitudes toward a social media influencer are positively impacted by the social media influencer's authenticity.
H_2: Social media influencer authenticity has a significant positive impact on consumer purchase intention
H_3: Consumers' attitudes toward a social media influencers significantly impact purchase intention.

Perceived Sincerity

Sincerity is a fundamental component of perceived authenticity for SMIs, significantly shaping consumer attitudes toward influencers and brands they endorse. Perceived sincerity refers to the extent to which consumers believe an influencer's content is genuine, honest, and free from manipulative intent (Lee & Eastin, 2021). Sincerity is a distinctive asset of influencers in marketing products and fostering a profound social connection with their followers (Tsai & Men 2017). Several studies have examined the role of sincerity in influencer marketing. Bansal & Pruthi (2023) found that SMIs who exhibit sincerity in their endorsements generate higher trust and positive attitudes among consumers, as their messages are perceived as more relatable and honest. Similarly, Weismueller et al. (2020) highlighted that perceived sincerity mitigates scepticism toward sponsored content, increasing consumers' likelihood of engaging with and accepting influencer recommendations. Followers meticulously assess the authenticity of SMIs to ascertain their genuineness and convey authentic experiences (Audrezet et al., 2018). An SMI characterized by pragmatism and accessibility is perceived as authentic, with this trait being closely associated with relatability. Prior research by Al-Emadi and Yahia (2020), Lee and Eastin (2020), and Zhafira et al. (2022) posited that the honesty, compassion, and integrity of SMIs align strongly with the notion of sincerity, hence encouraging consumer engagement with these influencers. In light of the aforementioned literature, we propose the following hypothesis:

H_{1a}: Consumers' attitudes toward a social media influencer when purchasing automobiles are positively impacted by the perceived sincerity of the influencer.

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Truthful Endorsements

When SMIs endorse firms that conflict with their personality and values, consumer marketing is inauthentic (Audrezet et al., 2020; Saima & Khan, 2020; Shan et al., 2020). SMIs strive to ensure transparency by clearly notifying their followers about any incentivized content, which reduces confusion and promotes authenticity through honest evaluations of products and services (Al-Emadi & Yahia, 2020; Audrezet et al., 2020). Authentic brand endorsements convey the perception that collaborations extend beyond the profit-driven exploitation of an influencer's audience. Instead, they serve as opportunities for influencers to express their identity and values by partnering with brands that resonate with their passions and personal interests (Aggad & Ahmad, 2021). Endorsements from SMIs hold significant influence when the endorser seems authentically driven to advocate for the product rather than acting out of self-interest (Choi et al., 2023). The perception of a post as being commercially motivated and under the control of a brand diminishes trust in the social media influencer, leads to a decline in interest in the content, and reduces the inclination to pursue further information regarding the promoted brand (Martínez-López et al., 2023). Deceptive endorsement tactics diminish consumer trust and engagement, while SMIs that excessively promote advertisements lead consumers to unfollow them owing to non-interest and ad avoidance (Djafarova & Trofimenko, 2019). We suggest the following hypothesis based on the significant insights from the previously stated literature.

H_{1b}: Consumers' attitudes toward a social media influencer when purchasing automobiles are positively impacted by the truthful endorsements of the influencer.

Perceived Visibility

Visibility denotes a state of openness and transparency. SMIs are motivated to publicly curate their personalities to foster perceptions of authenticity, thereby augmenting their net worth, as evidenced by the volume of likes, shares, and followers. Heightened levels of self-disclosure blur the distinction between frontstage and backstage, depicting the influencer as showcasing their genuine self in both physical and digital domains. Content that reveals influencers' shortcomings and negative emotions suggests a lack of engagement in strategic impression management by SMIs (Audrezet et al., 2020). Studies suggest that openness and honest self-disclosure contribute to perceptions of a leader's authenticity (Javed et al., 2021). The benefits of social media visibility and the intentional sharing of personal information have been noted in various contexts, encompassing brand CEOs, politicians, and SMIs (Javed et al., 2021; Kim & Kim, 2020). Studies have shown that revelations by influential individuals on social media enhance likability and elevate the quality of life for consumers by cultivating a more profound sense of camaraderie and relational closeness (Kim & Kim, 2020). We propose the following hypothesis based on the profound insights from the literature above.

H_{1c}: Consumers' attitudes toward a social media influencer when purchasing automobiles are positively impacted by the visibility of the influencer.

Perceived Expertise

Expertise denotes a source's recognized knowledge, skills, and experience, shaped by elements like education and achievements-expertise centres around the qualifications and abilities of the source (Kim & Kim, 2021). The content seems genuine and cohesive, stemming from a natural proficiency in the subject matter rather than being influenced by external factors (Sharipudin et al., 2023). Individuals recognized as Subject Matter Experts in a particular domain are esteemed for their authenticity, as their skills reflect a profound enthusiasm, genuine authenticity, and unwavering diligence. Brand community members are regarded as authentic when they can independently repair their vehicles (Choi et al., 2023). Thus, the possession of talent not only amplifies perceptions of authenticity but also serves to validate their acclaim. Various studies illustrate the importance of knowledge in shaping consumer attitudes and behaviours. Expertise in SMIs enhances views on opinion leadership, influences attitudes towards the SMI, shapes brand perceptions, affects product attitudes, and impacts purchase intentions while also promoting interaction with sponsored content (Akdevelioglu & Kara, 2020; Choi et al., 2023; Ki & Kim, 2019; Trivedi & Sama, 2020). Al-Emadi and Yahia (2020) recognized knowledge as a key factor influencing consumer engagement with SMIs, which are perceived as important

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information sources. We put forth the following hypothesis based on the valuable insights from the earlier literature.

H_{1d}: The influencer's expertise positively impacts consumers' attitudes toward a social media influencer when purchasing automobiles.

Perceived Uniqueness

SMIs, differentiated from other influencers by their unique personality and content, serve as the origin of one's actions and ideas, rendering them authentic. McRrae (2017) found that consumers perceive SMIs as producing often mundane and derivative content. The perceived uniqueness of a social media influencer's content has been shown to enhance consumers' willingness to engage with the influencer, adhere to their recommendations, and endorse the influencer to others (Casaló et al., 2018). This may stem from individuals' societal aspirations to preserve a sense of individuality, which serves as a driving factor for consumption. Consumers seek various forms of information, including brand-related data, and so pursue unique SMIs (Al-Emadi & Yahia, 2020). Based on the perceptive findings of the previously cited literature, we put out the following hypothesis.

H_{1e}: Consumers' attitudes toward a social media influencer when purchasing automobiles are positively impacted by the influencer's uniqueness.

Mediation Relationship of Consumer Attitudes Between SMIs Authenticity and Purchase Intentions

In the world of SMIs, authenticity significantly influences consumer attitudes, subsequently affecting purchase intentions (Lee & Eastin, 2021). Consumers are more inclined to form favourable attitudes toward an influencer and the products they endorse when they perceive the influencer as authentic. The attitudes mediate between the perceived authenticity of the SMI and the consumer's purchase intentions (Zhafira et al., 2022). To rephrase, the more honest and credible the influencer appears, the more favourable the consumer's attitude becomes, subsequently enhancing the likelihood of purchasing. This mediation relationship highlights the indirect effect of authenticity on purchase behaviour, emphasizing the importance of trust and relatability in the consumer decision-making process (Audrezet et al., 2020; Zhafira et al., 2022). Based on the perceptive findings of the previously cited literature on authenticity, customer attitude, and purchase intention, we put out the following hypothesis. The subsequent theoretical framework is employed to achieve the research objectives. This theoretical framework has been applied to examine the relationship between an influencer's trustworthiness, attractiveness, perceived similarity, and perceived sincerity, as mediated by attitude toward the brand and its impact on purchase intention.

H_4: Consumers' attitudes toward SMIs mediate the relationship between SMIs authenticity and consumer purchase intention when purchasing automobiles.

3. Research Methodology

The study's target population comprises individuals who actively engage with SMIs on Instagram and consume automobile-related content, including reviews, news, and posts about cars, auto accessories, and industry trends. The target population is also composed of individuals in the market who purchase or are already consumers of automobiles, influenced by marketing and recommendations, including those from SMIs. The target population consists of those residing in Lahore, Islamabad, and Karachi. The rationale for selecting these cities lies in their multi-ethnic demographics, the highest density of the Pakistani populace, and the most significant number of social media users. Furthermore, Instagram is among the most prevalent social media platforms, boasting approximately 17.69 million members (64.5% male and 35.5% female) as of January 2024 (Statista, 2020a). Respondents were sourced using online platforms through the networks of several SMIs in Pakistan. The survey link was disseminated through the Instagram story feature on the influencers' accounts. The public accessibility of these stories enabled a wider reach, extending beyond the influencers' followers and allowing for broader audience participation.

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Sample Size and Data Analysis Tool

This research utilized Structural Equation Modelling (SEM) to develop an integrated analysis model and to evaluate the hypothesis. The research sample comprised 385 respondents, established in accordance with the SEM sample size limitations.

Questionnaire Design and Measurement Scale

Questionnaires were disseminated to individuals via multiple social media platforms for data collection, utilizing the online survey software Question-Pro for this purpose. Perceived sincerity (SIN), truthful endorsement (TE), uniqueness (UNI), and visibility (VY) scales are adapted from the study of Lee and Eastin (2021), perceived expertise (EX) from the study of Mahmood et al. (2023). Nafees et al. (2020), customer attitude (CATT) towards SMIs from the study of Tan and Chia (2007) and Zhafira et al. (2022) the Consumer Purchase Intention (CPI) scale is derived from Mahmood et al. (2023). In contrast, the demographic scale is sourced from Zhafira et al. (2022) and Mahmood et al. (2023). Numerous components were incorporated and altered to align with the findings regarding influencers. The data were acquired using a five-point Likert scale, and SPSS was employed for preliminary data analysis, which indicated that the data collected for this study followed a normal distribution. The results of demographics are provided in Table 1.

4. Results

Following data screening and exploratory analyses that produced a sufficient dataset (N=385) for this research, the data were analyzed utilizing PLS-SEM to assess the hypotheses. Employing Smart-PLS for confirmatory factor analysis (CFA), items with a threshold below 0.70 were removed, and the reliability of the constructs, along with their convergent and discriminant validity, was assessed.

Table 1. Demographic Profile of the Respondents

Demographics		Frequency	Per cent
Gender	Male	296	77
	Female	89	23
Education	Higher Secondary	45	12
	Undergraduate	95	25
	Graduate	139	36
	Master	87	22
	Other	19	5
Age	25-30	90	23
	30-35	103	27
	35-40	107	27
	40-45	66	18
	Above 45	19	5
Income	Rs. 50,000-100,000	98	25
	Rs. 100,00-150,000	124	32
	Rs. 150,000-200,000	107	28
	Above 200,000	56	15
	6 months -1 year	10	2
	1-2 years	35	9
	3-5 Years	145	38
	More than 5 years	195	51
Have you ever considered buying automobiles promoted by a social media influencer on Instagram?	Yes	No	
	83%	17%	

The Measurement Model

Following the removal of items, a subsequent Confirmatory Factor Analysis (CFA) was performed on the remaining items, revealing that the reliability of most latent variables fell below the specified threshold. Demographic information is included to elucidate the characteristics of survey respondents (Table 1). The convergent validity of the components was assessed using composite reliability (CR) and average variance extracted (AVE). The results demonstrated that both CR and AVE values exceed the threshold, with CR values

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ranging from 0.926 to 0.971 and AVE values ranging from 0.701 to 0.810 (Table 2). All three available criteria were employed to assess the discriminant validity of the measurement model.

Heterotrait-Monotrait Ratio of Correlations (HTMT) Criterion: The correlation coefficients of latent variables are recommended to remain below 0.90 as a lenient threshold. This study identified the highest correlation value between latent variables as 0.746, close to the HTMT cutoff value (Table 3).

Table 2. Latent Variables, Items Loading, and Convergent Validity

Sr.	Items	Perceived Authenticity	Factor Loadings	CR	AVE
Sincerity					
		My favourite social media influencer to follow on Instagram:			
1	SIN1	seems kind and good-hearted.	0.901		
2	SIN2	is sincere when recommending products.	0.881	0.941	0.710
3	SIN3	comes off as very genuine in their content.	0.880		
4	SIN4	is down-to-earth.	0.810		
Truthful Endorsement					
		My favourite social media influencer to follow on Instagram:			
5	TE1	although they post ads, they give meaningful insights into the products	0.756		
6	TE2	gives very honest reviews on brands.	0.890	0.965	0.728
7	TE3	the brands they endorse vibe well with their personality.	0.869		
8	TE4	promotes products that they would actually use	0.859		
Expertise					
		My favourite social media influencer to follow on Instagram is:			
9	EX1	Experienced.	0.823		
10	EX2	Knowledgeable	0.833		
11	EX3	Qualified	0.863	0.960	0.810
12	EX4	Competent	0.865		
13	EX5	Professional	0.844		
Visibility					
	My favourite social media influencer to follow on Instagram is:				
14	VY1	posts about the genuine condition of their life	0.898		
15	VY2	talks about real-life issues in their life	0.924	0.971	0.721
16	VY3	talks about their flaws publicly	0.894		
17	VY4	reveals a lot of their personal life to the public	0.912		
Uniqueness					
	My favourite social media influencer to follow on Instagram:				
18	UNI1	has a unique personality	0.896		
19	UNI2	make me feel new when presenting the skin care products	0.852		
20	UNI3	make me feel new when presenting the skin care products	0.891		
21	UNI4	has its unique characteristics	0.819	0.932	0.807
Consumer Purchase Intention					
22	CPI1	I will make purchases of the automotive products and services that were suggested by the influencer on Instagram.	0.838		
23	CPI2	I give great importance to the matter of acquiring automotive products and services proposed by the influencer	0.901		
24	CPI3	I like to consider all alternatives advised by the influencer before making my final decision for automotive products	0.881	0.950	0.755
25	CPI4	I intend to continue making automotive purchases utilizing the platform built by the influencers I follow.	0.921		
26	CPI5	I would firmly advise others to adhere to my influencer recommendations while making automotive purchases.	0.868		
Attitude towards SMI					
27	CATT1	I regularly engage with my favourite SMIs.	0.768		
28	CATT2	I view the endorsed post from my favourite social media influencer positively.	0.864		
29	CATT3	Overall, I value the endorsed posts from my favourite social media influencer.	0.857	0.926	0.718
30	CATT4	I hold a favourable opinion of the endorsed posts by my favourite social media influencer.	0.859		

Fornell and Larcker's Criterion for establishing discriminant validity were comparing the square root of the Average Variance Extracted (AVE) values (bolded in Table 3) with the squared correlation coefficients (the remaining values) between each pair of components. The results indicated that the AVE values exceeded the

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squared correlation coefficients of analogous rows and columns among the constructs. Similarly, in the cross-loading criteria, all measurement items demonstrated a significantly higher loading to their respective latent variable than any other variable.

Table 3. Discriminant Validity through Fornell and Larcker Criterion

Latent Variables	TR	SIN	VY	UNI	EX	CATT	CPI
Truthful Endorsement	**0.805**						
Sincerity	0.705	**0.790**					
Visibility	0.494	0.475	**0.814**				
Uniqueness	0.668	0.755	0.501	**0.800**			
Expertise	0.482	0.507	0.631	0.490	**0.806**		
Attitude towards SMIs	0.427	0.467	0.589	0.406	0.604	**0.792**	
Consumer Purchase Intention	0.361	0.378	0.652	0.493	0.508	0.624	**0.788**

Discriminant Validity through Heterotrait-Monotrait Ratio of Correlations (HTMT)

Latent Variables	TR	SIN	VY	UNI	EX	CATT	CPI
Truthful Endorsement							
Sincerity	0.700						
Visibility	0.485	0.472					
Uniqueness	0.594	0.746	0.490				
Expertise	0.464	0.493	0.602	0.476			
Attitude towards SMIs	0.397	0.449	0.569	0.395	0.592		
Consumer Purchase Intention	0.356	0.377	0.636	0.490	0.498	0.484	

The Structural Model

Collinearity Assessment through VIF: The study revealed that VIF values for all exogenous constructs (Perceived Authenticity =1.203, Attitude towards SMIs=2.448) stayed below the threshold value (Hair et al., 2020), indicating that the model did not have any collinearity concerns and was eligible for further evaluation.

The significance of path coefficient (β): Table 4 illustrates that the impact of SIN on CATT was statistically significant (β=0.898; t=12.180; p=0.000), supporting hypothesis H_{1a}. The result revealed that H_{1b}: TE on CATT was statistically significant (β=0.821; t=11.65; p=0.000), H_{1c}: VY has a significant effect on CATT (β=0.874; t=9.953; p=0.000), H_{1d}: EXP has a significant effect on CATT (β=0.893; t=11.840; p=0.000), and H_{1d}: UNI (β=0.628; t=15.951; p=0.000) has a significant effect on CATT. Hypothesis H_1 stated that PA had a significant influence on CATT (β=0.639; t=16.153; p=0.000), H_2 postulated that PA had a significant influence on CPI (β=0.430; t=4.965; p=0.000), while H_3 claimed that CATT had a significant influence on CPI (β=0.746; t=18.312; p=0.000).

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Table 4. Result of Structural Model and Hypotheses Testing

	Hypothesis	Path Coefficient (β)	T-value	P-values	Decision
H_1	PA ➔ CATT	0.439	16.153	0.000	Supported
H_{1a}	SIN ➔ CATT	0.898	12.180	0.000	Supported
H_{1b}	TE ➔ CATT	0.821	11.651	0.000	Supported
H_{1c}	VY ➔ CATT	0.874	9.953	0.000	Supported
H_{1d}	EXP ➔ CATT	0.893	11.840	0.000	Supported
H_{1e}	UNI ➔ CATT	0.628	15.951	0.000	Supported
H_2	PA ➔ CPI	0.390	4.965	0.000	Supported
H_3	CATT➔ CPI	0.546	18.312	0.000	Supported
H_4	PA➔ CATT➔ CPI	0.278	2.638	0.000	Supported

Bootstrapping with 2,000 subsamples at a confidence interval of 99%. The critical t-value for tests at a significance level of 0.01 is 2.57.

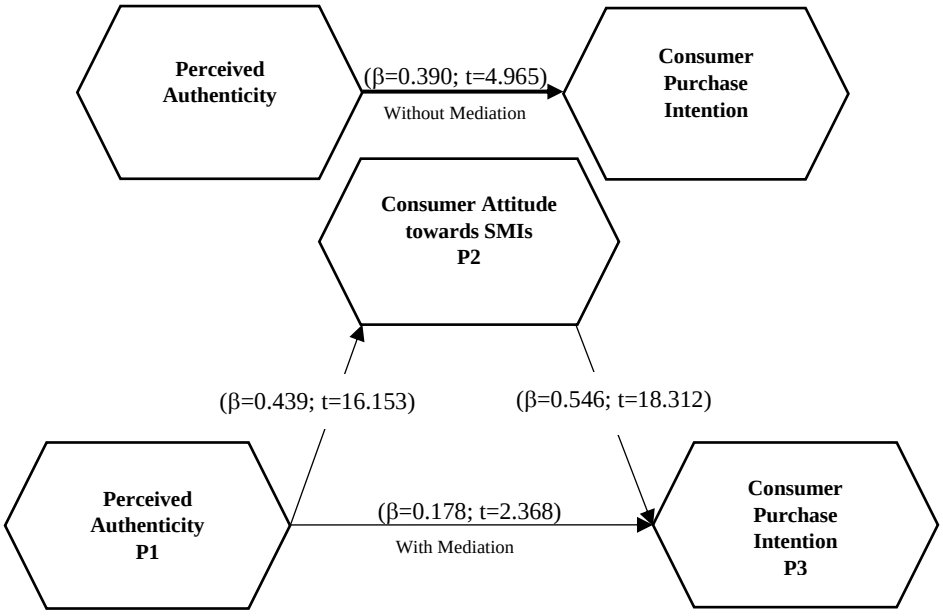


Figure 2. Mediation effect between Variables

Assessment of Mediating Effect: Hairet al. (2020) stated that specific conditions must be met for a model to assert mediation. The initial direct effect (β=0.390; t=4.965), as illustrated in Figure 2, and indirect effect through a mediator {$P12_{(\beta=0.439;\ t=16.153)}$ x $P23_{(\beta=0.546;\ t=18.312)}$} must be significant. Furthermore, the direct effect (excluding the mediator) is expected to diminish following the incorporation of the mediator variable, while all values maintain significance throughout all stages. Finally, the calculation of mediation should be based on the variance accounted for (VAF), expressed as VAF = {$P12_{(\beta=0.439;\ t=16.153)}$ x $P23_{(\beta=0.546;\ t=18.312)}$} / {$P12_{(\beta=0.439;\ t=16.153)}$ x $P23_{(\beta=0.546;\ t=18.312)}$+ $P13_{(\beta=0.178;\ t=2.368)}$}. A VAF value below 20% indicates no mediation, while a value between 20% and 80% signifies partial mediation and a value exceeding 80% is regarded as full mediation. The VAF analysis results indicated that consumer attitude towards SMIs partially mediates (VAF=46.2%) the relationship between perceived authenticity and consumer purchase intention.

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Model Fit: The SRMR and NFI meet the criteria for model fit, and the initial index values are below the upper limit of the 99 per cent confidence interval, signifying an acceptable model fit. This study complied with the guidelines established by Hair et al. (2020).

Table 5: Results of Model Fit Indices

Sr.	Indices	Model	Original Means	Confidence Interval		Cutt-off Criteria
				1% lower bound	99% upper bound	
1	SRMR	Saturated	0.037	0.013	0.040	< 0.08
		Estimated	0.037	0.013	0.040	
2	d_ULS	Saturated	0.049	0.011	0.064	should be compared against the upper bound of the confidence interval
		Estimated	0.049	0.011	0.064	
3	d_G1	Saturated	0.045	0.012	0.046	
		Estimated	0.045	0.012	0.046	
4	d_G2	Saturated	0.036	0.066	0.039	
		Estimated	0.036	0.066	0.039	
5	NFI			0.914		> 0.90

The explanatory Power of the Model (f^2) and Predictive Relevance (Q^2): The endogenous construct CPI accounts for 57.4% of Perceived Authenticity and Attitude towards SMIs (exogenous variables), supported by statistically significant t-values and p-values at a 99% confidence level (Hair et al., 2020). Thus, the results indicated that the model is parsimonious, as the R2 values for the endogenous construct satisfied the minimum threshold criteria. This study encompassed one endogenous construct (CPI) with Q^2 values of 0.460.

5. Discussion

The purpose of this research was to accomplish two primary objectives. First, to measure the effect of SMI perceived authenticity (multidimensional construct consisting of sincerity, truthful endorsements, visibility, expertise, and uniqueness) on consumer attitude towards SMIs and purchase intention. Second, to test whether consumer attitude towards SMIs mediates between SMI perceived authenticity and consumer purchase intention. This study utilized the Meaning Transferred Model of Celebrity Endorsement (McCracken, 1989) and the Authenticity Model of Computer-Mediated Communication (Lee, 2020), which are primarily grounded in source credibility theory (Ohanian, 1990), to seek the SMI perceived authenticity and consumer attitude towards SMI,s impact on consumer purchase intention while buying automotive product is Pakistan. The study's findings were consistent with previous literature about the constructs examined.

Study results revealed that all multidimensional constructs of perceived authenticity significantly impact consumer attitudes toward SMIs. For instance, study verdicts revealed (H_{1a}) that perceived sincerity significantly impacts consumer attitudes toward SMIs. Verdicts further explained that customer feedback has overwhelmingly affirmed positive sentiments towards their SMIs. Results shed light on why the SMI resonates so powerfully with their audience. They are admired not only for their content but also for the qualities that make them both trustworthy and relatable. The results also highlight that the SMI's success is built on their kindness, sincerity, genuine content, and down-to-earth nature.

The findings align with recent studies, for instance. Lee & Eastin (2020) discovered that perceived sincerity significantly influences attitudes toward a brand. Endorsements from high-sincerity influencers lead to a more positive attitude toward the brand for the product, in contrast to endorsements from low-sincerity influencers. Fans meticulously assess the authenticity of SMIs to ascertain the influencer's genuineness, presenting a genuine personality and conveying real-life experiences (Audrezet et al., 2020).

Results indicated that truthful endorsement significantly influences consumer attitudes toward the SMIs. The findings are consistent with recent studies, for example. Audrezet et al. (2020) and Shan et al. (2020) posited that when SMIs endorse brands that do not align with their personality and values, consumers view the partnership as being driven by external motivations (such as financial compensation) and consequently perceive it as inauthentic. SMIs endeavour to uphold transparency concerning their collaborations by explicitly notifying

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their audience about any incentivized content to prevent ambiguity. They cultivate a sense of authenticity by providing candid assessments of products and services (Al-Emadi & Yahia, 2020; Audrezet et al., 2020).

The findings indicated that perceived visibility substantially influences customer opinions toward the SMIs. Heightened self-disclosure blurs the line between frontstage and backstage, portraying the influencers as disclosing themselves in both physical and digital contexts.

Findings proved that perceived expertise significantly influences consumer attitudes toward the SMIs. The findings are consistent with recent studies; for example, researchers indicate that the endorser's expertise can impact brand attitude and facilitate changes in favour attitude (Zhu et al., 2022; Lee & Eastin, 2020), as well as influence opinion agreement (Karmarkar & Tormala, 2010). Contradictory results are evident in the literature, indicating that readers of reviews seldom consider source expertise indicators, such as the volume of reviews submitted (Filieri et al., 2021). Furthermore, source expertise has been found to have a weak or negative correlation with the perceived helpfulness of information (Breves, 2021).

Likewise, the results proved that perceived uniqueness significantly influences consumer attitudes toward the SMIs. The findings are consistent with recent studies, for example. Lee & Eastin (2020) posited that SMIs, characterized by their unique personality and content, serve as the origin of individual actions and ideas, thus establishing their authenticity. The perceived uniqueness of a social media influencer's content has been shown to enhance customers' willingness to engage with the influencer, adhere to their recommendations, and promote the influencer to others. This can be attributed to individuals' social aspirations to preserve a sense of distinctiveness, which drives consumption (Casaló et al., 2018).

In the same way, outcomes suggested that perceived authenticity significantly influences consumer attitudes toward SMIs. The findings are consistent with recent studies, for example. Lee and Eastin (2020) and Mahmood et al. (2023) demonstrate that when SMIs are perceived as authentic, they enhance their credibility and trustworthiness, positively influencing consumer perceptions of their recommendations, opinions, and content. Similarly, Audrezet et al. (2020) and Lee (2021) indicate that when consumers view SMIs as authentic, it typically results in positive attitudes, enhanced engagement, and a greater propensity to purchase or endorse the promoted products or services. A deficiency in authenticity may result in scepticism, reduced trust, and a detrimental effect on the influencer's perceived credibility.

Correspondingly, research findings indicated that perceived authenticity significantly influences consumer purchase intention. The findings are consistent with recent studies, for example. Erdogmuş and Çiçek (2012) suggest that a heightened perception of authenticity significantly increases the likelihood of consumers being influenced in purchasing decisions, establishing it as a crucial element in driving purchase intentions via influencer marketing. Lee & Eastin (2020) assert that perceived authenticity significantly influences consumer purchase intentions, particularly regarding SMIs. When consumers view an influencer as genuine, it enhances their readiness to buy products or services endorsed by that influencer.

Verdicts indicated that consumer attitudes towards SMIs significantly influence consumer purchase intentions. The findings are consistent with recent studies, for example. Consumers' attitudes towards SMIs considerably affect their intentions to make purchases. A favourable perception of a social media influencer enhances consumers' propensity to buy the products or services they promote. Similarly, Meahmood et al. (2023) posited that SMIs who evoke a positive response from consumers are viewed as more persuasive. Consumers tend to be swayed by the opinions, suggestions, and recommendations of influencers they hold in high regard, resulting in increased purchase intentions. Al-Emadi and Yahia (2020) determined that a consumer's positive attitude toward a social media influencer significantly increases the likelihood of considering and acting upon the influencer's product recommendations, resulting in enhanced purchase intentions.

The results also indicated that consumer attitude toward SMIs mediates the relationship between perceived authenticity and consumer purchase intention. The findings align with recent studies, for instance. Phua et al. (2020) argued that when an influencer is perceived as authentic, it positively shapes the consumer's attitude

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toward the influencer, and this improved attitude, in turn, enhances purchase intention. Their study found that the perceived authenticity of SMIs enhances consumers' attitudes toward the influencer, positively impacting purchase intentions. They suggest that authenticity fosters emotional connections, which mediate the influence of authenticity on consumer behaviour.

Audrezet et al. (2020) argue that authenticity in influencer marketing results in more favourable consumer attitudes. The favourable perception of the influencer enhances the likelihood of purchasing the products they promote. The research indicates that attitude is a significant mediating variable between perceived authenticity and purchase intention. Lou and Yuan (2019) investigated the impact of authenticity in influencer marketing, revealing that perceived authenticity positively influences consumers' attitudes toward the influencer and their purchase intentions. Consumer attitude is a mediating factor, indicating that positive consumer attitudes arising from authenticity result in increased purchase intentions.

Theoretical Contributions

This study adds to the existing literature on influencer marketing by examining the effect of SMI authenticity on consumer attitudes and purchase intentions within the automobile sector in Pakistan. This study integrates the Meaning Transfer Model of Celebrity Endorsement (McCracken, 1989) with the Authenticity Model of Computer-Mediated Communication (Lee, 2020). the study provides a novel framework for understanding how authenticity, as perceived by consumers, influences their behaviour in a technology-mediated environment. Both models, grounded in Ohanian's (1990) Source Credibility Theory, are adapted to reflect the unique dynamics of SMIs, extending the theoretical application of these models beyond traditional celebrity endorsements to the digital sphere.

The study also advances the understanding of the Meaning Transfer Model by demonstrating that the symbolic meaning associated with SMIs, when perceived as authentic, can effectively transfer to products in the automotive industry, influencing consumer attitudes and purchase decisions. This extends McCracken's original model, traditionally applied to celebrity endorsements, into a social media context, further validating its relevance in modern marketing strategies. Moreover, by applying the Authenticity Model of Computer-Mediated Communication to the automotive industry, this research contributes to understanding how consumers evaluate authenticity in influencer marketing within a specific sector. This focus on the automobile industry enriches the generalizability of authenticity models, offering new insights into how authenticity influences consumer attitudes and purchase intention in high-involvement, decision-heavy markets like automotive purchases.

Implications for Marketers

Marketers in the automotive industry should prioritize partnering with SMIs perceived as authentic and trustworthy by their audience. Authenticity strengthens consumer trust, which positively impacts attitudes and purchase intentions. To maximize the effectiveness of influencer marketing campaigns, marketers should ensure that influencers authentically align with the brand's values and products. Additionally, marketers can leverage influencers to create content that resonates emotionally with consumers, as this can foster stronger brand loyalty and engagement in high-involvement purchasing decisions, such as those related to automobiles.

Limitations and Future Research Directions

This study focuses exclusively on the automobile industry in Pakistan, potentially limiting the applicability of the findings to other sectors or geographical areas. Consumer behaviour and attitudes toward social media influencers vary significantly across cultures and markets, meaning the results may not fully apply to other countries or industries. Future research should examine the impact of social media influencer authenticity domains on consumer purchase intention in other product lines. Exploring how different authenticity dimensions, such as sincerity, visibility, expertise, truthful endorsement, and uniqueness, affect consumer trust and decision-making across various industries can provide valuable insights for marketers. Additionally, future studies could analyze the role of perceived alignment between an influencer's personal brand and the endorsed product, as this alignment may influence consumer engagement and brand perception.

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CONTENT MARKETING, BRAND AWARENESS, AND CUSTOMER LOYALTY IN EMERGING MARKET

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Abstract. In the dynamic landscape of emerging markets, where digital transformation and cultural nuances shape consumer behaviour, this study delves into the intricate interplay between content marketing, brand awareness, and customer loyalty within Egypt's burgeoning automobile industry from October 2024 to mid-January 2025. By employing a dual-perspective approach—capturing insights from both marketing teams and consumers—this research uncovers the pivotal role of brand awareness as a mediator in transforming content marketing efforts into enduring customer loyalty. Through a robust methodology involving 763 participants and advanced statistical analyses, the study reveals that while content marketing significantly enhances brand awareness, this heightened awareness ultimately drives customer loyalty. The findings underscore the importance of crafting high-quality, culturally resonant content that balances informational and entertainment value, particularly in a market characterized by diverse consumer preferences and digital literacy levels. Notably, the study highlights that brand loyalty is more strongly influenced by brand awareness than content marketing alone, emphasizing the need for marketers to prioritize strategies that amplify brand visibility and emotional connection. This research contributes to the growing body of knowledge on content marketing in emerging markets and offers actionable insights for practitioners aiming to navigate the complexities of the Egyptian market. This study provides a roadmap for leveraging content marketing to build brand equity and foster long-term customer loyalty in rapidly evolving economic environments by bridging the gap between theory and practice.

Keywords: content marketing; brand awareness; customer loyalty; Egypt; automobile market

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1. Introduction

The success of brands in emerging markets relies on fostering robust relationships with consumers (Vydeshwari, 2024). Establishing client loyalty is vital, particularly in dynamic and competitive settings like Egypt (Nagaty & El-Menawy, 2023). Establishing and maintaining these interactions depends on brand awareness—the degree of customer knowledge of a brand and its goods (Saleem et al., 2015; Ge & Ge, 2023). It influences overall brand propensity and customer buying decisions (Tolba, 2011). Content marketing is a powerful tool for increasing brand recognition and creating close relationships with target markets (Muharam et al., 2024). It means producing and distributing valuable, relevant, consistent information to draw in and keep a mainly targeted audience (Rady, 2018). Strategic content generation allows companies to interact with consumers, tell them about their goods, and establish themselves as thought leaders in their fields (Gaber & Elsamadicy, 2021; Eltokhy et al., 2024). Content marketing and customer loyalty have a complex relationship (Huang & Bunchapattanasakda, 2023). Good content marketing can improve brand awareness and influence customer loyalty, but this link is not direct (Huang & Bunchapattanasakda, 2023). Content marketing's ability to build

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consumer loyalty is impacted by several mediating variables (Omar, 2020; Bazi et al., 2023). Previous studies have shown the importance of brand awareness in tying customer loyalty with marketing campaigns (Alam et al., 2023). Research shows that in this connection brand awareness acts as a mediator between awareness of brands (Ishaq et al., 2014; Saleem et al., 2015). Content marketing's ability to create customer loyalty depends on brand recognition (Saleem et al., 2015). Research shows that client purchase intentions are much influenced by brand awareness, therefore impacting customer loyalty (Gaber & Elsamadicy, 2021).

Emerging markets provide different challenges and opportunities for marketers (Hollebeek et al., 2022). These markets show quick economic growth, rising disposable income and a growing middle class (Dabija et al., 2018). Still, they run against challenges, including poor infrastructure, changing economic times, and a diverse client base (Jimenez et al., 2016). Marketers must adapt their approaches to negotiate these obstacles and effectively include consumers in these evolving environments (Kristiyono et al., 2023). In Egypt, Eltokhy et al. (2024) discovered that customers' opinion of brand image in the telecoms sector is much influenced by digital content marketing (DCM). This implies that interesting and memorable materials can build confidence and favorable impressions, improving brand recognition. The study covers only one industry. Hence, its conclusions might not apply to other areas. More studies are required to investigate how content marketing affects brand awareness in various sectors of the Egyptian economy. The link between content marketing and client loyalty depends critically on brand recognition. As Shaina (2024) points out, brand awareness shows the consumer's capacity to identify and remember a particular brand, affecting purchasing decisions and loyalty. Khan et al. (2022) state that higher brand awareness increases familiarity, trust, and favorable brand connections, fostering consumer loyalty.

Brand awareness considerably enhances customer loyalty in emerging nations such as Egypt. In Bangladesh, Alam et al. (2023) discovered a positive relationship between brand awareness and consumer loyalty, implying that customer loyalty may also rise when brand awareness increases. However, the study does not investigate the precise processes by which brand awareness affects loyalty in Egypt. This discrepancy emphasizes the necessity of more investigation to comprehend how cultural and market-specific elements might influence this interaction. Various settings have been used to investigate the mediator function of brand awareness in the link between content marketing and consumer loyalty. Using their impact on brand image, Saleem et al. (2015) discovered that brand awareness favorably affects brand loyalty. Likewise, Anwar and Ali (2017) showed via customer satisfaction that brand awareness significantly affects consumer loyalty. These results imply that content marketing may raise brand recognition, fostering consumer loyalty and satisfaction.

However, there is little research on the mediating function of brand awareness in the Egyptian setting. By developing client loyalty, Nagi and Mohammed (2021) underline the relevance of digital marketing, especially content marketing, in generating long-term business development. Their research does not look at the mediating function of brand awareness. This disparity emphasizes the necessity of more studies to investigate how brand awareness moderates Egypt's link between content marketing and consumer loyalty.

Egypt offers special chances and difficulties for content marketing as an emerging market. Content marketing tactics find a suitable environment in the fast acceptance of digital technology and the presence of mobile devices (Nagi & Mohammed, 2021). However, issues like different degrees of digital literacy, poor access to trustworthy internet services, and a varied customer base need careful thought when creating and running content marketing efforts. Furthermore, cultural subtleties are pretty important in determining consumer behaviour in Egypt. Mohamed and Fahmi (2014) underline in building successful content marketing strategies, they need to know the cultural legacy, different demography, and changing societal values. The literature on the influence of cultural elements on brand recognition and consumer loyalty in Egypt is scant, nonetheless. Investigating how cultural subtleties affect the efficacy of content marketing techniques in increasing brand recognition and developing consumer loyalty is still much needed.

Brand awareness is A fundamental mediator between consumer loyalty and content marketing. It acts as a means of channelling the effectiveness of content marketing campaigns in fostering customer loyalty. It helps build a strong brand presence, which is essential to turning marketing initiatives into lifelong customer relationships (Zia et al., 2022; Ismail, 2017; Julaeha, 2024). It's based on the following. Boosting brand loyalty: Through

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raising brand awareness, content marketing may significantly increase brand loyalty. Customers who recognize and know organizations they value are more likely to build emotional ties and trust with them (Zia et al., 2022; Tijjang et al., 2023; Julaeha, 2024). Content marketing strategies that improve brand awareness through customer interaction are more successful: instructional articles, amusing films, and engaging social media posts. A key component of brand loyalty and client participation is raised by this consciousness (Julaeha, 2024). Brand awareness is essential to brand loyalty under trust and emotional connection, which helps consumers build trust and emotional relationships with them. Consumer knowledge of a brand improves confidence and emotional connection, increasing loyalty (Tijjang et al., 2023; Julaeha, 2024). Greater brand recognition raises the apparent value and quality of the material. Consumers are more willing to connect with and enjoy information from known brands, thereby building loyalty (Julaeha, 2024).

Evaluating brand awareness as a mediator between content marketing and customer loyalty has great potential benefits for academics. This area of research might assist in understanding how the efficacy of content marketing strategies in building consumer loyalty depends on brand awareness. By improving the mediation effects between content marketing and customer loyalty, academics may learn more about the mechanisms behind customer loyalty (Zollo et al., 2020; Aljuhmani et al., 2022; Bui et al., 2023). Especially in digital and social media contexts, knowing the mediating function of brand awareness helps academics assist businesses in developing more effective content marketing strategies that enhance brand loyalty (Tyrväinen et al., 2023; Bui et al., 2023; Al-Dmour et al., 2023).

Logistics, travel, and banking (Tijjang et al., 2023; Al-Dmour et al., 2023; Chahal & Bala, 2023), among other industries, may find a use for the outcomes. They offer a framework for assessing how brand awareness shapes customer loyalty in the banking, tourism, and logistics sectors. Supporting Brand Equity Research: This study might serve to enlarge the broader field of brand equity by understanding how brand awareness, as part of brand equity, impacts customer views and loyalty (Zollo et al., 2020; Ibrahim, 2021).The knowledge gained might direct further research initiatives, including looking at the impact of brand awareness on numerous types of content marketing or the function of brand awareness in different cultural or economic settings (Khamitov et al., 2019; Chahal & Bala, 2023). Researching brand awareness as a mediator between content marketing and customer loyalty would greatly help academics. It enhances the broader field of brand equity research, helps to build winning strategies, and clarifies knowledge of marketing dynamics. This study area offers prospective cross-industry applications and creates a foundation for further research initiatives.

This paper aims to analyze, in Egypt as an emerging market, the mediating variable between content marketing and consumer loyalty: brand awareness (e.g., Andespa et al., 2023). This study looks at the mediating function of brand awareness to clarify how content marketing tactics could effectively build customer loyalty in a dynamic and expanding market (e.g., Almohaimmeed, 2019). Understanding these elements can give marketers hoping to use content marketing important new perspectives (e.g., ElAydi, 2018). This will help to increase brand visibility and support ongoing client interactions in Egypt.

2. Theoretical framework and literature review

For companies trying to establish strong customer connections, content marketing—a deliberate method to produce and distribute excellent, relevant, and consistent material to attract and keep a well-defined audience—has become even more critical (Nagi & Mohammed, 2021). Still, there is much to learn about the particular processes by which content marketing affects consumer loyalty. This section attempts to clarify the possible mediating role of brand awareness, a fundamental concept in marketing that denotes the consumer's knowledge and comprehension of a particular brand (Saleem et al., 2015).

For marketers, emerging markets like Egypt provide special possibilities and problems. These markets have complicated customer demographics, different degrees of digital literacy, and competitive environments, even if their development potential is sometimes great. In such surroundings, increasing the visibility and legitimacy of a company depends on raising brand awareness. Studies imply that consumer loyalty in emerging markets is much influenced by brand awareness (Alam et al., 2023; Anwar, 2023; Sunday & Olasoji, 2023). This is so because brand awareness can:

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A. A highly conscious client is likelier to see a brand favourably, fostering more confidence and loyalty (Sunday & Olasoji, 2023).
B. Foster brand competency: Brand awareness may indicate the dependability and knowledge of a brand, so guiding consumers to choose it above rivals (Sunday & Olasoji, 2023).
C. Customers who know a brand are more likely to connect it with specific values and advantages, influencing their buying behaviour (Sunday & Olasoji, 2023).

Especially in the digital realm, content marketing techniques can significantly raise brand awareness. Businesses may reach their target markets by producing interesting, educational, and relevant material, strengthening brand awareness and good relationships. Numerous studies show how well content marketing raises brand awareness:

A. Social Media Marketing: Research on the Egyptian telecommunications sector indicates that digital content marketing (DCM) substantially affects consumers' brand image perceptions (Eltokhy et al., 2024). Engaging and memorable content cultivates trust and favorable perceptions, enhancing brand image and awareness.
B. User-Generated Content (UGC): Although UGC and firm-generated content (FGC) did not exhibit a direct significant effect on brand loyalty, they remain pertinent to brand awareness (Zia et al., 2022). This implies that content marketing strategies should promote user participation and interaction to elevate brand awareness.
C. Online Brand Community Engagement: Research on medical aesthetic clinics in Thailand illustrates the correlation between online brand community engagement and brand loyalty, underscoring the significance of brand awareness in this context (Phijaranakul, 2022).

These results imply that good content marketing may raise brand recognition through social media, user-generated content, and online community participation. On the other hand, the research implies that brand awareness might mediate between content marketing and consumer loyalty. This implies that content marketing indirectly shapes client loyalty by affecting brand awareness.
Studies conducted on its impact on brand image and brand awareness favourably affect brand loyalty (Saleem et al., 2015). This implies that a stronger brand image resulting from content marketing techniques raising brand awareness can inspire customer loyalty.

A. Studies in Pakistan's textile industry and in relation to Laurier goods in Indonesia have revealed that brand awareness greatly affects consumer loyalty through customer satisfaction (Anwar & Ali, 2017; Anwar, 2023). These results imply that content marketing may raise brand recognition, increasing customer happiness and driving customer loyalty.
B. Mediators' trust and loyalty: Studies on Kentucky Fried Chicken in Indonesia show the need for trust and loyalty as mediators in the link between brand awareness and brand equity (Rohman & Wijayanti, 2023). This suggests that content marketing may raise brand awareness, strengthen trust and loyalty, and support brand equity.

Although the literature provides convincing evidence for the mediation role of brand awareness in the content marketing-customer loyalty connection, more study is required to investigate this dynamic in the Egyptian environment.

A. Egypt, an emerging market, offers both possibilities and difficulties for content marketing. Content marketing tactics find a suitable environment in the fast acceptance of digital technology and the presence of mobile devices (Nagi & Mohammed, 2021). However, issues like different degrees of digital literacy, restricted access to dependable internet connections, and a varied customer base need careful thought when creating and running content marketing efforts.
B. Effective content marketing in Egypt depends on a knowledge of cultural quirks and consumer tastes. The rich cultural legacy, varied population, and changing societal values of the nation call for a sophisticated strategy for content development and delivery (Mohamed & Fahmi, 2014).
C. Restricted Research Concentration: Though content marketing is becoming increasingly important in Egypt, there are few studies on the mediating effect of brand awareness in this emerging market. More studies are required to investigate how content marketing shapes consumer loyalty and brand recognition in Egypt.

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This research assessment has underlined the important mediator role of brand awareness in the link between content marketing and consumer loyalty. Although studies conducted in other settings show clear proof of this dynamic, more studies are required to investigate these phenomena in the Egyptian market.

3. Study methodology and design

3.1 Research gap

Particularly in Egypt, an emerging market, this portion seeks to highlight gaps in the current research on the mediating role of brand awareness in the link between content marketing and consumer loyalty. Although much research has looked at the unique impacts of brand awareness, content marketing, and consumer loyalty, a thorough knowledge of how brand awareness is a mediating variable in this particular link remains elusive. Examining the body of current research, this review highlights important conclusions, points up areas of agreement and disagreement, and points up significant gaps that demand more study.

Many studies have shown how important brand awareness is for fostering consumer loyalty. Establishing brand awareness can help improve customer retention since (Zia et al., 2022) observed that brand awareness favourably affected brand loyalty in the fast-food sector. Tanudjaja and Sugiyanto (2023) similarly showed, especially when mediated by customer satisfaction, the significant impact of brand knowledge on customer loyalty in the Yoshinoya restaurant chain. These results highlight the need for brand awareness as a necessary antecedent to client loyalty.

Still, a major void in the literature is the dearth of particular studies examining the mediating role of brand awareness within Egypt. Although studies such as (ElAydi, 2018) have examined how social media marketing affects brand recognition in Egypt's mobile services industry, they do not specifically look at the relationship between brand awareness and consumer loyalty using content marketing. This emphasizes the importance of more study in the Egyptian market to grasp how brand awareness is a mediator in this particular link.

Conversely, content marketing has become quite an effective instrument for raising brand recognition and involving consumers. Content marketing is a useful digital marketing tool for improving brand exposure, according to (Vydeshwari, 2024), which implies that businesses making good use of this tool have better brand recognition. Gaber and Elsamadicy (2021) underlined, even more, the part user-generated content on social media plays in affecting airline brand equity, including brand awareness, in 2021. These studies support how effectively content marketing raises brand recognition.

The literature does not, however, clearly show how content marketing, in its mediating capacity of brand awareness, especially fosters customer loyalty. Although Canny and Tunjungsari (2021) looked at the mediating effects of brand awareness and brand loyalty in the link between firm-generated content and purchase intention, they did not look at the direct influence of content marketing on customer loyalty mediated by brand awareness. The lack of empirical research, especially looking at this relationship in the Egyptian market, highlights this disparity even more and leaves a great void in our knowledge of how content marketing affects customer loyalty in this emerging market.

Many studies have looked at the several dimensions of consumer loyalty and its importance for the operation of companies. Saleem et al. (2015) showed that the beverage sector's brand loyalty is impacted by brand image, which is shaped by brand awareness and perceived quality. In the fashion sector, Sudirjo et al. (2023) likewise discovered a strong correlation between brand recognition and customer loyalty, suggesting that acknowledged brand qualities help to keep consumers. These results underline client loyalty's critical need to reach long-term corporate success.

The body of research does not fully grasp how content marketing, mediated by brand awareness, influences consumer loyalty. Although studies like those of Górska-Warsewicz and Kulykovets (2020) have looked at hotel customer loyalty, they do not address the particular role of brand awareness in mediating the link between content marketing and customer loyalty. In Egypt, where the emerging market environment offers special

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possibilities and difficulties for companies to foster consumer loyalty using successful content marketing strategies, this gap is especially pertinent.

Examining the mediating role of brand awareness in the interaction between content marketing and consumer loyalty finds a special setting in the Egyptian market. Egypt has great chances for companies in a growing market to develop strong brands and foster devoted consumer bases. Nagaty and El-Menawy (2023) underlined the need for entrepreneurial marketing to drive business sustainability in Egypt's small and medium-sized businesses (SMEs), stressing the need for creative marketing strategies for success.

Nonetheless, there is a dearth of particular research examining the mediating influence of brand awareness in the framework of content marketing and consumer loyalty within the Egyptian market. Though studies like ElAydi (2018) have looked at social media marketing and brand awareness in Egypt, they do not thoroughly examine how brand awareness moderates the link between content marketing and consumer loyalty. This discrepancy in the literature emphasizes the necessity of more investigation to grasp the particular dynamics of brand development and consumer interaction in the Egyptian market.

3.2 Study problem

This paper explores the critical role of brand awareness as a mediator in the link between content marketing and consumer loyalty, especially looking at the Egyptian market as an emerging economy. Although many studies have looked at how digital marketing affects brand awareness and customer loyalty (Khan et al., 2022; Raj, 2024; Shaina, 2024), a major knowledge vacuum exists about the mediating role of brand awareness in the framework of content marketing, especially in the particular terrain of Egypt.

The Egyptian market is characterized by a growing digitally aware customer base (Sadek et al., 2018). This creates both possibilities and problems for businesses wanting to embrace content marketing. On one side, digital channels offer a direct means of interacting with and reaching customers (Van & Fah, 2022.). Conversely, customers are becoming more discriminating and demanding and want firms to offer interesting and customized information that fits their particular needs (Thundeniya & Dissanayake, 2024).

Developing good content marketing plans depends on an awareness of Egypt's changing customer behaviour patterns. This covers examining elements like:

A. Finding the most often used social media sites and knowing how users interact with material on them would help one better understand their behavior (Eltokhy et al., 2024).
B. Determining the kinds of information Egyptian customers find appealing—video content, interactive materials, or instructional materials—will help you target them better (Maisarah & Santoso, 2024).
C. Examining customers' research and buying decisions—including the part internet reviews and suggestions play—helps one better understand their behaviour (Hermarenand Achyar, 2018).
D. Knowing how Egyptian customers see various brands and the elements influencing their brand choices can help one to understand them better (Rohman & Wijayanti, 2023).

This study has major ramifications for companies in Egypt trying to use content marketing to boost brand awareness and customer loyalty. Understanding the mediating role of brand awareness helps businesses' content initiatives to be more focused and successful.

Based on the foregoing, the following question arises:

What is the role of brand awareness in the relationship between content marketing and customer loyalty in the Egyptian markets?

3.3 Study aims

This study sheds important light on the role of brand awareness as a mediator in the Egyptian market between content marketing and consumer loyalty. This information can enable companies and marketers to create more successful content marketing plans that support long-term brand survival.

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3.4 Importance of the study

Particularly, this study can offer an understanding of:

A. Finding the most successful content forms and channels for interacting and reaching target consumers in the Egyptian market will help to maximize content production and distribution strategies (Khasgiwala et al., 2024; Thundeniya & Dissanayake, 2024).
B. Creating material that appeals to Egyptian consumers: Knowing the particular interests and motivations of various consumer categories, and customizing material in line with them (Eltokhy et al., 2024; Maisarah & Santoso, 2024).
C. Leveraging social media effectively: Engaging consumers, raising brand awareness, and strengthening community (Van & Fah, 2022; Eltokhy et al., 2024).
D. Evaluating content marketing's influence: Monitoring important indicators of brand recognition, interaction, and loyalty can help one evaluate the success of content marketing programs (Alam et al., 2023; Raj, 2024).

3.5 Study hypotheses

Based on a critical review of the given literature and their applicability to the research issue, this part presents the hypotheses of the study: Brand awareness as a mediator between content marketing and consumer loyalty: evidence from Egypt as emerging market.

Hypothesis 1: Content marketing positively influences brand awareness.

This theory suggests a straight positive link between brand recognition and content marketing initiatives. It is consistent with the results of several studies stressing the need of digital marketing in improving brand exposure and recognition (Izza et al., 2024; Khasgiwala et al., 2024; Raj, 2024; Vydeshwari, 2024). For example, content and influencer marketing help increase brand recognition among TikHub Shop users in Cirebon City, according to Izza et al. (2024). Analogously, Khasgiwala et al. (2024) found a notable and favorable relationship between digital marketing strategies and brand recognition among users of digital media.

The basic ideas of content marketing help to justify this theory. Content marketing seeks to provide consistent, relevant, and valuable material to draw in and interact with a well-defined audience, therefore promoting lucrative consumer activity (Iqbal et al., 2024). Through a variety of content formats—blog entries, films, infographics, and social media updates—valuable information, entertainment, or solutions can help companies be more visible and reach a larger audience. More brand knowledge and recognition among possible consumers follow from this visibility.

This hypothesis should provide a positive link between brand awareness levels and the degree of content marketing activity intensity. This suggests that brand recognition within their target market would be better for companies using more successful and consistent content marketing techniques.

Hypothesis 2: Brand awareness positively influences customer loyalty.

This hypothesis implies a direct positive association between brand awareness and consumer loyalty. It extends on the accepted knowledge that developing consumer interactions depends critically on brand recognition and familiarity (Khan et al., 2022; Alam et al., 2023; Iqbal et al., 2024). Research has underlined how brand awareness influences customer loyalty, implying that customers are more likely to be devoted to companies they know and identify (Saleem et al., 2015; Khan et al., 2022; Alam et al., 2023). For instance, brand awareness mediated by social media marketing identified a favorable link between social media marketing and brand loyalty, Khan et al. (2022) reported.

The ideas of familiarity and trust justify this theory. Consumers are more likely to view a brand as trustworthy and reliable when they know of it (Sadek et al., 2018). This familiarity lowers doubt and danger about selecting a certain brand, fostering more confidence and loyalty. Long-term customer loyalty results from consumers being more likely to repeatedly buy items from brands they know and trust.

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This theory's intended result is a positive link between consumer loyalty ratings and brand awareness degrees. Higher degrees of brand awareness implies that brands will attract more customer loyalty as customers are more likely to be familiar with, trust, and routinely buy from these companies.

Hypothesis 3: Brand awareness mediates the relationship between content marketing and customer loyalty. According to this theory, customer loyalty and content marketing mediate brand recognition. It suggests that content marketing influences customers.

3.6 Research design

This study employs two questionnaires to examine the relationships among content marketing, brand awareness, and customer loyalty. A design structured questionnaire based on validated measurement scales from prior literature tests the hypotheses. The study adopts a survey approach to collect customer and marketing teams' data, ensuring comprehensive perspectives on the constructs. The study applies a purposive sampling technique to ensure that participants have relevant experience with the brand and its marketing initiatives. The sample size is figured out using statistical power analysis, and at least 763 responses are needed to ensure that structural equation modelling (SEM) works well.

The constructs are measured using Likert-scale items adapted from prior studies, such as Content Marketing (Customer Point of View), and measured using items related to informative and entertainment value. Brand Awareness from the Marketing Teams' Perspective: Items assess customers' attention, recall, and engagement (Sánchez-Mena & Martí-Parreño, 2017; Samala et al., 2019). However, from the customers' perspective, the items assess factors such as logo recall, brand familiarity, and uniqueness (Yoo et al., 2000; Graciola et al., 2020). Finally, Customer Loyalty from the Marketing Teams' Perspective: Items capture customer commitment, advocacy, and the intention to recommend (Harwood & Garry, 2015; Samala et al., 2019). However, from the customers' perspective, items assess brand preference, purchase intent, and exclusivity (Yoo et al., 2000; Yoo &Donthu, 2001).

The study distributed the questionnaire electronically through email and social media platforms. A pilot test with 30 respondents ensures clarity and reliability for the items for two targeted audiences—marketing teams and customers. The study informed respondents of its purpose and ensured their voluntary participation. The current study included 763 participants, including marketing teams and customers of automobile companies operating in Egypt, whether locally manufactured or imported. In other words, the study utilized two samples of marketing teams and consumers, each comprising 384 participants. The study obtained the participants by running targeted advertisements for the Egyptian automotive sector on Google and Facebook.

3.7 Limitations

Potential limitations include self-reported biases and the study's cross-sectional nature, which limits causal inference. Future studies could use longitudinal designs or experimental methods for deeper insights.

4. Data analysis and hypothesis testing

4.1 Study sample characteristics

The study shows the characteristics of the participants in the questionnaire through three demographic characteristics.

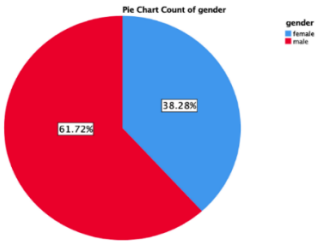


Figure 1. study sample according to gender
Source: based on SPSS v25 output

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Figure 1 illustrates the distribution of the study sample by gender, with males representing the largest proportion at 61.72%, while females account for 38.28%. This distribution highlights a distinct disparity in gender representation within the sample, which may reflect the characteristics of the study or the circumstances surrounding participant selection.

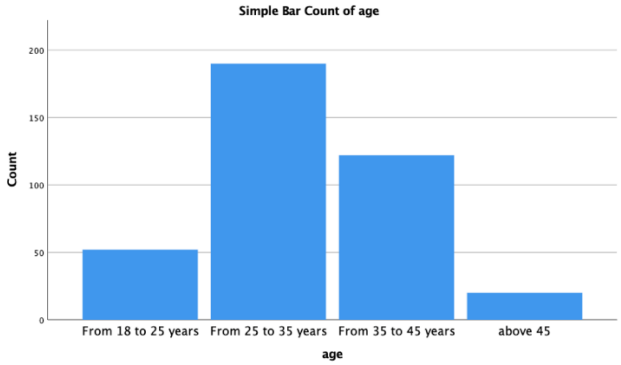


Figure 2. study sample according to age
Source: based on SPSS v25 output

The Figure 2 illustrates the age group distribution within the sample. It reveals that the 25-35 age group has the highest representation in the study, surpassing all other groups in participant numbers. Following this, the 35-45 age group also demonstrates significant representation, albeit less than the 25-35 category. In contrast, the 18-25 age group accounts for the fewest participants, with a marked decline in participants over 45 years old. This distribution suggests a trend skewed towards younger to middle-aged participants (25-45 years old), potentially reflecting the study's focus or the intended demographic.

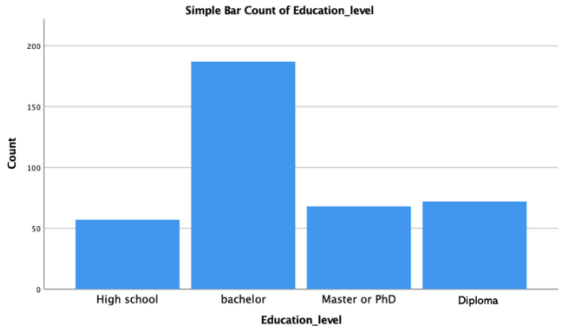


Figure 2. study sample according to Education level
Source: based on SPSS v25 output

Figure 3 illustrates the education level distribution among the sample. It reveals that most participants possess a bachelor's degree, the most predominant category. In contrast, other categories, including high school graduates, individuals with advanced qualifications (master's or doctorate), and those with diplomas, show considerably lower percentages.

4.2 Reliability and validity

Table 1 presents the reliability and validity analysis findings for the study variables, as viewed by both marketing teams and customers. The results demonstrate strong reliability and validity for most variables, confirming the dependability and precision of the data collection tools employed.

Table 1. Reliability and validity result

Variables	code	items	Cronbach's alpha	validity
Marketing teams' point of view				
Brand awareness	BAM	4	0.796	0.892
Brand loyalty	BLM	4	0.806	0.898
Content Marketing based on entertainment value	cmmiv	4	0.848	0.921
Content Marketing based on informative value	cmmev	4	0.735	0.857

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Variables	code	items	Cronbach's alpha	validity
Customers' point of view				
Brand awareness	BAC	5	0.786	0.887
Brand loyalty	BLC	3	0.789	0.888
Content Marketing based on entertainment value	cmif	4	0.784	0.886
Content Marketing based oninformative value	cmev	4	0.798	0.893

Source: based on SPSS v25 output.

4.2.1 From the perspective of marketing teams

4.2.1.1 Reliability: The variables showed high levels of reliability, as Cronbach's Alpha values exceeded the acceptable limit (0.7). The highest value was for content marketing, with its entertainment value (0.848), reflecting the high reliability of the tool used to measure this variable.

4.2.1.2 Validity: The values associated with validity for all variables were high, exceeding 0.85, indicating the quality of the tools in accurately measuring the variables. The results generally reflect the reliability and accuracy of the tools used to measure brand awareness, brand loyalty, and content marketing (entertainment and informational aspects).

4.2.2 From the perspective of customers

4.2.2.1 Reliability: The reliability levels for all variables were good, as Cronbach's Alpha values ranged between 0.784 and 0.798, indicating the consistency of the tools.

4.2.2.2 Validity: The values associated with validity were also high for all variables, exceeding 0.88, which enhances the reliability of the instruments.

These results reflect that marketing teams and customers have consistent and accurate responses regarding brand awareness, brand loyalty, and content marketing (entertainment and informational aspects).The results indicate that the instruments used to measure the variables are reliable and valid from both the marketing teams and customer perspectives. The high reliability and validity values demonstrate the ability of these instruments to accurately and effectively measure the targeted concepts. Accordingly, these instruments can be relied upon to provide reliable results for the study and its analysis.

4.3 Descriptive statistics

This section outlines the descriptive statistical measures relevant to the research variables. The data presented in Table 2 vividly illustrate which statements garnered the highest and lowest levels of agreement based on the study sample's responses. Following this, the general trends in responses for each research item are discussed.

The means indicate the average responses, showing that most items have means ranging from 3.81 to 4.19, reflecting a generally positive response level. Furthermore, the standard deviation (between 0.546 and 1.104) is relatively low, suggesting good convergence in the participants' responses.

Table 2. Descriptive measures from the marketing teams' point of view

Items	Skewness		Kurtosis		Mean	Std. Deviation	coefficient of variation
	Statistic	Std. Error	Statistic	Std. Error			
Customers would like to learn more about our brand	-1.122	0.125	0.777	0.248	3.99	1.082	27.12%
Customers will pay much attention to anything about our brand	-1.228	0.125	1.503	0.248	4.19	0.925	22.08%
Anything related to our brand will grab the attention of customers	-1.109	0.125	0.621	0.248	4.11	1.017	24.74%
Customer sharing of their experience and recalling memories will help increase brand awareness	-1.143	0.125	1.013	0.248	4.11	0.979	23.82%
Brand awareness	**-1.574**	**0.125**	**2.999**	**0.248**	**4.102**	**0.708**	**17.25%**
Using our product will increase customer commitment to our brand	-1.119	0.125	1.1	0.248	4.11	0.959	23.33%
Customers would intend to keep using our brand	-1.108	0.125	1.03	0.248	4.04	0.996	24.65%

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Items	Skewness		Kurtosis		Mean	Std. Deviation	coefficient of variation
	Statistic	Std. Error	Statistic	Std. Error			
Customers will speak positively about our brand	-1.07	0.125	0.755	0.248	4.02	1.015	25.25%
Customers will recommend our brand to others	-1.114	0.125	0.691	0.248	3.97	1.104	27.81%
Brand loyalty	**-1.355**	**0.125**	**2.093**	**0.248**	**4.038**	**0.729**	**18.05%**
Our videos provide relevant product information	-0.596	0.125	1.52	0.248	4	0.682	17.05%
Our videos provide timely product information	-1.363	0.125	2.926	0.248	3.86	0.841	21.79%
Our videos provide useful product information	-0.887	0.125	0.968	0.248	3.86	0.841	21.79%
Our videos provide valuable product information.	-0.759	0.125	0.592	0.248	3.81	0.874	22.94%
Content Marketing: Informative value	-0.943	0.125	2.443	0.248	3.882	0.576	14.84%
Our videos are entertaining.	-1.218	0.125	2.419	0.248	4.02	0.788	19.60%
Our videos are enjoyable.	-0.861	0.125	0.44	0.248	3.91	0.918	23.48%
Our videos are exciting.	-1.022	0.125	1.292	0.248	3.86	0.907	23.50%
Our videos are pleasing.	-0.643	0.125	0.064	0.248	3.84	0.918	23.91%
Content Marketing: Entertainment value	-0.897	0.125	1.593	0.248	3.907	0.676	17.31%
Content Marketing	**-0.972**	**0.125**	**2.937**	**0.248**	**3.894**	**0.546**	**14.02%**

Source: based on SPSS v25 output.

The Coefficient of Variation indicates the extent of data variation relative to the mean. The values are relatively low, ranging from 14.02% to 27.81%, reflecting a moderate to low degree of variation in the data, which signals a positive indicator of response consistency.

Skewness: All values are negative, suggesting that the distribution is slightly skewed towards higher values (positive). Kurtosis values are near zero, indicating that the distribution is approximately normal for some items while others exhibit slight skewness.
In addition, the previous Table 2 shows the following:

A. Brand Awareness: A low coefficient of variation (17.25%) indicates close responses and skewness and kurtosis indicate a close-to-normal distribution.
B. Brand Loyalty: The mean (4.038) and low standard deviation (0.729) reflect high loyalty, and low variance (18.05%), enhancing homogeneity.

Content Marketing: Items related to “entertainment value” and “informational value” show stable distributions and a tendency toward positive responses, with a low coefficient of variation (<15% for total value).

Table 3. Descriptive measures from the customers' perspective

Items	Skewness		Kurtosis		Mean	Std. Deviation	coefficient of variation
	Statistic	Std. Error	Statistic	Std. Error			
When I think of the company, the symbol or the logo comes to mind.	-1.204	0.125	1.252	0.248	4.09	0.996	24.35%
I am very acquainted or accustomed with the brand of this company.	-1.252	0.125	1.184	0.248	4.14	1.01	24.40%
This brand differs from other competing brands.	-1.166	0.125	1.058	0.248	3.99	1.038	26.02%
I am aware of product’s company	-1.529	0.125	2.908	0.248	4.29	0.858	20.00%
I can quickly recall the symbol or logo of the automobile company I own	-1.091	0.125	0.821	0.248	4.09	0.991	24.23%
Brand awareness	**-1.71**	**0.125**	**4.392**	**0.248**	**4.121**	**0.640**	**15.53%**

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Items	Skewness		Kurtosis		Mean	Std. Deviation	coefficient of variation
	Statistic	Std. Error	Statistic	Std. Error			
I consider myself to be loyal to brand of my automobile	-0.953	0.125	0.302	0.248	3.97	1.069	26.93%
brand of my automobile would be my first choice.	-1.156	0.125	0.98	0.248	4.05	1.042	25.73%
I will not buy other brands if brand of my automobile is available at the store.	-1.382	0.125	1.844	0.248	4.31	0.882	20.46%
Brand loyalty	**-1.182**	**0.125**	**1.441**	**0.248**	**4.111**	**0.747**	**18.18%**
The videos' brand of my automobile I have watched provide relevant product information	-1.426	0.125	1.969	0.248	4.24	0.935	22.05%
The videos' brand of my automobile I have watched provide timely product information	-1.432	0.125	2.102	0.248	4.17	0.963	23.09%
The videos' brand of my automobile I have watched provide useful product information	-1.364	0.125	1.796	0.248	4.19	0.975	23.27%
The videos' brand of my automobile I have watched provide valuable product information.	-1.199	0.125	1.277	0.248	4.14	0.97	23.43%
Content Marketing: Informative value	-1.7	0.125	3.905	0.248	4.186	0.677	16.18%
The videos about my automobile brand that I have watched are entertaining.	-1.128	0.125	1.254	0.248	4.11	0.942	22.92%
The videos about my automobile brand that I have watched are enjoyable.	-1.055	0.125	0.73	0.248	4.01	1.023	25.51%
The videos I've watched about my automobile brand have been exciting.	-1.157	0.125	1.085	0.248	4.2	0.94	22.38%
The videos I've watched about my automobile brand are enjoyable.	-0.969	0.125	0.926	0.248	3.99	0.942	23.61%
Content Marketing: Entertainment value	-1.585	0.125	3.776	0.248	4.079	0.665	16.30%
Content Marketing	**-1.944**	**0.125**	**5.948**	**0.248**	**4.132**	**0.593**	**14.36%**

Source: authors, based on SPSS v25 output

Most values show negative skewness, indicating that the distributions are slightly skewed to the left; most responses tend toward high ratings. The skewness values fall within the acceptable range for indicating a normal distribution (from -2 to +2), suggesting that the distribution is generally quite symmetrical.

The kurtosis values are also within the acceptable range (from -2 to +2), indicating that the distribution is close to normal. Some items, such as BAC4 and cmif2, exhibited slightly higher kurtosis, suggesting more pronounced peaks in the distribution.

The average values for all items are relatively high (ranging from 3.9 to 4.3), indicating a positive rating from customers for most variables. The standard deviation values are moderate, suggesting variability in the responses, but not to an excessive degree.
Also, the previous Table 3 the following:

A. Brand awareness: mean = 4.392 and coefficient of variation = 15.53% (the lowest among all dimensions). Thus, the responses are consistent and have a high degree of customer agreement.
B. Brand Loyalty: Items such as BLC3 show slight variance (coefficient of variation = 20.46%), but the overall mean (4.111) indicates a strong positive perception of loyalty.
C. Content Marketing, Informational Value: The mean is high (4.186), and the coefficient of variation is low (16.18%), indicating a strong and consistent appreciation of informational value.

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D. Entertainment Value: The mean = 4.079 and the coefficient of variation = 16.30%. This indicates that customers value the entertainment aspect of content marketing with a moderate degree of agreement.

Overall, the ratings are positive (all means exceed 4.0), reflecting a favorable perception of the variables studied from the customers' viewpoint. The low coefficients of variation for some items demonstrate a strong level of agreement, particularly in areas such as brand awareness and the informational value of content marketing.

4.4 Correlation analysis

The correlation coefficient results express the strength of the relationships between the variables. All positive values indicate a direct relationship, meaning that as one variable increases, the other variable also increases. Values closer to 1 represent a very strong relationship, while values between 0.3 and 0.7 indicate a medium relationship. Values less than 0.3 are considered weak.

Table 4 shows the correlation analysis between the study dimensions from the marketing teams point of view using Pearson's correlation coefficient.

Table 4. Correlation between study dimensions from marketing teams' point of view

		BAM	BLM	cmmiv	cmmev
BAM	Pearson Correlation	1	.453**	.011	.112*
	Sig. (2-tailed)		.000	.830	.028
	N	384	384	384	384
BLM	Pearson Correlation	.453**	1	.051	.070
	Sig. (2-tailed)	.000		.314	.173
	N	384	384	384	384
cmmiv	Pearson Correlation	.011	.051	1	.517**
	Sig. (2-tailed)	.830	.314		.000
	N	384	384	384	384
cmmev	Pearson Correlation	.112*	.070	.517**	1
	Sig. (2-tailed)	.028	.173	.000	
	N	384	384	384	384

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

*. Correlation is significant at the 0.05 level (2-tailed).

Source: authors, based on SPSS v25 output.

Table 5 shows the correlation analysis between the study dimensions from the customers' perspective using Pearson's correlation coefficient. The results indicate a strong positive correlation between all dimensions, with high statistical significance at the 0.01 level.

Table 5. Correlation between study dimensions from customers' point of view

		BAC	BLC	cmif	cmev
BAC	Pearson Correlation	1	.503**	.555**	.550**
	Sig. (2-tailed)		.000	.000	.000
	N	384	384	384	384
BLC	Pearson Correlation	.503**	1	.518**	.468**
	Sig. (2-tailed)	.000		.000	.000
	N	384	384	384	384
cmif	Pearson Correlation	.555**	.518**	1	.564**
	Sig. (2-tailed)	.000	.000		.000
	N	384	384	384	384
cmev	Pearson Correlation	.550**	.468**	.564**	1
	Sig. (2-tailed)	.000	.000	.000	
	N	384	384	384	384

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

Source: authors, based on SPSS v25 output.

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4.5 Hypotheses' results based on marketing teams' point of view

Figure 4 illustrates the path analysis for examining the dimensions from a marketing teams perspective, leading to the following conclusions:

Brand awareness: Figure 4 shows it as a central element connected to the four indicators (BAM1, BAM2, BAM3, BAM4). The values associated with these indicators (0.784, 0.630, 0.730, 0.662) reflect strong and positive contributions to shaping brand awareness.

Brand loyalty: It is associated with indicators (BLM1, BLM2, BLM3, BLM4) that have values (0.659, 0.777, 0.712, 0.707). These high values highlight the significance of these indicators in strengthening brand loyalty.
Content marketing based on informational value: The results indicate a direct effect of brand awareness (0.015) and an effect of brand loyalty (0.088) on the informational value of content marketing. The indicators related to this value (cmmiv1, cmmiv2, cmmiv3, cmmiv4) demonstrate strong values (0.345, 0.752, 0.529, 0.880), reflecting the quality of the information provided in this marketing area.

Content marketing based on entertainment value: There is an effect of brand awareness (0.112) and a moderate effect of brand loyalty (0.030) on the entertainment value of content marketing. The indicators related to this value (cmmev1, cmmev2, cmmev3, cmmev4) show high values (0.819, 0.755, 0.831, 0.641), demonstrating the effectiveness of this type of content in enhancing appeal and entertainment.

The most substantial relationship among the indicators was observed in the effect of loyalty and brand awareness on the dimensions of content marketing, with the indicators linked to each dimension (awareness, loyalty, content marketing) demonstrating high levels of positive influence on the core dimensions. These findings emphasize the significance of integrating awareness and brand loyalty as crucial elements in enhancing content marketing strategies.

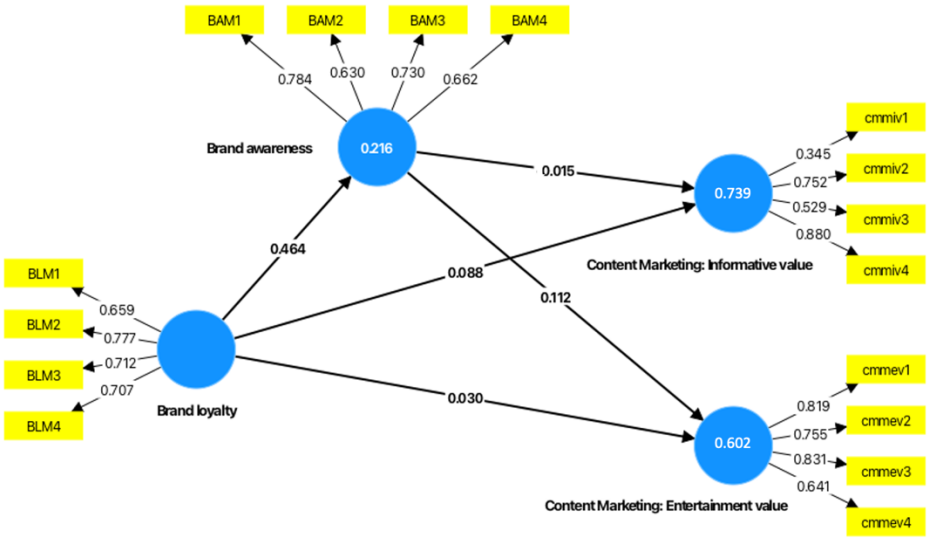


Figure 4. Path analysis to study dimensions from marketing teams' point of view
Source: authors, based on smart-Pls v4 output.

Table 6 shows the impact of brand awareness on content marketing (entertainment value). The table indicates that the path coefficient (Coff) between brand awareness and content marketing: entertainment value is 0.112, with a high T-statistic value of 5.666 and a very low P-value (0.000), signifying a significant impact. This implies a positive and significant relationship between brand awareness and the entertainment value of marketing content.

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The impact between brand awareness and content marketing (information value): Although the path coefficient (Coff) between "brand awareness" and "content marketing: information value" is much lower (0.015), the T-value is 2.890 and the P-value is also 0.000. This indicates a significant but weak impact compared to the previous relationship.

The impact between brand loyalty and brand awareness: The path coefficient between "brand loyalty" and "brand awareness" was 0.464, the highest in Table 6, indicating a strong impact. In addition, the T-value was 8.365 and the P-value was 0.000, confirming the significance of this impact. This indicates that brand loyalty has a significant role in enhancing brand awareness.

The impact between brand loyalty and content marketing (entertainment value): The path coefficient between "brand loyalty" and "content marketing: entertainment value" was 0.030, with a T-statistic of 3.979 and a P-value of 0.000, indicating a significant but weak impact. This indicates that brand loyalty is associated with the entertainment value of marketing content, but to a weak degree.

The impact between brand loyalty and content marketing (informational value): The table shows that the path coefficient is 0.088, with a t-statistic value of 8.898 and a p-value of 0.000. Although the impact is not as strong as the relationship between loyalty and awareness, it is significant and significant, meaning that brand loyalty affects the informational value of marketing content.

These results suggest that brand awareness is important in enhancing both brand loyalty and content marketing, both in terms of entertainment and informational value. While brand awareness shows a stronger impact on entertainment value than on informational value.

Table 6. Path coefficient for study dimensions from the marketing teams' point of view

Path	Coff	T statistics	P values
Brand awareness -> Content Marketing: Entertainment value	0.112	5.666	0.000
Brand awareness -> Content Marketing: Informative value	0.015	2.890	0.000
Brand loyalty -> Brand awareness	0.464	8.365	0.000
Brand loyalty -> Content Marketing: Entertainment value	0.030	3.979	0.000
Brand loyalty -> Content Marketing: Informative value	0.088	8.898	0.000

Source: authors, based on smart-Pls v4 output.

Figure 5 shows that brand awareness is represented as an influential factor on content marketing. It is associated with indicators (BAM1, BAM2, BAM3, BAM4) with high coefficient values ranging between (0.628 - 0.783), reflecting the strength of these indicators in shaping awareness.

The impact of brand awareness on content marketing appears with a value of (0.108), which is a positive but moderate effect. This indicates that brand awareness plays an important role but is not the only factor affecting the quality and effectiveness of content marketing.

Brand loyalty is associated with indicators (BLM1, BLM2, BLM3, BLM4) with coefficient values ranging between (0.664 - 0.776), indicating a significant contribution of these indicators in enhancing loyalty. The relationship between brand loyalty and brand awareness appears with a value of (0.464), indicating a strong and positive effect. This reflects that enhancing customer loyalty enhances their perception and awareness of the brand. The effect of loyalty on content marketing came with a value of (0.037), which is a weak effect, indicating that the effect of loyalty on the quality of marketing content is less important compared to the effect of brand awareness.

Content marketing is explained through two types of value: entertainment value and informational value. The indicators related to entertainment value (cmmev1, cmmev2, cmmev3, cmmev4) have strong coefficients ranging between (0.627 - 0.825), reflecting a major role for content marketing in attracting customers through entertainment elements.

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The indicators related to informational value (cmmiv1, cmmiv2, cmmiv3, cmmiv4) have moderate coefficients (0.133 - 0.662), indicating that informational content is still important but has less impact compared to entertainment value.

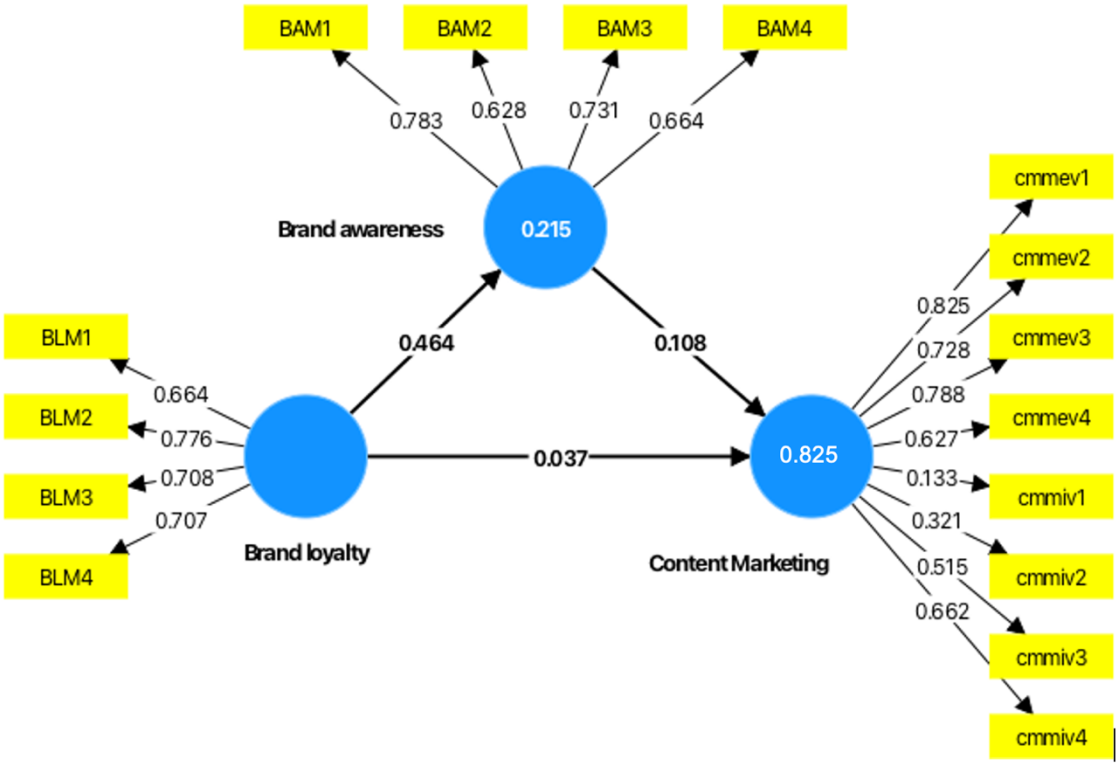


Figure 5. Path analysis for Mediating variables from marketing teams' point of view
Source: authors, based on smart-Pls v4 output.

It is also clear from the Figure 5 that Brand loyalty explains 21.5% of the change in Brand awareness, while both Brand loyalty and the Brand awareness variable explain 82.5% of the change in Content Marketing. At the same time, the remaining percentage is due to other factors that were not included in the study model. The following Table 8 will show path coefficient for Mediating variables from the Customers' point of view.

Table 7. Path coefficient for Mediating variables from the marketing teams' point of view

Path – Direct effect	Coff	T statistics	P values
Brand awareness -> Content Marketing	0.108	8.714	0.000
Brand loyalty -> Brand awareness	0.464	8.371	0.000
Brand loyalty -> Content Marketing	0.037	3.738	0.000
Path - Indirect effect			
Brand loyalty -> Brand awareness -> Content Marketing	0.050	5.476	0.000

Source: authors, based on smart-Pls v4 output.

The results of the previous table show the following:

A. Direct effect between brand awareness and content marketing: The path coefficient (Coff) was 0.108, with a very high T-statistic value (8.714) and a P-value of 0.000. This indicates a direct, positive, and strong statistically significant relationship between brand awareness and content marketing, which means that increasing brand awareness contributes to enhancing the effectiveness of content marketing.
B. Direct effect between brand loyalty and brand awareness: The path coefficient was 0.464, which is the highest among the other values in the direct effect, with a T-statistic value of 8.371 and a P-value of

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0.000. This indicates that brand loyalty has a strong and significant effect on enhancing brand awareness.

C. Direct effect between brand loyalty and content marketing: The path coefficient (Coff) was 0.037 with a t-statistic value of (3.738) and a p-value of 0.000, indicating a weak but significant direct effect between brand loyalty and content marketing.
D. Indirect effect between brand loyalty, brand awareness, and then content marketing: The path coefficient for the indirect effect was 0.050 with a t-statistic value of 5.476 and a p-value of 0.000. This indicates a significant and positive indirect effect, meaning that brand loyalty indirectly affects content marketing by enhancing brand awareness.

Brand loyalty plays a vital role in influencing content marketing both directly and indirectly by enhancing brand awareness. The direct effect between brand awareness and content marketing was much higher compared to the direct effect of loyalty on content marketing. The indirect effect shows an important mediating role of brand awareness in enhancing the effectiveness of content marketing when increasing brand loyalty.

4.6 Hypotheses results based on customers' point of view

The path analysis results shown in figure (6) highlight the relationships between different dimensions from the customer perspective using the structural model. The commentary on the results can be summarized as follows:

Brand awareness is strongly correlated with a set of indicators (BAC1 to BAC5) with values ranging from 0.553 to 0.725, indicating that these indicators play a fundamental role in shaping customers' perception of brand awareness. Brand awareness also directly affects "Content Marketing: Entertainment Value," with a path value of 0.426, reflecting the importance of awareness in improving customers' perception of the entertainment value of content. Brand awareness also affects "Content Marketing: Informational Value" with a path value of 0.395, significantly impacting information delivery through marketing content.

Brand loyalty is closely correlated with indicators (BLC1 to BLC3) with values ranging from 0.631 to 0.801, showing that these indicators are essential in forming customer loyalty. Brand loyalty strongly influences brand awareness with a path value of 0.506, meaning that increased loyalty leads to enhanced brand awareness. Loyalty also directly influences "Content Marketing: Entertainment Value" with a path value of 0.256 and "Content Marketing: Informational Value" with a path value of 0.319. Although the influence is smaller than the relationship with awareness, they are statistically significant.

Content marketing based on entertainment value is more influenced by brand awareness (0.426) than brand loyalty (0.256), indicating the importance of enhancing awareness to highlight the entertainment aspect of content.

Content marketing based on informational value shows a greater influence than brand loyalty (0.319) and brand awareness (0.395), indicating the role of awareness and loyalty in supporting informational value.The supporting indicators for both entertainment and informational value record high loading values (0.640-0.766 for informational value and 0.655-0.739 for entertainment value), highlighting the reliability of these indicators in explaining content marketing variables.

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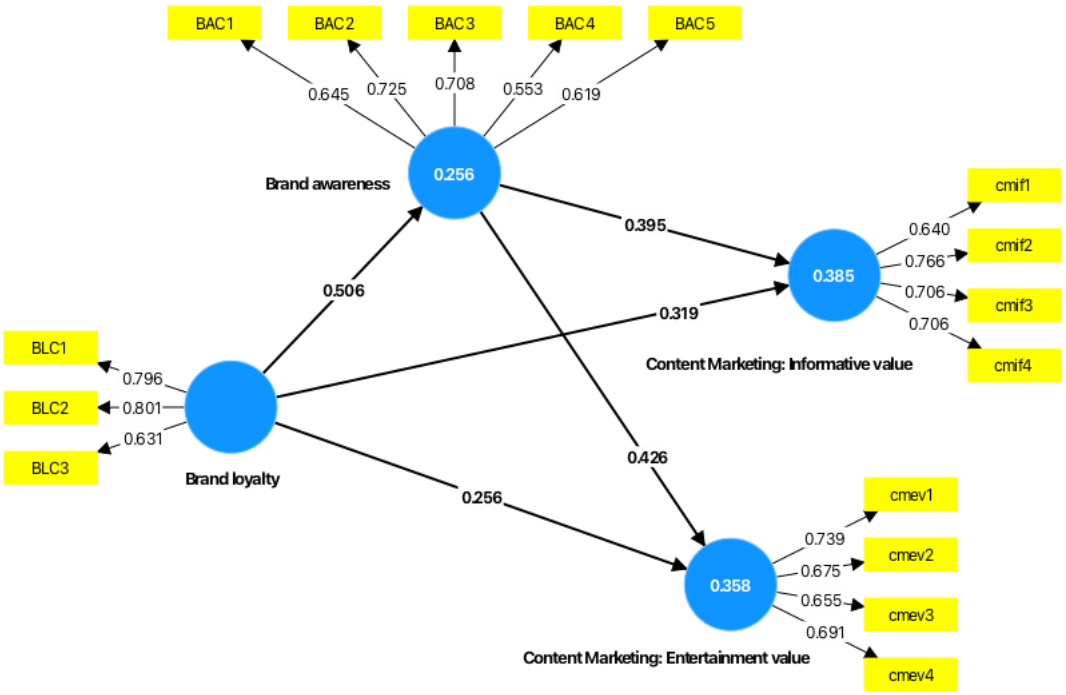


Figure 6. Path analysis to study dimensions from Customers' point of view
Source: authors, based on smart-Pls v4 output.

Table (8) results indicate the analysis of direct paths between different dimensions from the customers' perspective using the structural equation model (PLS). The relationship between brand awareness and entertainment content value: The standardized path value (Coff) is 0.426 with a t-statistic of 7.965, indicating a strong and statistically significant positive effect (P-value = 0.000). This means that brand awareness has a significant positive effect on customers' perception of entertainment content value.

The relationship between brand awareness and informational content value: The standardized path value is 0.395, with a t-statistic of 6.819, which also indicates a statistically significant positive effect (P-value = 0.000). This indicates that brand awareness enhances customers' perception of informational content value.

Table 8. Path coefficient for study dimensions from the Customers' point of view

Path – Direct effect	Coff	T statistics	P values
Brand awareness -> Content Marketing: Entertainment value	0.426	7.965	0.000
Brand awareness -> Content Marketing: Informative value	0.395	6.819	0.000
Brand loyalty -> Brand awareness	0.506	9.057	0.000
Brand loyalty -> Content Marketing: Entertainment value	0.256	4.982	0.000
Brand loyalty -> Content Marketing: Informative value	0.319	6.241	0.000

Source: authors, based on smart-Pls v4 output.

Also, the relationship between brand loyalty and brand awareness: The standardized path value is 0.506 with a t-statistic of 9.057, indicating a statistically significant positive effect (P-value = 0.000). This indicates that increased brand loyalty is associated with a significant increase in brand awareness.

The relationship between brand loyalty and entertainment content value: The standardized path value is 0.256 with a t-statistic of 4.982, indicating a positive but less strong effect than other paths (P-value = 0.000). This indicates that brand loyalty moderately enhances customers' perception of entertainment content value.

The relationship between brand loyalty and informational content value: The standardized path value is 0.319 with a t-statistic of 6.241, indicating a moderate and statistically significant positive effect (P-value = 0.000). This means that brand loyalty contributes to customers' perception of the value of informational content.

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Figure 7 provides a detailed analysis of the role of mediating variables between brand loyalty, brand awareness, and content marketing. The analysis indicates significant direct and indirect effects between these variables.

First, brand awareness plays a key mediating role between brand loyalty and content marketing. This is demonstrated by the path between brand loyalty and brand awareness, which was 0.506, reflecting a strong positive effect. The path between brand awareness and content marketing was 0.463, indicating that increasing brand awareness contributes significantly to enhancing the effectiveness of content marketing.

Second, the direct effect between brand loyalty and content marketing was relatively lower, at 0.326. However, the analysis shows that the indirect effect via brand awareness has a stronger effect, meaning that enhancing brand loyalty is positively reflected in content marketing if it is associated with increasing brand awareness.

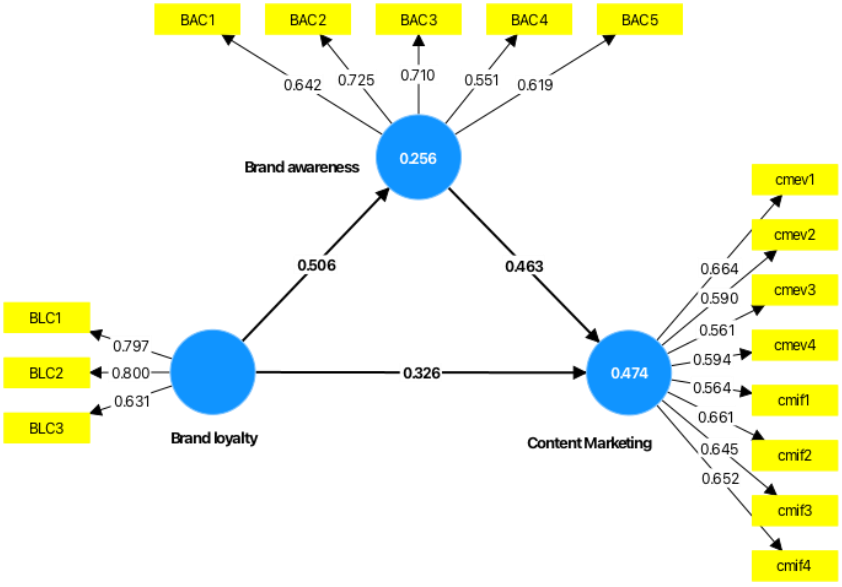


Figure 7. Path analysis for Mediating variables from Customers' point of view
Source: authors, based on smart-Pls v4 output.

Third, content marketing is a pivotal element in the analysis, with content marketing indicators (entertainment and informational aspects) showing high loading values ranging from 0.561 to 0.664. This indicates that customers evaluate content marketing based on its entertainment (cmev) and informational (cmif) aspects, reflecting the importance of balancing these aspects to meet customer expectations effectively.

Finally, brand awareness and loyalty indicators also recorded high loading values (between 0.551 and 0.800). This highlights the importance of enhancing elements that contribute to improving brand awareness and increasing customer loyalty, as these elements are considered factors that directly and indirectly influence improving the content marketing experience.

Thus, enhancing brand awareness and loyalty is an effective strategy for improving the quality of content marketing and increasing its impact on customers.

Table 9. Path coefficient for Mediating variables from the Customers' point of view

Path – Direct effect	**Coff**	**T statistics**	**P values**
Brand awareness -> Content Marketing	0.463	9.551	0.000
Brand loyalty -> Brand awareness	0.506	9.097	0.000
Brand loyalty -> Content Marketing	0.326	7.192	0.000
Path - Indirect effect			
Brand loyalty -> Brand awareness -> Content Marketing	0.234	5.655	0.000

Source: authors, based on smart-Pls v4 output.

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The results of the previous table show the following:

A. Direct effect between brand awareness and content marketing: The path coefficient (Coff) was 0.463, with a very high T-statistic (9.551) and a P-value of 0.000. This indicates a strong and positive direct relationship between brand awareness and content marketing. Thus, increasing brand awareness leads to improving the effectiveness of content marketing from the customer's perspective.
B. Direct effect between brand loyalty and brand awareness: The path coefficient was 0.506, with a very high T-value (9.097) and a P-value of 0.000, indicating a strong and significant effect between brand loyalty and brand awareness. This shows that brand loyalty contributes significantly to raising brand awareness among customers.
C. Direct effect between brand loyalty and content marketing: The path coefficient was 0.326, with a T-statistic (7.192) and a P-value of 0.000. Although the effect is smaller than the effect between loyalty and awareness, it indicates a significant and significant effect between brand loyalty and content marketing.
D. The indirect effect between brand loyalty, brand awareness, and content marketing: The path coefficient for the indirect effect was 0.234, with a t-statistic of 5.655 and a p-value of 0.000. This indicates a significant and positive indirect effect, indicating that brand loyalty enhances content marketing by raising brand awareness.

Brand awareness significantly impacts content marketing success from the customer's perspective, highlighting its crucial role. Additionally, brand loyalty positively influences both brand awareness and content marketing. The indirect relation between loyalty and content marketing through brand awareness emphasizes that establishing brand awareness is essential for enhancing content marketing.

4.7 Differences in gender, educational level, and age from marketing teams' point of view

Table 10 outlines gender differences in brand awareness, loyalty, and content marketing (informational and entertainment) from a marketing teams' perspective. Males and females have similar means across all variables, with minor, non-significant differences, except in "Content Marketing: Entertainment Value," where significance (Sig.) is 0.032, indicating a statistically significant gender difference. Gender's effect on the other variables is weak, with Eta Squared values below 0.012, signifying limited influence.

Table 10. Significance testing results of difference based on gender from marketing teams' point of view

Gender		Brand awareness	Brand loyalty	Content Marketing: Informative value	Content Marketing: Entertainment value
female	Mean	4.1684	4.0306	3.8605	3.8129
	N	147	147	147	147
	Std. Deviation	0.68943	0.75393	0.52435	0.69726
male	Mean	4.0612	4.0422	3.8945	3.9652
	N	237	237	237	237
	Std. Deviation	0.71711	0.71442	0.60668	0.6575
Total	Mean	4.1022	4.0378	3.8815	3.9069
	N	384	384	384	384
	Std. Deviation	0.70766	0.72884	0.57609	0.67617
ANOVA	F	2.087	0.023	0.315	4.644
	Sig.	0.149	0.88	0.575	0.032
	Eta	0.074	0.008	0.029	0.11
	Eta Squared	0.005	0	0.001	0.012

Source: authors, based on SPSS v25 output.

Table 11 shows the age-based difference test results on brand awareness, loyalty, and content marketing values (informational and entertainment). Most age groups have similar means with no significant differences, as all significance values (Sig.) exceeded 0.05 except for "Content Marketing: Entertainment Value" (Sig. = 0.047), indicating a significant difference. However, age effects were weak, with Eta Squared values below 0.021, suggesting age has a limited impact on perceptions of the studied variables.

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Table 11. Significance testing results of difference based on age from the marketing teams' point of view

Age		Brand awareness	Brand loyalty	Content Marketing: Informative value	Content Marketing: Entertainment value
From 18 to 25 years	Mean	4.0817	3.9904	3.8798	3.9471
	N	52	52	52	52
	Std. Deviation	0.75848	0.89383	0.51803	0.6518
From 25 to 35 years	Mean	4.0645	4.0066	3.8539	3.8526
	N	190	190	190	190
	Std. Deviation	0.70438	0.76913	0.54255	0.63464
From 35 to 45 years	Mean	4.1537	4.0881	3.957	4.0184
	N	122	122	122	122
	Std. Deviation	0.70157	0.60722	0.59673	0.67891
above 45	Mean	4.2	4.15	3.6875	3.6375
	N	20	20	20	20
	Std. Deviation	0.66193	0.53435	0.83064	0.97155
Total	Mean	4.1022	4.0378	3.8815	3.9069
	N	384	384	384	384
	Std. Deviation	0.70766	0.72884	0.57609	0.67617
ANOVA test	F	0.535	0.539	1.607	2.669
	Sig.	0.658	0.656	0.187	0.047
	Eta	0.065	0.065	0.112	0.144
	Eta Squared	0.004	0.004	0.013	0.021

Source: based on SPSS v25 output.

Table 12 summarizes the analysis of differences in brand awareness, loyalty, and content marketing values (informational and entertainment) from the marketing team's viewpoint based on education levels. The averages across education levels are similar, with most variables showing no statistically significant differences, as significance values (Sig.) exceeded 0.05. The impact of education on the variables was minimal, with Eta Squared values below 0.014. Thus, education level does not significantly affect the perception of these dimensions.

Table 12. Significance testing results of difference based on Education level (from marketing teams' point of view)

Education level		Brand awareness	Brand loyalty	Content Marketing: Informative value	Content Marketing: Entertainment value
High school	Mean	4.2061	4.0395	3.9035	3.9518
	N	57	57	57	57
	Std. Deviation	0.59971	0.75414	0.6387	0.5478
bachelor	Mean	4.0896	4.0628	3.865	3.9452
	N	187	187	187	187
	Std. Deviation	0.71865	0.69638	0.59242	0.68146
Master or PhD	Mean	4.1324	4.1434	3.9338	3.8088
	N	68	68	68	68
	Std. Deviation	0.6614	0.63381	0.56585	0.72549
Diploma	Mean	4.0243	3.8715	3.8576	3.8646
	N	72	72	72	72
	Std. Deviation	0.7974	0.8527	0.4926	0.70703
Total	Mean	4.1022	4.0378	3.8815	3.9069
	N	384	384	384	384
	Std. Deviation	0.70766	0.72884	0.57609	0.67617
ANOVA test	F	0.76	1.81	0.306	0.853
	Sig.	0.517	0.145	0.821	0.465
	Eta	0.077	0.119	0.049	0.082
	Eta Squared	0.006	0.014	0.002	0.007

Source: authors, based on SPSS v25 output

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4.8 Differences in gender, educational level, and age (from customers' point of view)

Table 13 shows gender differences in brand awareness, loyalty, and content marketing values from the customers' perspective. The results indicate no statistically significant differences between males and females, as significance values exceeded 0.05 for all variables. Furthermore, the low Eta Squared values (under 0.007) suggest a minimal effect of gender on these variables. Thus, customers' perception of the studied variables remains largely unaffected by gender.

Table 13. Significance testing results of difference based on gender (from the customers' point of view)

Gender		Brand awareness	Brand loyalty	Content Marketing: Informative value	Content Marketing: Entertainment value
female	Mean	4.073	4.088	4.191	4.007
	N	147	147	147	147
	Std. Deviation	0.705	0.741	0.688	0.679
male	Mean	4.150	4.125	4.183	4.123
	N	237	237	237	237
	Std. Deviation	0.596	0.753	0.672	0.653
Total	Mean	4.121	4.111	4.186	4.079
	N	384	384	384	384
	Std. Deviation	0.640	0.747	0.677	0.665
ANOVA test	F	1.306	0.219	0.013	2.804
	Sig.	0.254	0.64	0.911	0.095
	Eta	0.058	0.024	0.006	0.085
	Eta Squared	0.003	0.001	0	0.007

Source: based on SPSS v25 output.

Table 14 shows that age group differences in brand awareness, loyalty, and content marketing values revealed no statistically significant differences (Sig. > 0.05). The low Eta Squared values (less than 0.013) indicate a weak effect of age on these variables. Thus, the age group does not significantly influence customers' perceptions.

Table 14. Significance testing results of difference based on age (from the customers' point of view)

Age		Brand awareness	Brand loyalty	Content Marketing: Informative value	Content Marketing: Entertainment value
From 18 to 25 years	Mean	4.0385	4.0321	4.1875	3.9952
	N	52	52	52	52
	Std. Deviation	0.8550	0.8764	0.7716	0.7597
From 25 to 35 years	Mean	4.0874	4.0561	4.1197	4.0487
	N	190	190	190	190
	Std. Deviation	0.6191	0.7685	0.6875	0.6765
From 35 to 45 years	Mean	4.1770	4.2322	4.2889	4.1516
	N	122	122	122	122
	Std. Deviation	0.5971	0.6282	0.6461	0.6344
above 45	Mean	4.3100	4.1000	4.1750	4.1375
	N	20	20	20	20
	Std. Deviation	0.3463	0.8172	0.4222	0.4252
Total	Mean	4.1208	4.1111	4.1855	4.0788
	N	384	384	384	384
	Std. Deviation	0.6398	0.7474	0.6773	0.6649
ANOVA test	F	1.361	1.614	1.554	0.944
	Sig.	0.254	0.186	0.2	0.42
	Eta	0.103	0.112	0.11	0.086
	Eta Squared	0.011	0.013	0.012	0.007

Source: based on SPSS v25 output.

Table 15 shows the education level's impact on customers' perception of brand awareness, loyalty, and content marketing values. Results indicated significant differences in brand loyalty (Sig. = 0.006) and informational value (Sig. = 0.021), demonstrating education's effect on these factors. However, overall effects were weak,

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with low Eta Squared values (less than 0.032). Individuals with higher degrees (master's and doctorate) generally scored higher in these dimensions, suggesting that education enhances customers' perceptions.

Table 15. Significance testing results of difference based on Education level (from customers' point of view)

Education level		Brand awareness	Brand loyalty	Content Marketing: Informative value	Content Marketing: Entertainment value
High school	Mean	4.0526	4.2573	4.2895	4.1272
	N	57	57	57	57
	Std. Deviation	0.6809	0.6872	0.5193	0.6126
bachelor	Mean	4.1722	4.1016	4.1912	4.0655
	N	187	187	187	187
	Std. Deviation	0.6022	0.7516	0.6339	0.6756
Master or PhD	Mean	4.1912	4.2647	4.2978	4.2243
	N	68	68	68	68
	Std. Deviation	0.5858	0.5630	0.6293	0.5700
Diploma	Mean	3.9750	3.8750	3.9826	3.9375
	N	72	72	72	72
	Std. Deviation	0.7292	0.8747	0.8795	0.7373
Total	Mean	4.1208	4.1111	4.1855	4.0788
	N	384	384	384	384
	Std. Deviation	0.6398	0.7474	0.6773	0.6649
ANOVA test	F	2.158	4.192	3.286	2.318
	Sig.	0.093	0.006	0.021	0.075
	Eta	0.129	0.179	0.159	0.134
	Eta Squared	0.017	0.032	0.025	0.018

Source: based on SPSS v25 output.

4.9 Discussion of results

The findings of this study provide valuable insights into the role of content marketing in building brand awareness and customer loyalty within the Egyptian automobile market. This discussion compares the study's results with existing literature to evaluate consistency, identify gaps, and highlight key implications for marketing strategies.

The study confirmed that content marketing significantly influences brand awareness, with a direct effect coefficient of 0.108 from the management perspective and 0.463 from the customers' perspective. These findings align with prior research that emphasizes content marketing's role in enhancing brand visibility and customer engagement (Hollebeek & Macky, 2019). Content marketing strategies such as informative and entertaining content contribute to a brand's perceived authenticity and credibility, which, in turn, strengthens brand awareness (Kim & Ko, 2012).

Existing research supports the notion that interactive and high-quality content fosters stronger consumer-brand relationships (Pulizzi, 2014). The study results demonstrate that both informational and entertainment content positively impact brand awareness, reinforcing the findings of Lemon and Verhoef (2016), who argue that digital and experiential content enhances consumer knowledge and emotional connection to brands.

With a path coefficient of 0.464 from the management perspective and 0.506 from the consumer perspective, the study revealed a significant relationship between brand awareness and brand loyalty. This strengthens the case that more brand awareness builds consumer confidence, which finally results in more brand loyalty (Brodie et al., 2013). According to the research, understanding lowers perceived risk—a major factor influencing consumer loyalty (Hapsari et al., 2017). Moreover, Aaker's brand equity model underlines that brand loyalty cannot exist without brand awareness (Longwell, 1994). The present results support this notion by showing that customers who identify and remember a brand are more likely to create a strong emotional connection that results in recurrent purchases and advocacy (Keller, 2009).

Particularly by means of its mediating effect on brand awareness, the path analysis of the study demonstrated that content marketing considerably influences consumer loyalty. According to the findings, brand awareness

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(coefficient = 0.506) influences brand loyalty more so than content marketing (coefficient = 0.326). This result is in line with earlier studies showing that content marketing by itself does not directly inspire loyalty but rather helps to strengthen brand reputation and interaction (Chaffey & Smith, 2017).

Furthermore, the survey revealed that consumers see the educational and entertainment value of content marketing to be main drivers of loyalty, in line with other studies stressing the need of narrative and interactive digital content in creating emotional connections (Batra & Keller, 2016). Further supporting this is research by Taufique and Vaithianathan (2018), which shows that brands funding premium, interesting content have better retention rates.

The study also examined demographic factors affecting brand awareness, loyalty, and content marketing effectiveness. Gender differences were minimal, except for content marketing's entertainment value, where males showed a slightly higher mean score. This aligns with previous studies suggesting that men and women may engage with marketing content differently based on entertainment appeal (McMahan, 2009).

Age-related differences were also limited, except in content marketing's entertainment value, where younger respondents (18–25) showed higher engagement. This supports studies indicating that younger audiences prefer visually engaging and entertaining content, particularly in digital formats (De Vries et al., 2012).

Education level showed a significant impact on brand loyalty and informational content value, with higher-educated consumers demonstrating stronger engagement. This supports prior research suggesting that more educated consumers seek in-depth, informative content when making purchasing decisions (Hollebeek et al., 2014).

Given the study's findings, content marketing strategies in the Egyptian automobile market should prioritize high-quality, engaging content that enhances brand awareness, ultimately fostering loyalty. Brands should balance both informational and entertainment content to appeal to diverse consumer preferences. Moreover, using digital channels to provide interactive and immersive content may improve brand interaction especially for younger consumers. By announcing the personal and societal benefits of switching to electric cars, which supports entrepreneurshipin the automobile industry (Wagdi et al. 2022)

5. Conclusion and recommendations

5.1 Conclusion

The research examined the significant role of brand awareness as a mediating variable in the correlation between content marketing and customer loyalty, specifically within the context of Egypt as an emerging market (ElAydi, 2018; Gaber and Elsamadicy, 2021; Zia et al., 2022; Ge and Ge, 2023; Kristiyono et al., 2023; Nagaty & El-Menawy, 2023; Thyagaraju, 2023; Eltokhy et al., 2024; Muharam et al., 2024; Vydeshwari, 2024). The findings demonstrate a complex interaction among these critical components, underscoring the substantial influence of brand awareness on consumer engagement and loyalty.

The examined studies consistently emphasize the significance of brand awareness in bolstering customer loyalty via content marketing (ElAydi, 2018; Gaber & Elsamadicy, 2021; Zia et al., 2022; Ge & Ge, 2023; Kristiyono et al., 2023; Nagaty & El-Menawy, 2023; Thyagaraju, 2023; Eltokhy et al., 2024; Muharam et al., 2024; Vydeshwari, 2024). Numerous studies indicate that good content marketing techniques, aimed at engaging and informing customers, directly enhance brand awareness. (ElAydi, 2018; Gaber & Elsamadicy, 2021; Eltokhy et al., 2024; Vydeshwari, 2024) This increased brand awareness acts as a catalyst for fostering customer loyalty, as customers get more acquainted with and attached to the brand (Gaber & Elsamadicy, 2021; Zia et al., 2022; Nagaty & El-Menawy, 2023; Thyagaraju, 2023; Muharam et al., 2024; Vydeshwari, 2024).

Studies looking at Egypt's telecoms, for instance, show that airline-created social media content directly affects brand recognition and, thus, consumer loyalty (Gaber & Elsamadicy, 2021). Comparably, studies on the effect of social media marketing on brand awareness in the mobile services industry in Egypt find six main elements of social media marketing that support brand awareness, therefore affecting customer involvement and loyalty

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(ElAydi, 2018). These results underline the need of including social media marketing into general marketing plans to improve brand exposure and finally build consumer loyalty (ElAydi, 2018).

Brand awareness is obviously a major mediator in the link between content marketing and consumer loyalty (Zia et al., 2022; Nagaty & El-Menawy, 2023; Thyagaraju, 2023; Muharam et al., 2024; Vydeshwari, 2024). Content marketing by itself does not so immediately ensure consumer loyalty. Rather, its success relies on its capacity to raise brand awareness, which then acts as the link from content marketing initiatives and consumer loyalty (Zia et al., 2022; Nagaty & El-Menawy, 2023; Thyagaraju, 2023; Muharam et al., 2024; Vydeshwari, 2024).

The studies examined show the special difficulties and possibilities connected to content marketing in emerging countries such as Egypt. ElAydi, 2018; Zia et al., 2022; Nagaty and El-Menawy, 2023; Eltokhy et al., 2024; Muharam et al., 2024; Vydeshwari, 2024 Emerging markets can show different customer behaviors and preferences, therefore marketers have to modify their methods (ElAydi, 2018; Zia et al., 2022; Nagaty & El-Menawy, 2023; Eltokhy et al., 2024; Muharam et al., 2024; Vydeshwari, 2024). Research on the Egyptian telecom sector, for instance, emphasizes the need of producing interesting and unforgettable material that builds confidence and good brand impression. (Eltokhy et al., 2024) This implies that content marketing plans should be customized to the particular social and cultural setting of emerging countries (Eltokhy et al., 2024).

By offering insightful analysis catered to the Egyptian market, this literature review and statistical results for the Egyptian automobile market help to contribute to the body of knowledge already in existence on brand awareness, content marketing, and customer loyalty. The results highlight the critical need of brand awareness in mediating the link between content marketing and consumer loyalty in this particular setting (ElAydi, 2018; Gaber & Elsamadicy, 2021; Zia et al., 2022; Nagaty & El-Menawy, 2023; Eltokhy et al., 2024). This study also emphasizes the special issues for content marketing in emerging countries and stresses the requirement of customized plans that fit local customer behavior and tastes. ElAydi, 2018; Zia et al., 2022; Nagaty & El-Menawy, 2023; Eltokhy et al., 2024; Muharam et al., 2024; Vydeshwari, 2024).

Particularly in emerging countries like Egypt, the results of this literature review and statistical analysis for the Egyptian automotive industry point to brand awareness as a critical mediating variable in the interaction between content marketing and consumer loyalty. Egyptian companies have to give brand awareness first priority if they want to properly use content marketing and foster enduring client loyalty. Future studies should keep looking at the dynamic interaction among content marketing, brand awareness, and customer loyalty in emerging countries, so offering insightful analysis for companies and legislators trying to promote effective marketing strategies in these fast-changing economic environments.

Content marketing has two purposes in the context of the automotive sector: it offers informational value by teaching consumers about product features and entertainment value by involving them via storytelling and interactive content (Hudson et al., 2016). Limited studies have, however, looked at these dynamics in emerging nations such as Egypt, where cultural and economic elements might affect customer behavior differently (El-Bassiouny, 2014). By offering empirical data from the Egyptian automotive industry, this research seeks to close this disparity.

Using two surveys to gather data from 763 participants—including marketing teams and consumers of Egyptian automakers—the study takes a descriptive analytical approach. Random sampling was used to choose the sample such that it represented gender, age, and education levels all around. Reliability, validity, and structural correlations between the variables were tested by means of SPSS v25 and Smart-PLS v4 data analysis.

With Cronbach's Alpha values topping 0.7 and validity values over 0.85, the results show great dependability and validity for all variables (see Table 1). These findings align with previous studies that emphasize the importance of robust measurement tools in marketing research (Leguina, 20215).

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The descriptive analysis reveals that participants generally perceive brand awareness and loyalty positively, with mean scores ranging from 3.9 to 4.3 (see Tables 2 and 3). This is consistent with the literature, which suggests that high brand awareness correlates with strong customer loyalty (Keller, 2016).

The correlation analysis shows a strong positive relationship between brand awareness and customer loyalty ($r = 0.453$, $p < 0.01$) (see Table 4). This finding supports the notion that brand awareness is a key driver of customer loyalty (Aaker, 1991). Additionally, content marketing dimensions (entertainment and informational value) exhibit moderate to strong correlations with brand awareness and loyalty, highlighting their complementary roles in enhancing customer engagement (Hudson et al., 2016).

The path analysis reveals that brand awareness mediates the relationship between content marketing and customer loyalty (see Figures 4-7). Specifically, the indirect effect of brand loyalty on content marketing through brand awareness is significant ($\beta = 0.234$, $p < 0.001$) (see Table 9). This finding aligns with the literature, which posits that brand awareness acts as a bridge between marketing efforts and customer loyalty (Keller, 2016).

The study also examines the impact of demographic factors (gender, age, and education) on the study variables. While gender and age show minimal influence, education level significantly affects brand loyalty and informational value (see Tables 10-15). Higher education levels seem to improve consumers' capacity to digest and value informative content, according to past studies (Hollebeek & Macky, 2019).

Empirical data regarding the interaction of content marketing, brand awareness, and customer loyalty in the Egyptian automotive industry is given in this paper. The results highlight the need of including entertainment and educational value into content marketing plans to raise consumer loyalty and improve brand recognition.

5.2 Recommendations

According to the above conclusion, the study provides recommendations for two groups of stakeholders, the first is firms and the second is academic researchers, as shown in Table 16.

Table 16. Recommendations

Recommendation Area	Action Steps	Timeline	Responsible Parties	Expected Outcomes
Firms	Investing in Content Marketing Strategies			
	- Allocate budgets for high-quality, engaging content creation	Immediate	Marketing teams, C-suite executives	Increased brand awareness and customer engagement
	- Use storytelling and interactive content to enhance emotional connections with customers	Ongoing	Creative teams, digital marketing agencies	Stronger brand loyalty and higher customer retention
	Targeting Local Culture and Consumer Values			
	- Customize content marketing campaigns to reflect local cultural nuances and preferences	6 months	Marketing teams, cultural consultants	Higher relevance and resonance of marketing efforts
	- Conduct market research to understand local consumer behavior and preferences	3 months	Market research teams	Data-driven insights to inform content marketing strategies
	Utilizing Social Media Platforms			
	- Integrate social media into overall marketing plans	Immediate	Digital marketing teams	Broader reach and improved customer interaction
	- Leverage influencers and community-building activities on social media	Ongoing	Social media managers, PR teams	Strengthened brand presence and community engagement
Future Research Directions	Exploring Factors Influencing Brand Awareness in Emerging Markets			
	- Study the impact of cultural values, economic factors, and media consumption patterns	12–24 months	Academics, researchers, marketing professionals	Insights into effective content marketing strategies in diverse contexts
	Longitudinal Studies to Track Brand Awareness and Customer Loyalty			

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Table 16. Recommendations

Recommendation Area	Action Steps	Timeline	Responsible Parties	Expected Outcomes
	- Conduct long-term studies to assess changes in brand awareness and loyalty over time	24–36 months	Academics, researchers, industry analysts	Understanding of sustainable strategies for building brand loyalty
	Investigating Different Content Marketing Strategies			
	- Analyze the effects of personalized content, user-generated content, and firm-generated content	12 months	Researchers, marketing practitioners	Identification of most effective content types for specific markets
	- Explore the role of content formats (e.g., videos, infographics) and distribution channels	12 months	Researchers, content creators	Optimized content strategies for improving brand awareness
	Comparative Studies Between Emerging and Developed Markets			
	- Compare consumer behavior and content marketing effectiveness across markets	18–24 months	Cross-cultural research teams	Benchmarking strategies for global and local markets
	Examining the Impact of Digital Transformation			
	- Study the role of e-commerce, mobile commerce, AI, and big data in shaping brand dynamics	12–18 months	Technologists, marketing researchers	Insights into leveraging technology for brand growth
	Exploring Interaction Between Brand Awareness and Other Mediating Variables			
	- Investigate the interplay between brand awareness, brand image, customer satisfaction, and trust	12–24 months	Researchers, academics	Holistic understanding of brand-building processes

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Competing interests
The authors declare that they have no competing interests regarding the publication of this paper.

Authors' contribution
All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

Transparency
The authors confirm that the manuscript is an honest, accurate and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

Institutional review board statement
The ethical committee of the Helwan University, Egypt has granted approval for this study on January 7, 2024 (Ref. No. 41001).

Data availability statement
This study conducted an anonymous survey and does not involve personal privacy. The materials and data used in this research will be availed by the authors upon a reasonable request.

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PROCUREMENT VS INBOUND LOGISTICS: A CASE STUDY OF CZECH COMPANIES*

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Abstract. The main aim of this paper was to establish the link between the importance of procurement and inbound logistics, investment in these areas and the economic impact during the recession. The research question was answered by testing seven hypotheses that focused on the interrelationship between procurement and inbound logistics on issues of perceived importance, investment, and the impact of economic results on this relationship. The parametric two-sample one-factor ANOVA was used to test the hypotheses. The correlation between the change in the importance of procurement and inbound logistics was most confirmed for micro-service firms. The shift in importance during the recession affected investment only in procurement, not in inbound logistics processes. A stronger link between the change in the importance of procurement and the change in the importance of inbound logistics was observed for profitable enterprises. The limitations of the research include, for example, geographical limitations (the research focuses on companies in the Czech Republic) and time limitations (i.e., the study focuses exclusively on a short-term (1 year) observation period).

Keywords: value chain; primary and support processes; measuring efficiency; procurement; inbound logistics

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JEL Classifications: M10, M21

1. Introduction

The value chain concept can be viewed from two perspectives: internal (focusing on internal operational efficiency) and external (focusing on the linkages between external systems) (Baştuğ et al., 2020; Aliane et al., 2023; Xu & Zhang, 2024). Current issues in supply chain management (external perspective of the value chain) include, for example, the issue of supply chain feasibility (Supply Chain Visibility-SCV) (Kalaiarasan et al., 2021) and management in times of economic recession (Navrátilová, 2021). The COVID-19 pandemic has disrupted global value chains. Castañeda-Navarrete et al. (2021) exposed vulnerabilities in global supply chains, creating supply, demand and logistics challenges (Chase et al., 2022). The pandemic has been shown to have a negative impact on both procurement processes and supplier-customer relationships in the global supply chain (Hayakawa & Mukunoki, 2021). The degree of impact depended on each industry's characteristics, such as the ability to work remotely, the durability of goods, and participation in global supply chains (Espitia et al., 2022). The ultimate goal of SCM and all related processes is to achieve the necessary supply chain performance (Song et al., 2022). An effective procurement strategy that focuses on, e.g., identifying the right supplier, supplier management, etc., reduces procurement costs and strengthens the supply chain (Fontana et al., 2021; Modgil et

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al., 2022). Internal value chain efficiency is one of the key issues in the current business environment (Zimmermannová et al., 2016). In view of this, decision-making within the value chain concept is also gaining importance (Kuzniar, 2017; Anwer et al., 2020).

The five primary activities, namely inbound logistics, operations, outbound logistics, marketing and sales, and service, are the activities that involve creation, transfer, and providing service to the customers (Porter, 1985). These activities are reinforced by support activities that consist of firm infrastructure, human resource management, technology development, and procurement (Porter, 1985).

Based on the above findings, it is logical to focus on the differences in the perception and development of inbound logistics and procurement within the internal Value Chain concept. Procurement includes activities related to building and streamlining supplier-customer relationship management. Inbound logistics, on the other hand, deals primarily with the material flow towards the company, its planning and operational management (Ong et al., 2024).

Procurement management plays a significant role in building supply chain resilience. As a result of the COVID-19 pandemic, new strategies and measures suitable for a resilient procurement system have been identified (Shivajee et al., 2023). Some procurement strategies increase sales and profit for manufacturers but can negatively impact vendors and the entire supply chain if not set up appropriately (Wang & Ma, 2023). Current procurement issues include, for example, the area of digitalisation (transition to e-procurement) (Mélon & Spruk, 2020; Wilhelm & Villena, 2021), sustainability (sustainable procurement) (Opoku et al., 2022; Etse et al., 2023). The development of digital procurement has a positive impact on supply chain performance (Hallikas et al., 2021). Procurement and distribution processes can be improved through sustainable approaches considering the three dimensions of sustainability (Cammarano et al., 2022).

Inbound logistics is one of the key issues in material flow management (Fontaine et al., 2017). Material management is a key part of manufacturing logistics that manages production inbounds, outputs and processes (Song et al., 2022). One of the current issues in inbound logistics is the so-called WMS (warehouse management system) and how to monitor its performance (Pereira et al., 2020).

The boundaries between logistics and procurement, R&D, production, marketing, information management and other departments are gradually blurring and tend to integrate (Song et al., 2022). Monitoring and optimising linkages within value chains is key when considering integration within GVCs (Pereira et al., 2020). The importance of research on linkages within global value chains is highlighted by (Epede & Wang, 2022), among others. However, there are necessary prerequisites, resources and strategies that need to be put together to ensure successful integration and growth (upgrading) within GVCs (Epede & Wang, 2022).

In line with modern economic theory, it can be assumed that changes in the external environment will affect procurement and inbound logistics differently. Both process categories (input logistics and procurement) implement the material flow into the company. Inbound logistics focuses on the operational management of material flow, while procurement deals with the building and strategic planning of supplier-customer relationships. As a traditional primary process, the authors expect that inbound logistics will succumb to more changes and be perceived as more affected than procurement.

On the one hand, these processes have a similar goal (timely and complete provision of the company with the necessary material elements), both of which must be implemented in the company. On the other hand, the activities and focus of the processes themselves differ (procurement addresses purchasing as part of strategic development, and input logistics concentrates on material provision of immediate needs). The paper explores how these processes are perceived and implemented in the wake of the recession.

The paper's main objective is to determine the difference in the perceived importance of procurement and inbound logistics and to see if there is a link between importance, investment in the area and economic impact in times of recession.

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To achieve the objective of the paper, four research questions are defined:
RQ1: Is there a link between the importance of inbound logistics and the importance of procurement?
RQ2: How do selected factors (factors: size, industry, presence (national, multinational) affect the link between the importance of procurement and inbound logistics?
RQ3: How does the growth in the importance of procurement and inbound logistics affect investment in these areas?
RQ4: How is the change in the importance of procurement and inbound logistics related to the profitability of the firm?

2. Research objective and methodology

Several studies have been carried out with themes related to the objectives of this paper. For example, the aim of Pattanayak & Punyatoya (2020) was to investigate the effect of electronic sourcing (EP) and supply chain technology internalisation (SCTI) on supply chain performance (SCP-Supply Chain Performance) through supply chain integration (SCI-Supply Chain Integration). A questionnaire survey was used to collect data. Structural equation modelling (SEM) using AMOS software was used to test the hypotheses.

The study by Kumar & Ganguly (2020) focuses on the research on the effect of supply chain coordination on a firm's financial performance through external diffusion of e-procurement. A survey of professionals working with B2B e-procurement was used to collect data. For data processing, a validated measurement model using confirmatory factor analysis was used to establish reliability and validity, followed by structural equation modelling (SEM) using AMOS 22 software to test the hypotheses of the research model. A phantom model approach by Kumar & Ganguly (2020) was used to test for multi-agent effects.

Liu et al. (2019) assess the impact of procurement strategy on supply chain performance. For data processing, the authors used theoretical modelling to generate data. The basis of their analysis is a two-stage Stackelberg game model, which they extended with loss aversion scenarios of logistics integrators and service providers. The results were obtained by comparing the four models to assess the impact of loss aversion on the decisions of supply chain participants and then optimising the purchase volume and pricing strategy, which provided insights into the effects of demand upgrading and loss aversion on decision-making processes in the logistics service chain.

The objective of Boruchowitch & Fritz (2022) was to explore the function of procurement in creating sustainable value in the value chain and to identify how procurement can contribute to operationalising sustainable development goals in the firm. Interviews with key procurement and sustainability employees, ethnographic observations, and content analysis were conducted to collect data. A qualitative mixed-methodology approach was used to process the data to provide contextual insight into everyday practices and identify patterns and themes.

The main objective of Kosmol et al. (2019) was to understand the mutual readiness of supply chain partners for e-procurement and identify the factors and performance impacts associated with adopting these digital practices. A literature search and dyadic case studies were conducted to collect data. A cross-case comparative case study method was used to process the data, in which all case studies were compared and contrasted to identify common patterns and dynamics of change. This process involved data coding, thematic analysis, and synthesis of patterns across the eight companies studied.

Plantinga et al. (2020) focused on exploring the alignment between procurement tools and organisations' strategic objectives. Document analysis, observation, and interaction with participants during the development of a new procurement process tool were used to collect data. Action research was used to process the data to explore and improve the process of developing a procurement tool in practice, divided into five phases: diagnosis, action planning, action implementation, evaluation, and defining learning.

Hayakawa & Mukunoki (2021) are oriented to explore the impact of the COVID-19 pandemic on global value chains with respect to bilateral trade in finished engineering products between January and June 2019 and 2020.

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Data was drawn from public sources such as the IHS Markit World Trade Atlas. To process the data, they applied a simple empirical model that analyses trade flows of finished machinery products between different countries. The model includes variables such as regional trade agreements, the GDP of countries, and the number of cases/deaths of COVID-19. The Poisson pseudo maximum likelihood (PPML) method and logarithms were used to analyse and evaluate some variables. The aim of Espitia et al. (2022) was to explore the impacts of the COVID-19 pandemic on global value chains. Data were used for two time periods: January-June 2019 and January-June 2020. Data were obtained from the COVID-19 Trade Watch and other data sources such as customs offices, Eurostat, the US Department of the Treasury and the US International Trade Commission. Regression analysis was used to process the data to examine the relationships between bilateral trade growth and various factors, including supply and demand shocks associated with the COVID-19 pandemic. There is, therefore, a certain contradiction within the current state of scientific knowledge. On the one hand, procurement and inbound logistics are among the key elements of the value chain and are considered as sources of potential competitiveness of the company. On the other hand, there is a lack of a common assessment of the evolution of the perception and behaviour of procurement and inbound logistics and the extent to which they are interconnected in the face of external asymmetric threats. There is a lack of a comprehensive assessment of the logically linked sequence of "importance - investment - economic impact" for both procurement and inbound logistics, and especially their comparison in the context of trend monitoring.

In the interest of reproducibility, please concisely describe the research material and scientific methods used. If these are not original methods, reference the paper where this method was originally published.

To meet the main objective of the paper, the following hypotheses were set as research questions:
RQ1: Is there a link between the importance of inbound logistics and the importance of procurement?
H0: There is no relationship between a change in the importance of inbound logistics and a change in the importance of procurement,
H1: there is a direct relationship between the change in the importance of inbound logistics and the change in the importance of procurement.
RQ2: How do selected factors (size, industry, scope) influence the link between the changing importance of procurement and inbound logistics during the recession?
H2: The company's size directly impacts the degree of association between the change in the importance of inbound logistics and the change in the importance of procurement (the larger the company, the greater the association).
H3: The degree of association between the importance of inbound logistics and procurement varies by business sector.
H4: There is a direct relationship between the scale of operation and the degree of association between the change in the importance of inbound logistics and procurement.
RQ3: How does the changing importance of procurement and inbound logistics affect investment in these areas during the recession?
H5: The change in the importance of procurement is unrelated to the change in investment in the area.
H6: the change in the importance of inbound logistics is related to the change in investment in inbound logistics.
RQ4: Does the degree of association between the change in the importance of procurement and the change in the importance of inbound logistics depend on the change in economic performance in a recession?
H7: The degree of association between the change in the importance of inbound logistics and procurement varies according to the nature of the change in economic performance during the recession.

The research structure is presented in Figure 1 below.

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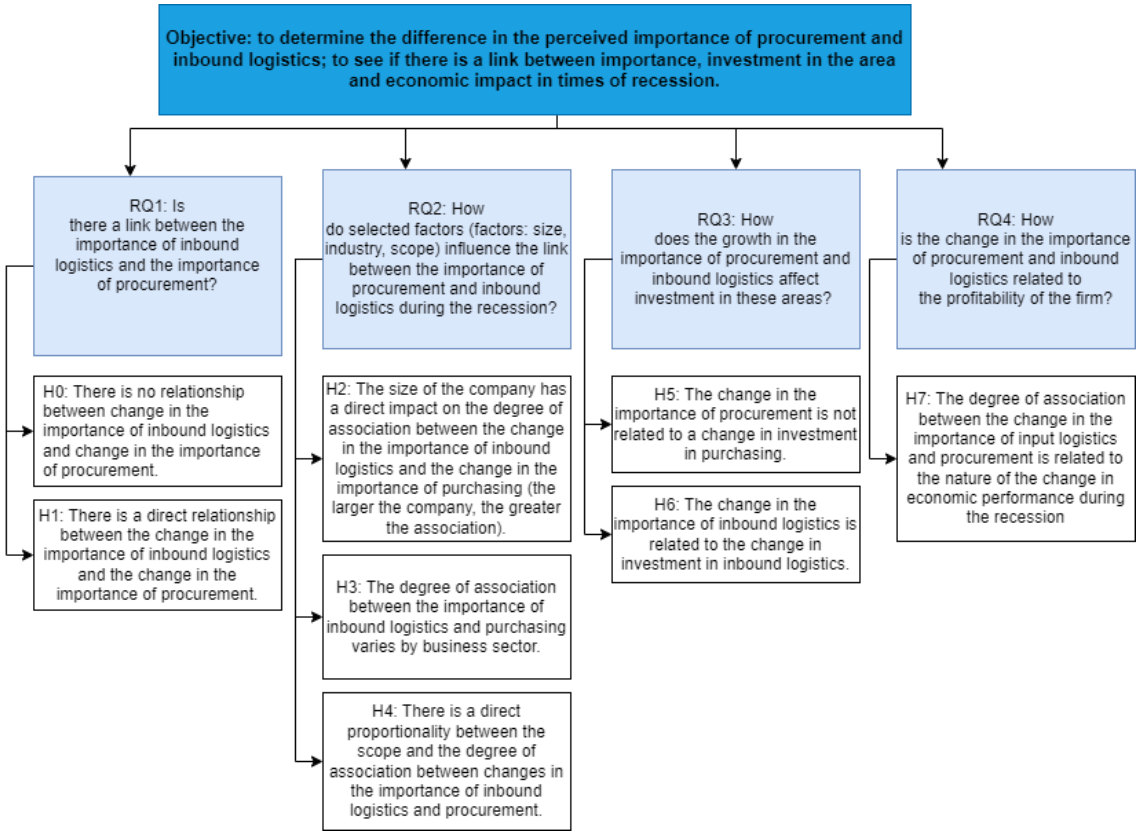


Figure 1. The structure of the research
Source: own processing

Methods of data collection

To meet the objectives of the paper, a primary quantitative survey will be conducted in Czech companies. The selection of respondents will be random and voluntary. The minimum return rate is set at 200 respondents. The questions include the measurement of the enterprise, size of the enterprise, the scope of the enterprise, the financial situation before COVID-19, the financial situation during COVID-19, investment costs before and during the pandemic in the area of procurement, investment costs before and during the pandemic in the area of inbound logistics, importance of inbound logistics and procurement before and during the pandemic.
The description of the sample for hypothesis testing is presented in Table 1.

Table 1. Description of variables for hypothesis testing

Hypothesis	Description of variables in the sample		
H0/H1	Change in importance of inbound logistics: A01: no change, A02: increase in importance, A03-decrease in importance	Change the meaning of purchase: A11: no change, A12: increase in importance, A13-decrease in importance	
H2	Change in importance of inbound logistics: A01: no change, A02: increase in importance, A03-decrease in importance	Change the meaning of purchase: A11: no change, A12: increase in importance, A13-decrease in importance	B21: micro-small enterprise B22: medium-sized B23: large enterprise
H3	Change in importance of inbound logistics: A01: no change, A02: increase in importance, A03-decrease in importance	Change the meaning of purchase: A11: no change, A12: increase in importance, A13-decrease in importance	B31: services B32: trade B33: industry
H4	Change in importance of inbound logistics: A01: no change, A02: increase in importance, A03-decrease in importance	Change the meaning of purchase: A11: no change, A12: increase in importance, A13-decrease in importance	B41: local B42: regional B43: national B44: transnational

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H5	A51: no change in the meaning of the purchase, A52: decrease in purchase importance, A53: increase in purchase importance,	B51: Investment growth, B52: no change in investment, B53: decrease in investment.	
H6	A61: no change in the importance of inbound logistics A62: decrease in the importance of inbound logistics, A63: increase in the importance of inbound logistics,	B61: investment growth, B62: no change in investment, B63: decrease in investment.	
H7	Change in importance of inbound logistics: A01: no change, A02: increase in importance, A03-decrease in importance	Change the meaning of purchase: A11: no change, A12: increase in importance, A13-decrease in importance	A71: there is a relationship (growth-growth, decline-decline, stagnation-stagnation) A72: no relationship (all others)

Source: own processing

Methods of data processing

The hypotheses will be tested in several stages. During the first stage, H0/H1 testing will be conducted. One-factor ANOVA will be used. Hypothesis H1 is considered to be confirmed if the p-value does not exceed 5 per cent. Otherwise, H0 is confirmed. During the second stage, H2, H3, H4 will be tested. One-factor Anova will be used for testing. The significance threshold is set at a 5 per cent p-value. The third stage focuses on testing H5 and H6. Again, the one-factor Anova tool will be used. The significance threshold is set at 5 per cent. During the fourth stage, H7 testing is conducted. The one-factor Anova tool will be used. The p-value significance threshold is set at 5 per cent.

4. Results and discussion

A total of 395 enterprises participated in the questionnaire survey. The composition by sector, size of enterprises and scope within this sample is presented in Figure 2 below.

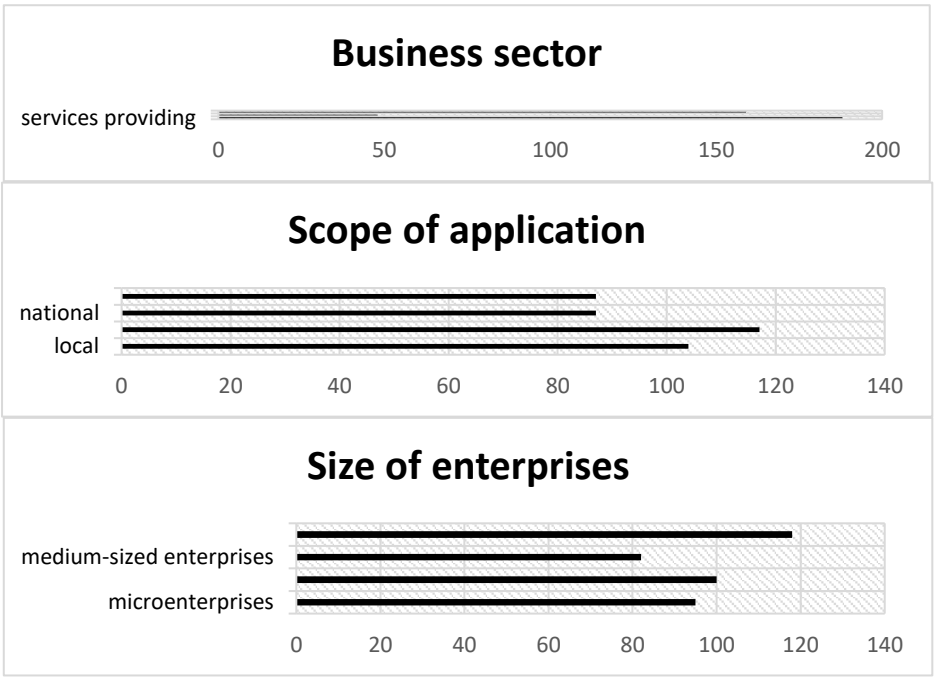


Figure 2. Distribution of respondents by factors: size, sector, scope
Source: own processing

RQ1: Is there a relationship between the importance of inbound logistics and the importance of procurement? The results of H0/H1 testing are presented in Table 2.

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Table 2. The result of testing H0/H1.

H0/H1 test, one-criteria ANOVA test					
	Changing the meaning of inbound logistics				
	Df	Sum Sq	Mean Sq	F value	Pr (>F)
Changing the meaning of purchase	2	10.17	5.086	12.48	0.00000558 ***
Residuals	392	159.79	0.408		

Source: own processing

The test results suggest that a change in the importance of procurement is associated with a change in the importance of inbound logistics. Hypothesis H1 is confirmed. Thus, the following hypotheses (H2-H7) will be tested.

RQ2: What selected factors (factors: size, industry, scope) influence the link between the changing importance of procurement and inbound logistics during the recession?

The results of H2 testing are presented in Table 3.

Table 3. H2 test results

H2 test, one-criteria ANOVA test					
	Changing the meaning of inbound logistics				
	Df	Sum Sq	Mean Sq	F value	Pr (>F)
Microenterprises					
Changing the meaning of purchase	2	2.816	1.408	4.294	0.0165*
Residuals	92	30.173	0.328		
Small enterprises					
Changing the meaning of purchase	2	2.65	1.325	3.193	0.0454*
Residuals	97	40.26	0.415		
Medium-sized enterprises					
Changing the meaning of purchase	2	1.77	0.8840	2.108	0.128
Residuals	79	33.12	0.4193		
Large enterprises					
Changing the meaning of purchase	2	3.46	1.7308	3.598	0.0305*
Residuals	115	55.33	0.4811		

Source: own processing

H2 testing showed that the association between the change in the importance of inbound logistics and the importance of procurement exists only for micro, small and large enterprises. For medium-sized enterprises, the link is not demonstrated. The strongest association between the importance of inbound logistics and the importance of procurement is defined in micro-enterprises. Since no direct relationship between firm size and the degree of association between the change in the importance of inbound logistics and procurement has been demonstrated, hypothesis H2 is not supported. Firm size does not directly affect the degree of association between the importance of inbound logistics and procurement. The results of H3 testing are shown in Table 4.

Table 4. H3 test results

Test H3, one-criteria ANOVA test					
	Changing the meaning of inbound logistics				
	Df	Sum Sq	Mean Sq	F value	Pr (>F)
Services					
Changing the meaning of purchase	2	7.65	3.825	10.3	0.0000575 ***
Residuals	185	68.71	0.371		
Production					
Changing the meaning of purchase	2	4.57	2.2872	5.011	0.00777 **
Residuals	156	71.20	0.4564		
Sales					
Changing the meaning of purchase	2	0.104	0.0521	0.139	0.871
Residuals	45	16.875	0.3750		

Source: own processing

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Based on H3 testing, the link between the importance of inbound logistics and the importance of procurement is confirmed for firms in the service and manufacturing sectors. On the contrary, this link was not confirmed for trading companies. The strongest link between the importance of inbound logistics and procurement is defined for service providers. Hypothesis H3 is confirmed: the degree of association between the importance of inbound logistics and procurement varies by business sector.
The results of H4 testing are shown in Table 5.

Table 5. H4 test results

Test H4, one-criteria ANOVA test					
	Changing the meaning of inbound logistics				
	Df	Sum Sq	Mean Sq	F value	Pr (>F)
Local					
Changing the meaning of purchase	2	5.89	2.942	8.998	0.000253 ***
Residuals	101	33.03	0.327		
Regional					
Changing the meaning of purchase	2	0.20	0.0981	0.203	0.816
Residuals	84	40.52	0.4823		
National					
Changing the meaning of purchase	2	1.216	0.6079	1.655	0.197
Residuals	84	30.853	0.3673		
Multinational					
Changing the meaning of purchase	2	4.66	2.3302	5.083	0.0768*
Residuals	114	52.26	0.4584		

Source: own processing

According to the results of H4 testing, the link between the importance of inbound logistics and procurement was confirmed for companies with local (local) operations and multinational companies. The link was not confirmed for enterprises with regional or national scope. The hypothesis was not confirmed. There is no direct correlation between the extent of the scope and the degree of association between the change in the importance of inbound logistics and procurement.
RQ3: How does the changing importance of procurement and inbound logistics affect investment in these areas during the recession?

The results of H5 testing are presented in Table 6.

Table 6. H5 test results

Test H5, one-criteria ANOVA test					
	Change in investment in procurement				
	Df	Sum Sq	Mean Sq	F value	Pr (>F)
Changing the meaning of purchase	2	10.44	5.218	8.727	0.000196 ***
Residuals	392	234.36	0.598		

Source: own processing

Based on the H5 testing, a link between the change in the importance of procurement and investment in the procurement area was demonstrated during the testing. The hypothesis is confirmed: with the increase in the

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importance of procurement comes an increase in investment in procurement. The results of H6 testing are presented in Table 7.

Table 7. H6 test results

Test H6, one-criteria ANOVA test					
	Change in investment in inbound logistics				
	Df	Sum Sq	Mean Sq	F value	Pr (>F)
Changing the meaning of inbound logistics	2	2.09	1.0428	1.72	0.18
Residuals	392	237.64	0.6062		

Source: own processing

The results of the H6 test show no direct relationship between the change in the importance of inbound logistics and the change in investment in inbound logistics. Hypothesis H6 is rejected. An increase in investment in this area does not accompany the increase in the importance of inbound logistics.

RQ4: Does the degree of association between the change in the importance of procurement and the change in the importance of inbound logistics depend on the change in the economy resulting in a recession?
The results of H7 testing are shown in Table 8.

Table 8. H7 test results

Test H7, one-criteria ANOVA test					
	Changing the meaning of procurement (supplier-customer relationships)				
	Df	Sum Sq	Mean Sq	F value	Pr (>F)
Negative change ER (economic result)					
Changing the meaning of inbound logistics	2	7.26	3.629	7.574	0.000861 ***
Residuals	101	48.40	0.479		
Neutral change ER					
Changing the meaning of inbound logistics	2	0.216	0.1078	0.261	0.773
Residuals	26	10.750	0.4135		
Positive change ER					
Changing the meaning of inbound logistics	2	6.9	3.45	7.504	0.000679 ***
Residuals	259	119.1	0.46		

Source: own processing

The relationship between the change in the importance of procurement and the change in the importance of inbound logistics is demonstrated for firms with an adverse change in profitability (ER) and firms with a positive change in ER. The association is not confirmed for firms with a stagnation of economic results. The hypothesis is confirmed: the degree of association between the change in the importance of inbound logistics and procurement varies according to the nature of the change in the economic result during the recession period.
In answering RQ1, the link between the growing importance of supplier-customer relationships and the importance of inbound logistics in the recession was confirmed.

The evolution of logistics capabilities and their impact on supply chain resilience is confirmed by a study by Song et al. (2022). The interrelationship between Global Value Chain elements is also noted by Epede & Wang (2022). The results suggest specific factors that could enable SMEs to use knowledge to support the

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development of GVCs. Thus, the interconnectedness of the procurement domain and the importance of the inbound logistics domain fit entirely into the current state of scientific knowledge of the GVC domain.

According to our results of the RQ2 solution, it can be concluded that the size of the company is a factor that influences the degree of the link between the change in the importance of inbound logistics and the change in the importance of procurement during the recession. However, a direct relationship between firm size and the degree of association between the change in the importance of inbound logistics and procurement has not been established. The business sector was defined as another factor influencing the degree of association between the change in the importance of inbound logistics and the change in the importance of procurement. The strongest association between change in the importance of procurement and change in the importance of inbound logistics was found for service providers. The link was also confirmed for manufacturing firms. The scope of operations impacts the link between the change in the importance of procurement and the change in the importance of inbound logistics. The correlation was confirmed for enterprises with a local (local) presence and multinationals. However, there is no direct correlation between the scope of the enterprise and the association between the change in the importance of procurement and the change in the importance of inbound logistics. The results are consistent with the findings of Espitia et al. (2022).

A study by Espitia et al. (2022) reported that the vulnerability/resilience of supply chains varied by factors such as industry, the ability to work remotely, the durability of goods, and participation in global supply chains. Song et al. (2022) list the degree of digitalisation, innovation and modularisation, and risk management, among the factors that influence interconnectedness. The results of our research show that the degree of association between the change in the importance of procurement and the change in the importance of inbound logistics is not constant across firm size, business sector or scope. The greatest association was found for micro-enterprises in the service sector with a local (site) presence.

Based on the results of RQ3, it can be concluded that there is a link between the importance of procurement and investment in procurement. On the other hand, the association between the importance of inbound logistics and area investment was not confirmed.

Thus, our results build on the findings of Hayakawa & Mukunoki (2021), which identify a greater influence of supply chain effects than output effects on trade flows and point to the importance of diversification of inbound sources and effective inventory management for the resilience of global trade in a recession.

The responses to RQ4 suggest that the degree of association between the change in the importance of inbound logistics and procurement varies according to the nature of the change in the economic outcome during a recession. For firms with a positive change in ER, there is a stronger association between the change in the importance of procurement and the change in the importance of inbound logistics in a recession. The testing findings correspond with the results of Kumar & Ganguly (2020), who state that the degree of e-procurement development directly affects the firm's financial performance.

Conclusions

The main objective of this paper is to investigate the difference in the perceived importance of procurement and inbound logistics and to see if there is a link between importance, investment in the area and economic impact in times of recession.

Recommendations for the target segment can be summarised in several points. The main recommendation is a detailed consideration and comprehensive monitoring of investment and efficiency in relation to the changing importance of procurement and inbound logistics, as well as other primary and secondary processes within the GVC concept. Transparency and openness must be ensured when monitoring the performance of each process. The research has several limitations. It focuses only on the Czech environment during the specific period of the COVID-19 pandemic. The survey was carried out in the short term. Therefore, it is not certain that with longer-term follow-up, the values and, consequently, the research context will be at the same level. The sample under

some questions may not meet the validity requirements, e.g. under H3 testing, only 45 business enterprises were in the sample.

Based on the results, the direction of future research can be defined. It is necessary to carry out research from a longer-term perspective, i.e., both in economic growth and economic recession. Another research direction is to look for interrelationships between other aspects of GVCs. Further research should focus on identifying the drivers of change in business performance in the context of individual business processes.

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USER EXPERIENCE DESIGN IN THE CONTEXT OF EXPERIENTIAL MARKETING

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Abstract. User experience is important to every successful company. In experiential marketing, the goal is to create a positive user experience, encouraging them to become loyal, share experiences, and become a brand ambassador. The article aims to investigate the peculiarities of user experience design in the context of experiential marketing. Qualitative research based on nine user experience professionals' interviews was conducted, and qualitative content analysis was performed. The research indicates a strong trend toward a more integrated, technology-enhanced, and user-focused approach to user experience design and its relationship with experiential marketing. Collaboration between user experience design and marketing will intensify, leveraging user experience data for more targeted, emotionally resonant marketing experiences. The research addresses the future of user experience design, emphasising AI, VR, and biometric integration, reflecting the latest trends in the field.

Keywords: user experience, experiential marketing, user experience indicators, user experience management process models

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1. Introduction

Growing competition reduces the value of price-based offers. It encourages online store suppliers to look for more effective and long-term ways of achieving competitive advantage in the digital space. In the digital space, companies compete not only on the local but also on the global market; business success depends on factors that influence user experience, knowledge, and understanding. Therefore, to gain a competitive advantage, it becomes essential to understand the user's experience and satisfaction with the services they provide (Ozfidan, & Ismail, 2023; Intal et al., 2023; Hsiao & Tang, 2024; Msosa et al., 2024; Jiang & Verhulsdonck, 2025; Fisher, 2025).

Although more and more attention has recently been paid to the concept of experience marketing, where special emphasis is placed on the creation of user experience, which has an impact on creating strong company-consumer relationships, there is a lack of research on the effects of user experience in the context of experiential marketing. This is a new, relatively little-analysed field of marketing theorists and practitioners.

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2. User experience and experiential marketing concept

User experience is an important topic; many possible definitions and peculiarities exist. Musulin and Strahonja (2023) argued that user experience is considered a holistic and phenomenological outcome of the user's interaction with an IT artefact, transcending the narrower concept of pragmatic use and emerging as an individual response to pursue higher motivational goals such as meanings and emotions. Hussain et al. (2022) stated that the meaning of user experience characteristics follows product features, user status, and contexts, while others have found associations between usability and heterogeneous factors such as gender differences, context usage, and usage patterns. Luther et al. (2020) mentioned that the concept of user experience is characterised by ambiguous and diverse expressions (e.g. "use" or "user consent"), which hinders precise definition. One reason is that usability is considered a sub-concept of user experience. Berni and Borgianni (2021) defined user experience as a consequence of brand image, presentation, functionality, system performance, interactive behaviour and assistive capabilities of the system, product or service. Marques et al. (2021) mentioned that user experience is a quality aspect that considers the emotions a system evokes, and the concept should be extended beyond efficiency, effectiveness and satisfaction.

Fayez et al. (2023) analysed the perception of user experience, which revolves around a person's impressions of an experience or the emotional aspect of the experience that marks the interaction between people and computers. Berni and Borgianni (2021) also determine the internal and physical state of the user, resulting from previous experiences, attitudes, skills, abilities, and personality, as well as from the context of use. Norman (2004) stated that emotion and cognition work together as consumers relate to products, and emotions are inseparable from and a necessary part of cognition, so emotionally appealing aesthetic elements are essential in "user-centred" design.

Corrales-Paredes et al. (2023) mentioned that user experience is a key concept in the design of physical and digital products such as devices, software, websites, and mobile apps. Krueger et al. (2020) defined that consumers' experience of products and services can be divided according to two different dimensions: hedonic and pragmatic properties: hedonic indicates the affective components of a product or service, such as enhancing a person's psychological state of well-being and pragmatic features include the functionality and usability of the product or service.

According to Marques et al. (2021), practitioners and researchers realise the importance of user experience evaluation, so plenty of research has been conducted in this area. Ntoa et al. (2021) stated that measuring user experience becomes a much more complex endeavour when the goal of the interaction is not only a technological system or program but also the entire intellectual environment and the systems in it.

Feng and Wei (2019) mentioned that previous user experience research has focused on short-term measurements emphasising experiential features related to improving the first impression of a product, such as ease of use and utility. In recent years, more and more researchers have begun to emphasise the importance of long-term user experience evaluation. Lee et al. (2022) examined the usability of digital native actors in detail. They suggested what engaging content, user experience, and interface aspects should be created from their point of view - elements that need to be added to the user experience have been obtained from the information architecture and usage environment categories.

Koonsanit et al. (2022) studies had measured user experience in order to improve end-user satisfaction, and the findings defined the fact that instantaneous user experience can affect episodic user experience; during real user experience, various factors will interact in a complex way, and accumulated experiences will determine the final user satisfaction. Veigas et al. (2023), in their user experience research, moved to an encouraging basis method, scrutinising specific methods used in various situations, delving into the basic principles of behaviour, and evaluating the significant influence of these methods on user behaviour.

According to Schmitt (1999), experiential marketing is not focused solely on the product or service and its features but also includes the experiences – both emotional and rational – that companies create for their customers. Yuan and Wu (2008) mentioned that experiential marketing is the user's perception of a product or

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service provider's company or brand, evaluation after experience activities, and received incentives. A positive experience increases the value of a product, brand, and/or company. Schmitt (1999) argues that the focus is not only on customer experience but also on its management, requiring marketing strategies and decisions to be updated based on five key elements: sensation, emotion, action, thinking, and interaction. Essential aspects of experiential marketing include consumer experience, consumption as a holistic process, customer rationality and emotionality, and the variety of applied marketing methods. According to Yuan and Wu (2008), there is no emphasis on the product or service quality. Still, on the contrary, the emphasis is on stimulating the user's emotions and senses, which are related to good service or product quality. Experiences can be created and developed. Companies should choose the theme of the experience, enhance the impression with positive elements (symbols), eliminate negative symbols, form an image of memorable items/services, and involve all the user's senses (sight, smell, touch, taste, and hearing). All experience elements must stimulate the user's five senses, including what they see, hear, taste, smell, and touch.

3. User experience indicators and management process

Companies use user experience indicators to understand whether a user is satisfied with a service or product. Usually, these indicators are obtained by surveying service users about key aspects of their experience with the company. When surveys are received from users, they can be processed using different methods, as user experience can be measured in several different ways. These metrics help business professionals understand how to improve user experience and encourage customer loyalty. Below are some key user experience metrics.
Ease of use: this indicator covers how easy it is for the user to use the interface of the product or service. This can include a clear navigation menu, intuitive design and quick response to user actions. Basukiam et al. (2022) mentioned that perceived usefulness is the degree to which a user believes using a particular smart speaker system can improve their productivity and work performance. Rauniar et al. (2014) defined perceived usefulness as the degree to which social media users believe using a particular website helps meet goal-seekers' needs.
Emotional reactions: user experience also refers to the emotional reactions when using a product or service. It can be related to joy, frustration, satisfaction or other emotional states. Marshall and Brown (2006) argued that this factor depends on what emotions one is considering. Expectations will influence some emotions. Almost by default, people are surprised when they experience an unexpected result. It is probably because of frustration, as this emotion also arises from inconsistent predictions and realisation.
Product effectiveness: this metric measures how well the product meets the user's needs and goals. This includes the product's functionality and ability to deliver what the user expects. Son et al. (2021) stated that organising and presenting product reviews on e-commerce sites can increase user experience and provide customers with more informative product feedback on time. Product reviews are more persuasive for users than a list of objective product features.
Satisfaction: user experience often leads to satisfaction. This indicator measures whether the user is satisfied with the product or service. Positive satisfaction often leads to loyalty. Wang et al. (2023) conducted research in the context of green food and stated that user experience satisfaction has a positive effect on green food repurchase intention. Also, user experience satisfaction can improve consumers' repurchase intention for organic food through consumer perception of social value, green self-efficacy and warm glow; the greater the degree of inertia of the user, the more substantial influence of green self-efficacy and warm glow on consumers' green food repurchase intention; and the higher the degree of consumers' subjective norms, the stronger the influence the consumer perceives social value, green self-efficacy, and the warm glow of the consumer's raw food repurchase intention.
Need satisfaction: user experience is also about whether a product or service meets the user's needs and expectations. Effective user experience management can help achieve this goal. Cuevas-Campos et al. (2020) research on need satisfaction showed that simply self-motivation played a mediating role in the need-intention relationship, and satisfaction of basic needs leads to higher levels of intention through increased self-motivation.
Frequency of use: this indicator shows how often users use the features provided by the product or service. Hu et al. (2022) studied teacher groups and defined that they achieved higher levels of self-efficacy and adaptive teaching when ICT was more commonly used in reading classrooms. Experienced teachers better facilitated adaptive teaching and self-efficacy using ICT.

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When analysing user experience management process models, there are structural frameworks that help understand and manage the user experience from start to finish. These models help business professionals understand consumer behaviour and how to influence it to create a good user experience.

Merino-Cajaraville et al. (2023) and Abbasi et al. (2012) analysed the User Experience Lifecycle Model, emphasising that the user experience constantly evolves. It includes four stages: the use process, the evaluation process, the testing process, and the evaluation process. Bicevskis et al. (2016) mentioned that the Event-Driven Model breaks down the user experience into specific events that occur during the consumption of a product or service; the example of this model can be many data processing systems we use in our daily lives - state information systems (population register, vehicle register, etc.), as well commercial solutions (e-shops, CRM, etc.). Matzavela and Alepis (2021) stated that The User Experience Tree Model represents the user experience as a tree with branches corresponding to different aspects such as functionality, efficiency, usability and emotional reactions. Zhou et al. (2011) present the User Experience Ecosystem Model, which focuses on how users interact with the different elements of products and services that make up a larger ecosystem. It helps you understand how these elements interact with each other and affect the user experience.
The research aims to investigate the peculiarities of user experience design in the context of experiential marketing.
Objectives of the research:
- to present the theoretical background of user experience and experiential marketing concept;
- to analyse user experience indicators and management processes;
- based on qualitative research, to evaluate the characteristics of user experience design and to discover the link between the user experience design and experiential marketing;
- create recommendations based on the results of in-depth interviews with the experts in user experience design.

4. Research methodology

Research method. Exploratory qualitative research was carried out with the purpose of gaining an in-depth understanding of user experience peculiarities in the context of experiential marketing by conducting nine expert interviews. The qualitative method was selected to interview the user experience professionals to collect expert opinions, which would help prepare a summary of experiential marketing recommendations. Qualitative content analysis was performed, which enables interpretation of text data, and qualitative categories were distinguished, including analysis and verification of research data (Cohen et al., 2007).

Research instrument. Interviews were conducted by presenting open-ended questions to the experts without standard possible answers and evaluation scales. A semi-structured interview was chosen as the data collection method. The preferred method should help to answer the research questions as best as possible (Elo et al., 2014). Saturation is when more information does not reproduce when new data is integrated. Questions covered the following topics:

- The most important elements of user experience design;
- Relationship between user experience design and experiential marketing;
- Future of user experience design.

Research sample. Determining what sample size should be held in qualitative research is challenging. The sample size depends on the details of the research, the research strategy, the informativeness of collected data, and the method of data collection. We selected nine experts based on methodological prerequisites reviewed in the classical test theory (Libby & Blashfield, 1978). Based on the theory, the number of decision-making experts and the reliability of aggregate decisions are linked by the variable value ratio (non-linear relationship). At the same time, the highest precision of estimates is reached in a group of 7-9 experts. The research sampling strategy was chosen because researchers could select informants based on established criteria who could ensure data quality and answer research questions (Graneheim & Lundman, 2004). The main criteria for selecting informants were competencies in the analysed field. The main information of informants can be seen in Table 1 below.

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Table 1. Interview participants

Code	Position	Tasks / Responsibilities
E1	UX researcher	Analyse theoretical aspects of user experience
E2	UX Architect	Team lead in content development/social media
E3	UX Designer	Design for users throughout a project
E4	Head of Marketing	Work with experiential marketing
E5	UI Designer	Design all the screens that make up a digital user interface
E6	UX Manager	Are in charge of the UX team
E7	UX researcher	Analyse theoretical aspects of user experience
E8	UX Manager	Are in charge of the UX team
E9	Head of Marketing	Lead marketing teams, work with experiential marketing

Organisation of the research. LinkedIn was used to find and communicate with experts (by a personal message inviting participation). The informants were allowed to choose a date and time that suited them and the type of contact they wanted to have with the researcher. Telephone calls, remote meetings and written questions were sent to the participants (they were able to select the most appropriate form). Data collection took place between September and November 2024.

Data analysis. While applying qualitative content analysis during this research, the data was systematised and summarised to reveal the meanings the informants gave. After preparation of the analysis, categories or concepts were acquired. The researchers decided on the choice of concept and categories.

Research ethics. To ensure research ethics and participant consent, participants were required to sign a compliance agreement before they participated in the interviews. This agreement outlined the purpose of the study, assured confidentiality and obtained informed consent from the participants. By adhering to ethical guidelines, the researchers ensured the protection of participants' rights and the integrity of the research process.

5. Qualitative Research Results

Interviews were focused on understanding the most important elements of user experience design, the relationship between user experience design and experiential marketing and the future of user experience design. When analysing answers about the most important elements of user experience design, the target audience and functional elements are of special importance (see Table 2).

Table 2. Category – the most important elements of user experience design

Subcategory	**Empirical study statements (indicators)**
Target audience	*"*(...) *The most important elements of UX design involve extensive user research, empathy, and usability testing, as these elements validate that the product truly serves its intended users*" [E1]*"*(...) *the top priority is to ensure all elements, from usability and accessibility to visual appeal, come together to create a cohesive user experience. (...)balancing these aspects with business goals, prioritising based on user needs and organisational objectives are very important"* [E6]; *"Usability and customers empathy, as these ensure that the experience resonates with real user behaviours and preferences"* [E7]; *"*(...) *the focus is on usability and emotional engagement of target audience, as these elements create lasting brand impressions. UX elements that encourage positive emotional connections are valuable to brand's perception and loyalty*" [E9].
Functional elements	*"UX design's backbone is information architecture and navigation flow, ensuring users can effortlessly find what they need"* [E2]; *"Core elements like usability, interaction design, and visual appeal are tools for crafting experiences that satisfy user needs and elevate brand engagement."* [E3, E4]; *"Visual consistency, aesthetics, and interaction design are essential in creating an intuitive and visually appealing interface*" [E5]; *"focus is on orchestrating elements like usability, accessibility, and aesthetics to ensure cohesive and efficient design workflows*" [E8]

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After analysing the results of the relationship between user experience design and experiential marketing, user focus and marketing focus could be defined as the main subcategories (see Table 3).

Table 3. Category – relationship between user experience design and experiential marketing

Subcategory	Empirical study statements (indicators)
User focus	*"*(...) *UX connects to experiential marketing by identifying users' expectations and emotional triggers. UX research provides insights that can guide marketing campaigns, ensuring they resonate with the target audience by creating memorable experiences that align with the product's actual usability"* [E1]; *"*(...) *experiential marketing aligns the product's design with campaign goals, ensuring that users find the same values in the experience that they see in promotional materials"* [E3]; *"UX design and experiential marketing intersect in their focus on customer satisfaction"* [E4, E6]. *"The customer research data forms experiential marketing strategies, ensuring they're grounded in real user insights*" [E7].
Marketing focus	*"Experiential marketing creates a seamless bridge between user expectations set by marketing campaigns and the product's structure. Designing consistent, easy-to-navigate frameworks supports the promises made by experiential marketing, leading to cohesive and satisfying user experiences"* [E2]; *"experiential marketing visually reinforces brand messages. The consistency created in UI design (from colours and fonts to layout) ensures that users feel the brand's presence throughout their interaction, bridging the gap between marketing and actual use"* [E5, E8]; "*UX is the extension of brand promises made in experiential marketing campaigns. Ensuring that UX elements align with the marketing vision allows to deliver on promises, building trust and enhancing brand perception*" [E9].

The results of user experience design showed that artificial intelligence, virtual reality, and functionality will shape this area (see Table 4).

Table 4. Category – future of user experience design

Subcategory	Empirical study statements (indicators)
AI/VR focus	*"*(...) *the future of UX design will emphasise even more user-centric insights, likely enhanced by AI and biometrics to gauge user emotions and refine products in real-time"* [E1]; *"*(...)*UX design will include AR/VR, voice interfaces, and possibly even emotional design. Design will have more adaptive and inclusive interfaces, where accessibility and personalisation shape each user's unique experience"* [E3]; *"*(...) *future will likely include designing for diverse devices and interfaces, like AR/VR and voice-controlled environments"* [E5]; *"*(...) *future holds increasing responsibility for managing interdisciplinary teams that include AI and data science experts to create adaptive, data-informed experiences*" [E6]; "*Emerging technologies like biometrics and AI will enrich your research, creating data-informed insights that further enhance personalisation"*[E7]; "*The future of UX involves managing more specialised roles within UX, including AI-driven design, emotion-based UX, and interdisciplinary collaboration with marketing and data science"* [E8].
Functionality	*"The future will involve a shift toward designing adaptable architectures that respond dynamically to user behaviours: increased reliance on machine learning to adjust pathways and refine information architecture on-the-fly based on real-time data"* [E2]; *"*(...) *future will be about deeper integration between UX and marketing, using real-time data to make product and brand experiences more personalised"* [E4]; *"UX data will help to drive more personalised and emotionally resonant marketing experiences"* [E9].

Tracking the user experience is critical for businesses seeking to grow. Today, no successful company is complete without monitoring the user experience. User experience is about digging deep and understanding what customers need, what they value, what they are capable of, and where they need help. Therefore, user experience involves interactions with a product, service or system. It is the customer's personal experience that customers have when using the product. It includes various factors during which the customer encounters ease of use, accessibility, design, functionality, and the user's reaction to the product during and after use.

Conclusions

Experiential marketing is used when examining consumer needs. This type of marketing differs from standard marketing in that its principles are related to the customer's experience, which makes this method specific and focused on the customer's needs to achieve satisfaction and further cooperation. Creating engaging and unique

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experiences is one of the best ways to connect with customers to ensure they want to learn more about the brand and the features it offers.

Qualitative research results showed that functional aspects like usability, accessibility, and visual appeal are consistently emphasised as the main elements of user experience design. Key experts' statements suggest that elements such as user empathy, usability testing, and cohesive design ensure that the product is both functional and engaging for the user. Balancing these with business goals is vital to a successful user experience design. User experience design in relation to experiential marketing is noted for its alignment with understanding users' emotional triggers and expectations, providing insights that guide marketing strategies. User experience and experiential marketing intersect by aligning product usability with marketing promises, ensuring users experience consistency across brand interactions. Combining marketing messages and user experience design enhances user trust, bridging brand promises with actual product experience. Emerging technologies like AI, virtual reality, and biometrics are expected to play a crucial role. These technologies enable real-time adaptation to user emotions, creating personalised and adaptive experiences. Experts' statements emphasise that the future of user experience design will likely incorporate AR/VR, voice interfaces, and emotion-based designs. Adaptability and data-driven decision-making will shape future user experience practices, with machine learning enabling dynamic adjustments in response to user interactions.

Novelty and research limitations

The study's novelty is based on an analysis of the relationship between user experience design and experiential marketing, two fields typically studied separately. By examining how user experience principles can inform and enhance experiential marketing strategies, the study offers insights that may benefit both design and marketing professionals, helping to bridge gaps between product usability and brand perception.

Limitations of the study - the study relies on interviews, and the findings may lack broad empirical validation. Interview-based insights reflect subjective perspectives, which, while valuable, may not be universally applicable without further quantitative research. The applicability of findings may be restricted to specific industries or digital environments that can leverage AI, VR, and experiential marketing. Fields focusing less on digital interaction may find limited relevance in this study's findings.

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USING DRONES FOR MANAGEMENT OF AUTOMOTIVE COMPANIES*

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Abstract. The introduction of drones in the automotive industry is a recent phenomenon with immense potential to revolutionize various aspects of production and logistics. This research paper investigates the integration of drone technology within the automotive industry, examining its potential to enhance economic and non-economic efficiency, inform decision-making, and support strategic management. Key findings demonstrate the transformative potential of drones in streamlining inventory management, optimizing logistics, and improving quality control. By leveraging drones for aerial inspections, parts delivery, and data collection, automotive manufacturers can enhance operational efficiency, reduce costs, improve safety, and gain a competitive edge. The study emphasizes the importance of considering economic and non-economic factors, such as environmental impact and social responsibility, in the strategic deployment of drone technology within the automotive sector. As drone technology continues to evolve, we can expect even more innovative applications to emerge in the coming years. Overall, drones have the potential to make automotive manufacturing faster, more efficient, and safer.

Keywords: drones; automotive; economic efficiency; decision-making in automotive companies

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JEL Classifications: J2, L1, G1

1. Introduction

The current era is forcing us to think more about the multifaceted impact of technological progress on society (e.g., Mohammed & Ahmad, 2025). Unmanned aerial vehicles are also included in the rapidly developing modern technology. The drone market is growing rapidly, and its use can be seen in various military, civilian and commercial deployment examples. They have become a tool for saving human lives during natural disasters, transporting medicines to hard-to-reach areas or transporting organs. They help farmers with irrigation, crop protection, and rescuers searching for lost mountain people. The commercial sector, aware of their advantages, uses drones, for example, for transport, mapping, filming and various types of inspections.

Drones open up new possibilities for various industrial sectors by streamlining the course of original processes and offering new, groundbreaking solutions. The automotive industry is significantly influenced by technological advances, especially in automation and robotization. Individual car factories are starting to look

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for ways to use the advantages of unmanned aircraft and gain a competitive advantage. A limiting factor is that there is little information on the use of unmanned aircraft in the automotive industry, and this area can be considered unexplored. For example, it could be the electromobility part of the innovation (Koman et al., 2024). Drone production is one of the world's fastest-growing and dynamically developing sectors (Kapustina, 2021). According to a report by DRONEII, there are already more than 500 manufacturers on the market (Drone Life, 2021). The drone market comprises various segments that cover defence, business, consumer, public safety, and logistics. Currently, examples of commercial drone deployment are growing exponentially. (Laricchia, 2022, b)

Predictions are optimistic, as a steady increase in sales of these devices is expected every year. According to the latest report on stastista.com, the global drone market is expected to grow from $15 billion (2020) to $90 billion by 2030. This assumption is based on national programs of individual states that plan to increase the deployment of UAVs (Unmanned Aerial Vehicle) for civil and military purposes, as well as the interest of large commercial corporations (Google, Amazon) in purchasing this technology. (Laricchia, 2022, b; Kapustina et al., 2021)

The market's attractiveness is due not only to the current versatile use but also to possible opportunities. These must be constantly explored since the commercial drone market is still in its infancy. (Kapustina et al., 2021) Therefore, there is still room for developing and implementing drone technologies, which can lead to mutual benefits for both manufacturers and operators.

According to a survey conducted by DRONEII, drones were most commonly used for maintenance and inspections worldwide. In addition to comparing individual areas, it also distinguishes between activities carried out by companies in-house and outsourced to specialists, which can be seen in the following Figure 1. (Kapustina et al., 2021)

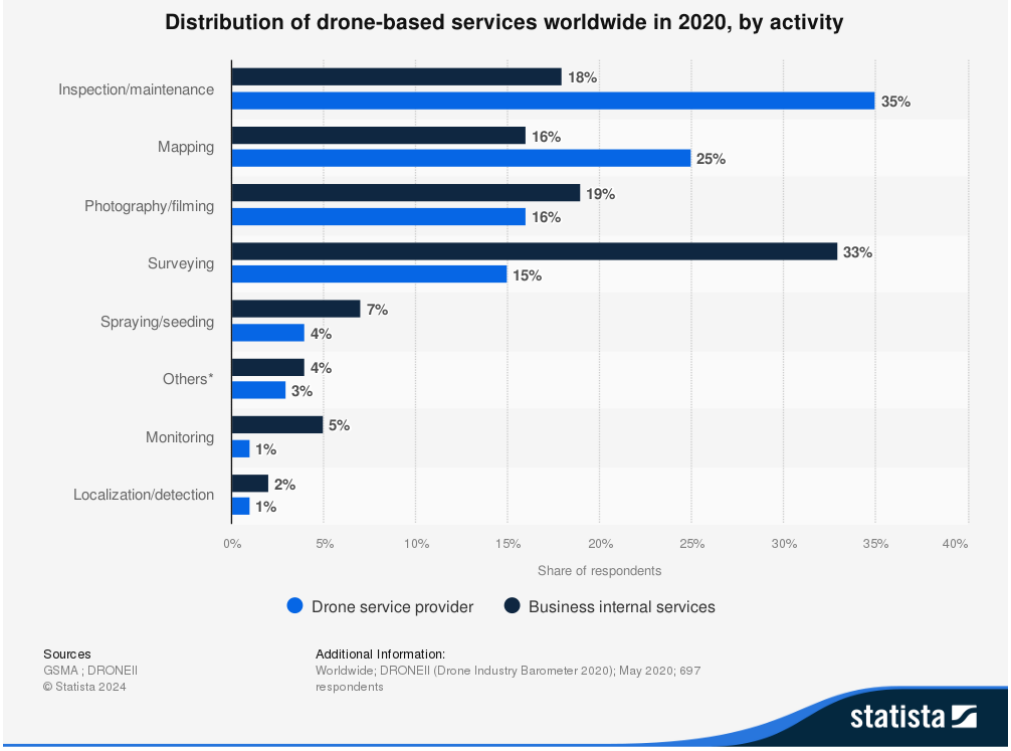


Figure 1. Share of drone services in 2020 by activity

Source: Laricchia, 2022, a

On the demand side, the United States has the highest demand for drones (31%), with 1.1 million devices registered in 2019, according to FAA data. This was followed by China (9%), Russia (8%), and the United Kingdom (6%). (Kapustina et al., 2021; Historia-bahia, 2024)

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Based on March 2021 data, the largest market share is held by the Chinese company DJI. By sales volume, its share was as high as 76%, making it the dominant commercial drone manufacturer in the world. It gained a competitive advantage by becoming the first company to offer drones for both commercial and personal use. It received its first permit from the FAA in 2006 and has since produced readily available drones for the public and businesses. It focuses primarily on agriculture, inspections, and public safety. (Tarek and Gorodetsky, 2018; Historia-bahia, 2024) As can be seen in Figure 2, other manufacturers have significantly smaller market shares.

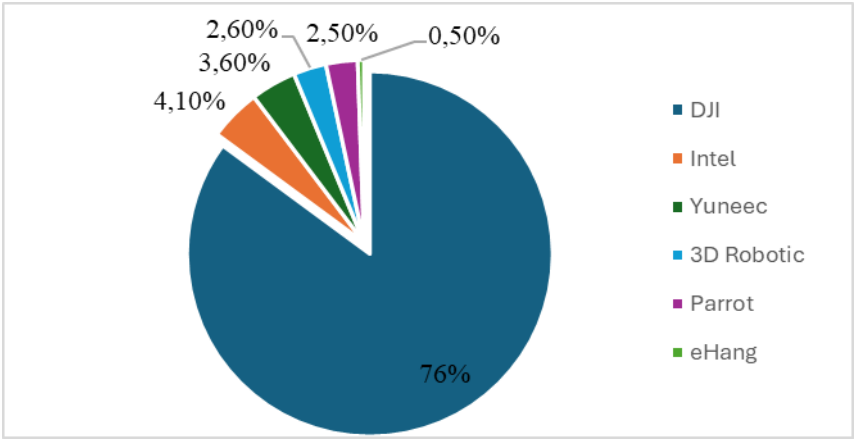


Figure 2. Global market share of commercial drone manufacturers in March 2021

Source: Historia-bahia, 2024

Despite optimistic market predictions, there are some areas where drone technology cannot yet be integrated. This was revealed in a survey by CompTIA, where some companies stated that introducing drones would not bring them process improvements. The most common reason was that they did not need the technology. Other reasons include lack of funding, lack of personnel to operate the equipment, low expected return on investment, legislative restrictions and the absence of drone service providers in their location. (Comptia, 2024)

The latest Drone Market Development Report 2021 lists current technological advances in this area. These include, for example, connecting UAVs to the internet, making them part of the cloud infrastructure. Each UAV acts as a web server, providing resources and services. Cloud integration allows UAVs to be equipped with an application programming interface (API) that offers various services and resources to the operator. Almost all UAVs support Wi-Fi connectivity. (Kapustina et al., 2021; Comptia, 2024) According to the study, the growing demand for UAVs in both the civilian and commercial sectors is driving the market growth. Drone technology also gained prominence during the COVID-19 pandemic, when the demand for contactless deliveries of not only medical supplies increased. (Markets & Markets, 2021) There are several possibilities for using drones. An interesting application is the use in sports and sports activities, not only in their monitoring but also in monitoring sports venues or their sustainability (Varmus & Kubina et al., 2024; Varmus et al., 2024). However, it is important to be careful and incorporate the possible positive and negative impacts on human capital that arise when implementing drone solutions in the commercial sphere. (Štaffenová & Kucharcíková, 2024)

Drones in Modern Industry and Logistics. Drones are a transformative technology with widespread applications in various industries, from logistics and warehousing to construction and agriculture. Their ability to efficiently perform multifaceted tasks and reduce costs makes them an invaluable tool for modern businesses. (Salazar et al., 2023) (Meng et al., 2023) (Zhang et al., 2023)

In logistics and warehousing, drones are revolutionizing how inventory is managed, and internal logistics operations are performed. Their use allows for faster and more accurate inventory tracking, crucial for effective supply chain management. In addition, drones optimize last-mile delivery, achieving cost and carbon emissions reductions compared to traditional delivery methods. Hybrid vehicle and drone models that combine both

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technologies are increasingly popular in maximizing delivery efficiency. (Sadok et al., 2024) (Raghunatha, et al., 2023) (Ali et al., 2024)

In urban environments, drones offer the potential for faster and cheaper delivery, but public acceptance remains low. To increase acceptance, concerns about safety, privacy and noise need to be addressed, as well as ensuring sufficient infrastructure and public awareness. (Al-e-Hashem et al., 2024)

The construction industry increases safety and productivity by enabling site monitoring and inspections in hard-to-reach areas. However, their use brings new risks that need to be identified and training and clear safety protocols need to be established. (Karakhan, and l-Mhdawi, 2024) It can also help build smart city concepts. (Vodák et al., 2021)

In agriculture, drones with artificial intelligence are improving crop quality assessment and enabling more accurate monitoring of field conditions. Their real-time ability to collect and analyze crop data helps farmers optimize irrigation, fertilization and pest control. (Baciu et al., 2024) In addition, drones are also finding applications in after-sales service, enabling faster and more efficient delivery of spare parts and enforcing rights. (Li et al., 2023)

Despite their many advantages, some challenges need to be overcome. These include legislative restrictions, technical issues related to battery life and range, and the need to optimize work and planning. (Fehling and Saraceni, 2023)

Drones represent a promising advantage with the potential to transform many industries. Using them to improve efficiency can benefit costs and minimize environmental impact. (Colajanni et al., 2023)

2. Research objective and methodology

The article consists of five main chapters. The first chapter is devoted to unmanned aircraft from the perspective of market development. The second chapter develops the methodology of the work, describing the procedures, sources and methods of obtaining and processing information. The third chapter contains an extensive analytical part and presents the results, which, based on predetermined indicators, describe examples of deployed and potential drone solutions in the automotive industry. The fourth chapter is formulated from them; the discussion contains economic and non-economic evaluations of how it is possible to deploy unmanned aircraft in a commercial environment.

The article aims to find the intersection between what unmanned aircraft offer and what the automotive industry requires, based on the analysis of information from relevant sources. A deployed, tested or potential solution is important if it is a source of economic or non-economic benefits for the company. The object of the work is unmanned aircraft (drones, UAV) and their possibilities for commercial use in the automotive industry. The properties and capabilities of drones are analyzed from the perspective of economic and non-economic values.

After processing the theoretical foundations, the methods necessary for creating the analytical part were determined. The analysis results serve as a basis for developing individual proposals for automotive manufacturers and drone service providers.

Primary sources, such as scientific publications, internet articles, and published statistical data, were used to prepare the article. Current statistical data on the development of the UAV market were obtained from the website statista.com. Scientific publications were used mainly to categorize drones and describe their technology. The authors primarily drew from the scientific databases Scopus and Web of Science, where they searched for information regarding unmanned aircraft's properties, capabilities and deployment options. Given the limited number of literature related to drones in the automotive industry, the authors linked general literature or drone deployment in other sectors to the automotive industry. This procedure required a thorough understanding of the issue and ongoing processes.

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The method of obtaining and processing information was mainly in the form of content analysis of documents. Furthermore, prioritization of the most suitable examples of drone solutions was used based on determining the area of investigation. Subsequently, we assessed the concretization of the deployment of individual uses in specific automotive plants. Overall, to compile the article, we used a synthesis of data that we combined into a coherent text. Primarily, we collected professional information about drone technology and knowledge about processes in the automotive industry. In which a deeper understanding of the issue of economic and non-economic values was studied.

The most important source for the analysis was the analysis of the websites of automotive manufacturers, who described how they managed to implement drones into processes on their media websites. This information was often incomplete, so professional literature from scientific databases was again used to supplement it. Published videos from specific automotive plants were also an important source. The creation of recommendations was primarily based on the author's observations resulting from the findings in the analytical part. The sources of information were also the websites of verified commercial service providers, with an effort to find out what services they can provide and what direction their latest products are taking.

The primary source of information for creating the discussion is knowledge from the analytical part and recommendations. The discussion uses the combination of information from the potential and deployed solution with the latest knowledge from the scientific and commercial fields. Also, the classification presents a synthesis of data for dividing drones into selected categories based on their properties and possible uses. Secondary financial and non-financial indicators supplemented these. The websites of vendors and providers in the UAV area were used to quantify the costs. The potential benefits of introducing drone technology into business processes were determined based on this. The processing of this information fulfils the article's purpose, namely the economic and non-economic evaluation of deploying a drone solution in an automotive plant.

3. Results

The analysis results are aimed primarily at automotive plants, whose production halls are large, and the management's goal is not only to streamline processes (in logistics and control) but also to focus on socially responsible business. The proposed drone solutions are also suitable for companies that want to follow concepts such as Industry 4.0 or smart factories because they open up new possibilities for automakers to implement original processes.

3.1 Inventory of final products in the outdoor parking lot

The first analysis is based on the deployed solution of Audi AG within drone technologies, which is considered to be the solution with the greatest potential for practical implementation. Approximately 15,000 to 100,000 vehicles are usually placed in the parking lot of an automobile plant. According to UAV system manager Danijel Jovanovic from Exponent Technology Services, manually searching for a specific product would take 3 to 4 days. Therefore, we recommend involving an unmanned aircraft in the inventory process and thus locating a particular asset within a few minutes. (Exponent, 2024, b)

Implementation of the German manufacturer AUDI AG, which uses RFID (Radio Frequency Identification) technology and a drone to identify assets. Our recommendation is based on this example and on information from Exponent Technology Services, which is engaged in integrating UAVs into the continuous operation of commercial enterprises and specializes in the use of passive RFID technology. It considers this method of inventory to be groundbreaking in the field of innovation and, in terms of economic indicators, fast, accurate and cost-saving. (Exponent, 2024, b; Exponent, 2024, b)

We propose to carry out the process with a fully autonomous commercial hexacopter or quadcopter. Autonomous flight following pre-programmed flight plans allows for more complex and repeatable missions. To ensure the greatest possible reliability of the system, it is advisable to use a finished product - a drone offered on the market instead of an assembled device. The drone must be equipped with a payload that reads data and is integrated with software for further data processing.

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A tag must be placed in each vehicle to use RFID technology to track manufactured cars in a sales parking lot. A drone flying over the parking lot uses a reading device to transmit electromagnetic waves, which the tag responds to. In this way, assigning each tag its geographical location is possible. The system can send inventory data to an in-house ERP (Enterprise-Resource-Planning). The technology is compatible with, for example, SAP (the name of the company that develops programs for the system), which is used by large companies such as automobile plants. (GlobalSpec Engineering360, 2024)

The manufacturer can encode any information about the vehicle on the tag, such as its identification number, colour, model, date of manufacture and, above all, the VIN identifier. The result of the scanning is the display of the position of each vehicle on a map. The provider, Exponent Technology Services, also offers Exponent's UTM portal software, which complements the entire solution. It displays the necessary information about the drone flight and points on the map representing individual vehicles. The software user interface is shown in Figure 3. 28. (Exponent, 2024, a)

An automobile plant can use this technology to monitor products regularly, locate a specific vehicle, and identify vehicles ready for sale. We also recommend that the process, once implemented by an external provider, be carried out by internal company employees after thorough training and understanding of the process.



RFID	RSSI	Read Time	Read Count	Latitude	Longitude	Row	Col
EF0001177D30202E525AEFFF	-59	12-Apr-2016 06:57	45	24.984700000	55.078790000	-1	-1
EF000118EE4BB1970D29EFFF	-44	12-Apr-2016 06:57	36	24.984710000	55.078720000	-1	-1
EF00011973F7D79D2C2BEFFF	-51	12-Apr-2016 06:57	24	24.984720000	55.078740000	-1	-1
EF00011D06CDC5769CBBEFFF	-50	12-Apr-2016 06:58	13	24.984840000	55.078560000	-1	-1
EF00012560B30C8D5BC0EFFF	-48	12-Apr-2016 06:58	34	24.984870000	55.078650000	-1	-1
EF00012683FBBF9203C5EFFF	-51	12-Apr-2016 06:57	33	24.984730000	55.078760000	-1	-1

Figure 3. Vehicle location using RFID technology

Source: Exponent, 2024, b

Exponent technology argues that it can ensure process accuracy of up to 99%, making it a reliable service provider. More and more providers on the market aspire to automate inventory for car parks. In Slovakia, GEFCO company is engaged in storage in the automotive industry. Dispatch parking lots with dimensions of several dozen hectares are an ideal place for deploying drone technology since inventory by human force is time-consuming. (GEFCO, 2022; RTVS, 2021)

3.2 Automated inventory of warehouse stocks indoors

Warehouse drones are a successfully deployed solution in various industries. This solution also has potential for automotive warehouses. Several companies specializing in the implementation of drone inventory in warehouses are already operating on the market. We are based on the implementation at Renault Trucks. The solution, therefore, also has high potential, as it is not new on the market; it is continuously improved, and it is known what can be expected from it. Companies providing these services can already estimate the return on

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investment, which is essential for management. For example, GEFCO, a logistics company in the automotive industry, states that implementing drone inventory in a warehouse measuring 10,000 m2 has a payback period of approximately 17 months. (GEFCO, 2022)

Drones represent a key technology for companies aiming to automate warehouse operations intelligently – given their ability to autonomously fly, hover, carry payloads (primarily a camera for the proposed process), avoid obstacles, navigate indoors with precision, land autonomously and be remotely controlled. (Heureka, 2024, a). Unmanned aircraft can be deployed semi-automatedly, as in Renault Trucks with the Eyesee drone. An employee places the drone at the starting position from where they want to take inventory and uses an app to launch it. This solution is halfway to the fully automated process we propose.

The recommended technological solution includes two autonomous quadcopters with sensors and a camera. Data capture can be based on barcodes (linear or matrix) or radio frequency. (Dimitris, 2021) For even greater efficiency, we suggest equipping the drone with a thermal camera (but only for relevant stocks), which can be used to determine whether the temperature of the stocks is within the required range. The drone should be equipped with a security system with the necessary functions.

From a process perspective, the drone should have a map of the entire warehouse and identification of individual objects (pallets, floor, shelves) should be performed using a neural network that enables understanding of the space. Neural networks are elements of artificial intelligence. The drone flight for a given process ranges between 30-40 minutes, after which the device needs to be charged. While in a semi-automated process, charging is done manually (batteries are replaced by operators), in a fully autonomous drone, we suggest charging via platforms, which are shown in the following Figure 4. The drone remembers the last location of the scan and continues its operation after charging. The scanned data is transferred to the corporate WMS and compared with the data. (UVL, 2024; RTVS, 2021)

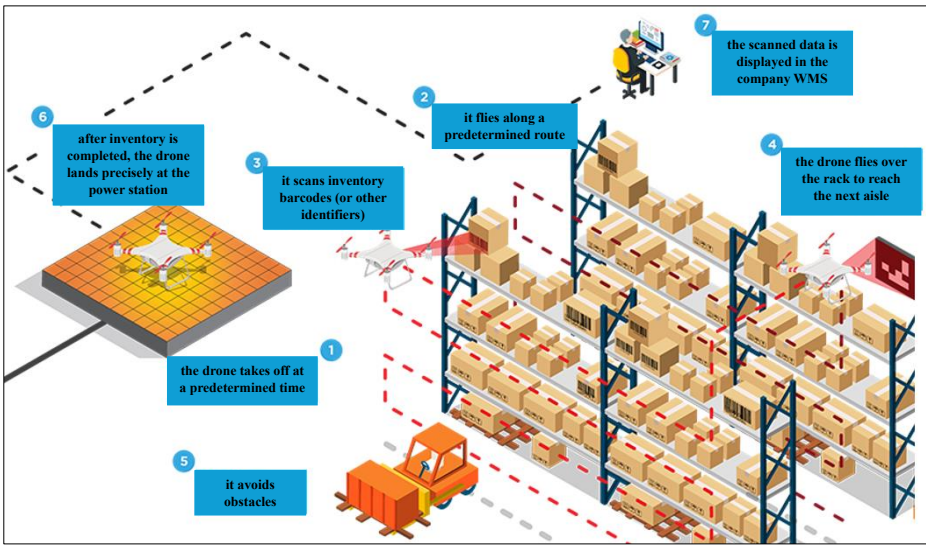


Figure 4. Recommended process of warehouse inventory using drones

Source: Supplychain247, 2019, a

To significantly streamline the process, we recommend using two hexacopters simultaneously. The reason is that the drone's service time is longer than the operational time. Charging via power platforms is slower because this technology does not yet allow a larger current to flow. The improved solution is, therefore, built on the principle that while one drone is capturing data, the other drone is being powered. Since inventory needs to be regularly performed in the warehouse, the drone solution would not be a one-time activity. Still, it would become a fixed part of the business processes.

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The manager of the logistics company GEFCO lists the advantages of this process, which include, for example, acceleration of the process, autonomous flight of the drone, and the ability to operate at heights and perform inventories more regularly, which results in more accurate information about warehouse stocks. (UVL, 2024) Other advantages include high accuracy, reliability and cost savings. The authors also recommend the drone solution from a safety perspective. In the original processes, employees performing inventory are exposed to height risks due to the high height of the inventory racks in automotive warehouses, as shown in Figure 5. For example, the process is carried out using a forklift and employees placed in a cage.

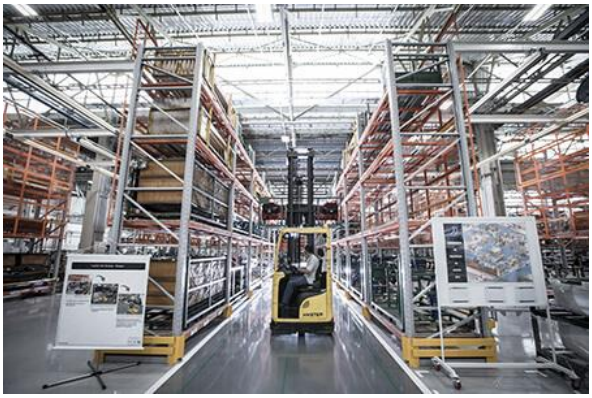


Figure 5. Mercedes Benz car factory warehouse

Source: Williams, 2018

3.3 Transport – drone as a means of transport in internal and external logistics

In the last decade, aerial delivery systems have been seen as a promising solution to the worsening traffic situation on congested roads. A study on drones in the supply chain lists the following potential benefits of integrating UAVs into the logistics process: shorter delivery times, lower costs, greater flexibility and a contribution to sustainability. (Abderahman et al., 2021; Kusnirova et al., 2024) SEAT has successfully tested the transport of parts between a logistics company and a production plant. The transport involved category A parts, which must be precisely delivered to the line to the second.

This is the potential for future delivery, a proposal for drone delivery that is currently more feasible and does not pose a risk to car plants. First of all, we recommend that any transport be carried out within the plant premises or between an adjacent factory (supplier) and the plant, with no other built-up area in between, which could lead to more significant legislative restrictions. Given UAVs' limitations and current technological level, we recommend transporting objects whose delivery may not be accurate to the second. Suitable examples include C-type components, protective equipment, tools or spare parts. The transport of spare parts and tools was pilot-tested at the German ZF Friedrichshafen AG plant.

The delivery of these components does not threaten the continuous operation of production lines. However, it can still bring time savings and greater flexibility to the car plant and contribute to reducing emissions produced by the original transport. Delivery does not occur regularly but in the event of an emerging need, which activates the drone flight plan for a given mission. Specific examples of deployment may vary, and for all loads, it is necessary to consider the maximum carrying capacity of the drone, which is why we recommend transporting lighter and smaller objects.

The first possible example of transport. A certain number of spare parts must be available in stock. These are usually brought from suppliers by trucks, which are a source of CO2 emissions. Thanks to integrating a drone into the process of delivering spare parts between the manufacturing plant and the supplier, the requirements for their warehouse stocks would decrease. If a spare part needs to be used from the warehouse to production, the replenishment of the warehouse from the supplier would be ensured by an air drone. The manufacturing plant thus gains greater flexibility in storing spare parts thanks to the fact that drone delivery can be made when necessary. Therefore, there is no need to accumulate a large number of parts.

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The second example of transport. An employee working within the premises of the manufacturing plant suddenly needs tools or protective equipment to perform their work, which are missing or damaged. Instead of someone having to walk to get the item or use a vehicle, the UAV transports the necessary item faster by air.
From a technological point of view, the solution can be set up in two ways, depending on the nature of the transported item and the process's requirements. Variant A: The transport is semi-autonomous, and the components are transported in a box. We recommend a carbon fibre capsule, which is durable and lightweight. The box can be attached to the drone using an electromagnet, or the drone can grab it using its grippers. The drone is operated by an employee who places the load in the capsule. An alternative is a winch, which Amazon also used for transport. The flight itself takes place autonomously along a pre-programmed flight path. Variant B: The transport is fully autonomous. The drone uses its grippers to grab and transport the object to a designated location. In the automotive industry, helmets, gloves, protective shields, or other equipment can be transported this way if necessary. A special recommendation is to use UAVs within the plant's interior to transfer parts from place A to place B. Lines and AVG devices are used to move material within the production plant. Problems and inefficiency arise when transferring material from one device to another is necessary. In the Dacia production plant, employees transferred components manually. (Dacia, 2018)

The employee performing this non-ergonomic, inefficient and repetitive task can be replaced by autonomous UAVs equipped with jaw grippers. The parts would be transported at a designated location a few meters away, with no employees or machines in the drone's flight zone. The potential transfer of parts, in which the drone moves autonomously within the plant and ensures delivery to parts, for example, directly to the production line, is complicated by the movements of robotic arms and other equipment. Two different UAVs must be used to transport parts inside and outside the plant, which differ significantly in their characteristics. These differ primarily in their design. Exterior drones are built to withstand various weather conditions, such as wind or rain. Therefore, they are constructed differently from interior drones, which must primarily be lightweight and smaller in size so as not to damage the car plant's equipment and be easier to manoeuvre. They would be unsustainable outdoors. However, it should be considered that the relationship between the maximum load capacity of the drone and its weight is directly proportional. The heavier the load that must be carried, the larger the drone platform. The load capacity of an indoor drone is, therefore, significantly limited.

There is also a difference in the drone's navigation. While GPS works reliably and accurately outdoors, more complex technologies such as LiDAR and SLAM, which enable navigation based on spatial vision, must be used indoors. For better orientation indoors, we recommend laser rangefinders, ultra-wideband radio signals (a type of indoor GPS), and a UWB system for tracking and locating the device. Outdoors, we recommend including a hexacopter with a load capacity of at least 5kg. We recommend a device with a 30 to 40 km speed per hour to save time. For indoor use, we suggest a quadcopter with a load capacity of 2kg and a speed of at least 8 km per hour. From a safety perspective, securing the propellers with a cage or other protection is advisable, as shown in Figure 6.



Figure 6. Indoor drones for transport

Source: Volkswagen Group Homepage, 2021; Baur and Manfred, 2024

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3.4 Inspection services – technical management of the interior and exterior of the premises in combination with a 3D model

One of the most common uses of UAVs is inspections. Drones have proven themselves in performing inspections of hard-to-reach places, such as oil platforms, bridges, monuments, windmills, solar panels, and tall buildings. Car factories occupy large areas, and it is necessary to check not only large roofs but also various even more difficult-to-access structures, such as the chimneys of the largest car factory, Volkswagen Wolfsburg Plant. The built-up area of this plant is up to 1.6 km2. The areas of other plants are also large; for example, in Slovakia, it is 0.57 km2 for the car manufacturer Kia Slovakia s.r.o. (KIA,2024).

Another proposal is to use drone technology to perform inspection work in the exterior and interior of production plants. The recommendation is based on the successful use at Ford Dagenham. Inspections should be performed preventively at least once a year for new plants, and their frequency should increase as the building ages. Inspections should be performed even if a problem has already arisen or if there is suspicion that some damage may have occurred, for example, after a storm, hail, frost or other adverse weather conditions. Therefore, preventive, predictive and service actions can be performed during the inspection.

Possible heat leaks, surface damage, cracks, corrosion, seal failures, blocked drains, etc. are checked during exterior inspection work. A drone equipped with the appropriate useful equipment is a suitable solution for determining the asset's condition and identifying possible problems. The car plant's advantages are time savings and cost reduction, and Figure 7 captured by a thermal imaging camera. These can detect problems based on unreasonably increased or decreased temperature.

In the plant's interior, it is necessary to inspect, for example, gantry cranes, high-rise structures, pipes, roofs and various large-sized machines. In the original inspection processes, employees had to overcome height differences of several tens of meters, which was dangerous and time-consuming. The process required interrupting production for several days, using extendable platforms, erecting scaffolding and then dismantling it again. We therefore recommend replacing all these devices with an inspection drone, which will replace many steps and resources in the process, significantly reducing the inspection time and, thus, the costs resulting from the need to interrupt operations.

Implementation of a successful drone deployment at the Ford Dagenham car plant, which argued that there was no need to interrupt operations at all for drone inspections. However, it is possible that it will be necessary for certain inspections to suspend production, but the duration of its suspension will be significantly shorter. For example, the drone inspected an area of the car plant in 12 minutes, while in the original process, it took workers up to 12 hours.

The inspection process begins with programming the drone's flight path. While the UAV performs the inspection, employees can monitor the flight and evaluate the data in real time, thanks to actual camera photos. After landing, the data is transferred to the appropriate processing software, as shown in Figure 7, where it is analyzed in detail. Workers evaluate drone footage without entering dangerous zones and taking unnecessary risks from heights associated with the original inspection process. The drone should have a vibration damper and gimbal to stabilize the actual photo and allow independent movement of the cameras. (ATP Journal, 2019)

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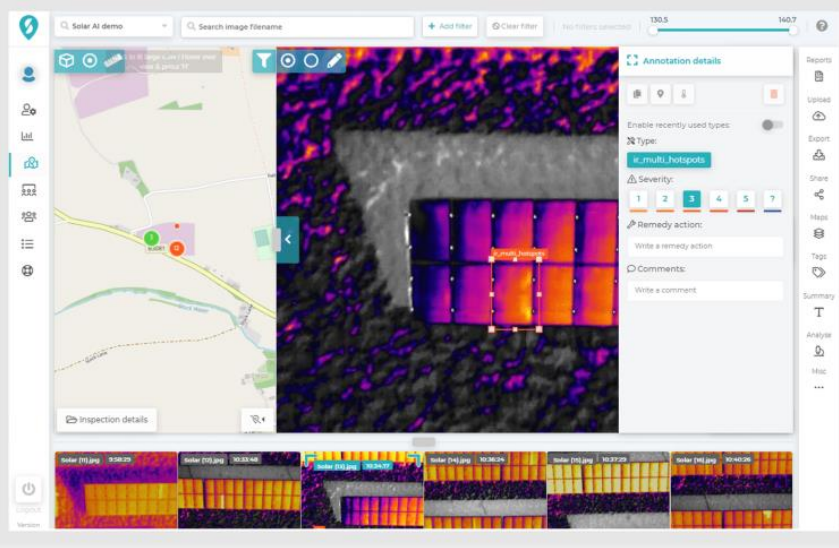


Figure 7. Software for processing drone inspection records

Source: Capterra, 2024

Similar to transportation, smaller and lighter devices are recommended for interior inspections that do not pose a major risk to property or employee health. Indoor drones can also operate autonomously if equipped with more advanced technology (LiDAR, SLAM) that can scan the surroundings. An alternative is operator-controlled flight. The device recommended for this process is the DJI Mavic 2 Pro, which is equipped with a safety cage. The attached payload should include a thermal camera and an orthophoto camera. The weight of such a device is around 1kg. The Mavic is equipped with sensors that detect distances to obstacles, but the operator who monitors them is still required to participate.

For exterior inspections, we suggest a more durable, heavier drone weighing 5 to 10 kg that can carry a payload (in this case, various types of high-quality cameras) weighing 2 to 3 kg. Since, in the outdoor environment, it is possible to rely on an accurate sleeping GPS, we propose an autonomous drone that performs an inspection along a pre-programmed route, and employees are responsible for evaluating the real photo in the software. The drone is equipped with several types of cameras, including the aforementioned thermal imaging camera, a Full Frame camera, and a camera with a 300 mm lens enabling detailed zooming. Photos can be taken from a safe distance, and the object can be zoomed in more than 1:1.

For inspections to be carried out when necessary and not only when the weather allows, we recommend a device with an operating temperature of -20° C to 50° C and wind resistance of up to 15 m/s. A reliable and robust solution on the market is, for example, the DJI Matrice 300 RTK drone. The process needs to be supplemented with a software platform for evaluating the captured real photo; we recommend the DJI FlightHub9 platform when using DJI technology. (Dronerepublic, 2024)

Before integrating drones into inspection processes, we suggest using UAVs to create an accurate digital 3D model of the plant as an improvement. It is up to the car plant to consider whether to create a digital twin, which is an extension of the 3D model, because it simulates the processes in the plant. From an inspection perspective, the 3D model itself also brings advantages when evaluating the captured photo. This allows workers to review the photo and create a more comprehensive conclusion more easily. For example, employees can see damage to a certain part of the asset in a detailed photo and, thanks to the 3D model, see where this damage is located and what impact it may have on the given area. Drone inspection is also advantageous for the car plant because 80-90% of inspection cases will be carried out without identifying problems that need to be fixed manually. (Flyability, 2024)

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4. Discussion

The discussion focuses on economic and non-economic evaluations of selected solutions, with attention paid to the benefits of introducing drone technology into the company, as shown in Figure 8. The discussion includes economic evaluations for each proposal separately. Part of the analysis is devoted to the main costs and the most significant benefits of introducing the drone solution. The authors go into more detail about calculating the initial investment costs. The car manufacturer will also encounter operating costs related to the maintenance of the equipment, which must be carried out after approximately 200 flight hours (Enterprise-insights, 2024). However, they are not a significant item when using the equipment correctly. Subsequently, the advantages of the drone solution for individual recommendations are analyzed, which, although they cannot be economically quantified, are expected to be a source of specific benefits for the company in the private sector.

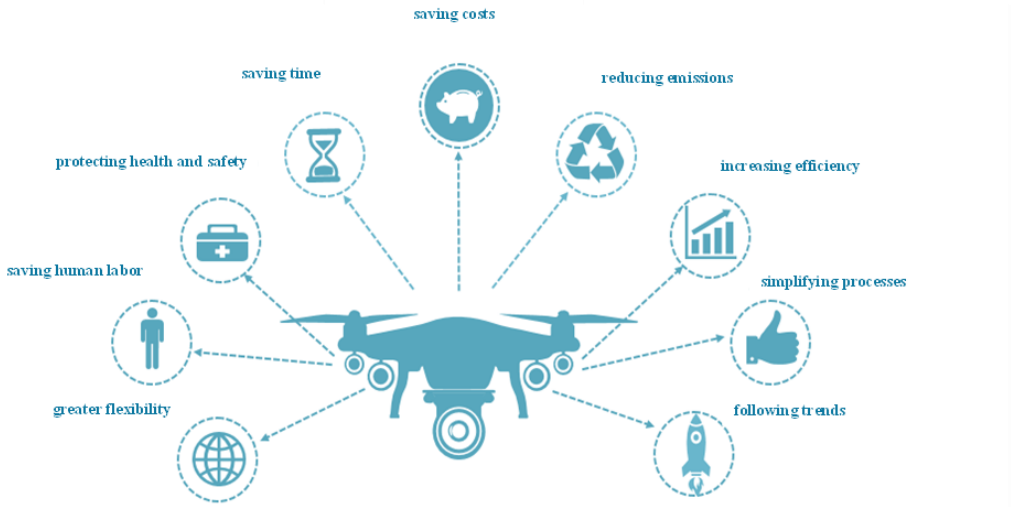


Figure 8. Benefits of introducing drones to the automotive industry

4.1 Inventory of final products in the outdoor parking lot

The initial costs for an automotive plant to implement drone RFID inventory include the following main items. The basic item is the drone. Considering the expert opinion, the authors selected the DJI Matrice 200 V2 device from a reliable commercial manufacturer, which costs 6954 euros. (Sunbeltsales, 2024) The reason for the selection is its features (robustness, durability, a maximum flight time of up to 38 minutes, anti-collision systems, etc.) and its successful pilot testing by the Normandy Flight Company in the RFID detection process. (DJI, 2024, b; NAE, 2022) Another cost is the useful equipment the drone must be equipped with. We recommend the DJI Zenmuse X5S camera, which is compatible with the drone and has a low weight. (Heureka, 2024, b) It is also necessary to place a high-frequency passive RFID reader on the drone, which is low in weight and has a range of at least 5 meters. For these criteria, an estimated indicative price of 1500 euros is determined based on a survey of readers with similar characteristics.

RFID technology cannot function without placing a passive tag in each vehicle. The price is 0.11 euros per tag when purchasing 20,000 units. The number of units will naturally vary depending on the needs of the car factory. (Rfid4u, 2024) The initial cost is also the processing software, the price of which is estimated at 5,000 euros after research. (Software Connect, 2024) After installing the solution, we suggest that the inventory be carried out by internal employees who need to be trained. The price per employee is 150 euros, and we recommend training six at the beginning. (Aprop, 2024) For a clear view, the costs are listed in Table 1. The costs for the implementation of RFID inventory for 20,000 vehicles are listed. The costs that arise but cannot be quantified include the integration of RFID into the corporate information system and the installation of the entire solution. (Yen et al., 2007) The authors assume that their price will be the largest item in the solution.

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Table 1. Selected initial costs for implementing RFID inventory

Item	Price in euros
DJI Matrice 200 V2 Drone	6 954
DJI Zenmuse X5S Camera	2 199
RFID Tags	2 200
RFID Reader	1 500
Processing Software	5 000
Employee Training (4 Employees)	900

The solution's benefits can be economically evaluated based on the data: Time savings are considered the biggest benefit of the first recommendation. The drone can fly over the parking lot in a few minutes. The exact time depends on the size of the parking lot and the mission, but time savings of up to 80% are estimated. Greater accuracy. Process providers argue for a greater possibility of obtaining more accurate asset data and achieving up to 99% process accuracy.

Since the improved process is simpler and takes only a few minutes, the car plant's advantage is the labour cost savings. The original inventory process required more labour, which had to be paid. However, the labour price cannot be accurately quantified because it is not sure whether this activity is performed manually by warehouse workers or by technical workers with the help of specific software, whose salaries vary significantly.

Non-economic evaluation. The introduction of UAVs into this activity replaces employees. Still, it follows the concept of a smart factory, which is manifested in simplifying logistics workers' work and making the company more efficient. While the drone performs this manual task, logistics workers can focus on activities that require thinking and creativity, thereby creating value for the company. The drone solution also introduces greater flexibility into logistics processes. A car factory can use a drone to identify vehicles ready for sale, for regular asset inventory, identify vacant spaces or find a specific vehicle for any purpose. Flexibility is also manifested in the fact that any information about the car can be placed on the tag.

4.2 Automated inventory of warehouse stocks indoors

In the economic evaluation of the first proposal, the authors calculated the cost of implementing an inventory using RFID, which was the most suitable method for the given solution. For inventory in the warehouse, the costs of implementing a solution using barcodes or QR codes will be calculated. The main cost item for the second recommendation is two identical autonomous drones involved in the process in parallel. The reliable DJI Mavic 3, an ideal interior inspection drone, was chosen for the process. It has the necessary sensors (including for omnidirectional obstacle detection), is lightweight (895g), and, therefore, does not threaten people or property. The price of one drone, 4,800 euros, also includes two built-in cameras. (Alza, 2024) The choice of this type of UAV is also based on the fact that providers used its previous series for this purpose.

The drone must be charged using a power platform for a fully automated process. One drone should perform the inventory for the most efficient inventory in larger warehouses while the other charges on the power platform. When choosing the devices, we, therefore, also took into account the flight time and power supply time. We decided on the HEISHA DNEST 2 platform, which can be integrated with the DJI Mavic 3. The device charges in 45 minutes and then flies for 46 minutes, a prerequisite for a smooth and autonomous inventory process. The DJI Mavic 3 and its power platform are new on the market. Data on its price is not yet available, but the price of the previous model of the platform for HEISHA DPAD for Mavic 2 is 5,080 euros. (Ozrobotics, 2024; Heishatech, 2024; DJI, 2024, e)

An initial cost is also the scanner, which needs to be attached to each drone for scanning codes. The scanner must have a low weight (usually no more than half the weight of the drone) and sufficient range. The price of such a scanner from Siemens is 3,231 euros, while it weighs only 250 grams and has a range of up to four meters. (Distrelec, 2024) After integrating the solution, we suggest the provider carry out the process by internal employees, who must undergo training. An overview of the quantifiable costs is in the following Table 2.

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Table 2. Selected initial costs for introducing drone inventory into a warehouse

Item	Price in euros
DJI Mavic 3 (2 pcs)	9 598
HEISHA DNEST Power Platform (min. price)	5 082
Scanner (2 pcs)	6 462
Employee Training (4 employees)	900

Like the previous process, the significant cost of implementing the solution into the company and integrating it into the internal warehouse management system is also the internal inventory. The amount depends primarily on the size of the warehouse, the required inventory frequency and the expected accuracy; therefore, it is impossible to quantify it, and the providers do not disclose it. (Agvnetwork, 2024) Given that drone inventory is already a solution offered on the market, it is appropriate for the car plant to cooperate with a provider that will not only implement the drone solution but also provide the hardware.

Among the benefits, both the solution providers and the company Renault Trucks implemented the solution, which considers time savings to be the main benefit. Both parties state that the process was accelerated by up to 10 times. The inventory of a location in the Renault warehouse took 6 seconds, while it took 1 minute manually. Another economic benefit results from the savings in labour costs. For example, it is possible to compare the cost of labour for a warehouse worker in the original process with the improved one. For instance, if the original process took 20 hours, the improved one is estimated to take only 2 hours, representing a saving of 198 euros. (Platy, 2024; Podnikajme, 2024)

Non-economic evaluation. Providers and users of drone technologies often struggle with uncertainty when calculating the return on investment of UAV implementation in a company. The advantage of indoor inventory inventory is that providers of this service can approximately calculate the payback period. Another benefit is the shift towards socially responsible business in the area of employee health and safety. In the manual process, warehouse workers were exposed to height risks when scanning inventory located in high places. They use various platforms and forklifts for this. This activity is also considered non-ergonomic and leads to damage to the musculoskeletal system. The consequences of such work are also called RIS and, according to OSHA, affect up to 1.8 million workers annually. (OSHA, 2021) Workers can be relieved of this unpopular and dangerous activity and focus on other areas of the logistics process from the safety of the ground.

Providers, as well as users of this service, also argue for greater accuracy. Drone inventory is significantly shorter and, therefore, can be performed more regularly, resulting in more accurate information about the state of the warehouse. Properly deployed drones are also less error-prone compared to humans. Thanks to precise warehouse information, a company can eliminate downtime in production.

4.3 Transport – drone as a means of transport in internal and external logistics

For outdoor transport, the initial load is a drone suitable for outdoor use. The authors have again chosen a reliable and proven solution: the DJI Matrice 600 Pro hexacopter. Its parameters meet the requirements for the given deployment because it is durable, has a load capacity of 6 kg and reaches a speed of 65 km/h. The market price of this type is 7,000 euros, and it is also necessary to equip the device with a camera. We recommend the compatible DJI Zenmuse X5S camera, which costs 2,200 euros. (Heureka, 2024, a; DJI, 2024, d) The number of drones for this process cannot be estimated because it depends on the plant, to what extent they want to use the drone and what they want to carry with it.

For safe landing outdoors, landing platforms are used, which are also an initial load. Their price varies; therefore, a specific platform designed for the proposed DJI Matrice 600 Pro was chosen. It is the HOODMAN LAUNCH PAD 5FT, which is around 180 Euros. (Heliguy, 2024, b) A different type of device with different features is required for indoor use. A suitable solution is, for example, the DJI MATRICE 200, the price of which, including the camera, is 5,600 euros. This drone, weighing only 3.8 kg, can carry up to 2.34 kg of payload, which does not pose a great risk for indoor use but can still carry various components. The drone needs to be equipped with

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protective elements (blade covers), which do not represent a large cost item. The number of indoor drones again depends on the needs of a particular plant. Still, if the device is to be used in continuous operation (transferring material from place A to B), at least two quadcopters must be available for one activity. This results from the need to replace the batteries. (Dronenerds, 2024, b; DJI, 2024, c) Both types of UAVs also need to be equipped with a useful device that will be used to transport the cargo. The item is not significant in terms of price (therefore, it is not listed), but it is key to implementing the process. The car plant can choose between a winch, a jaw gripper or a capsule (box).

A significant initial cost is, again, the cost of implementation, which will be increased by the "training" of the drone's neural network when the UAV is integrated into the plant's interior. The drone's movement within the car plant is more demanding than the exterior. The device must learn to recognize obstacles using a neural network to respond correctly to stimuli in the process. The cost also includes the amount of employee training, but its amount depends on the number of workers involved in the drone process. However, it is impossible to determine it in this recommendation because the solution is designed as a framework with several variations.

Benefits. As with the previous recommendations, an improved transportation process is a source of time savings. This will vary depending on the process and distance. Still, for a rough approximation, the authors provide two calculations: Based on the results of the international CASE conference, drones can significantly speed up logistics operations within the plant premises. The report cites malfunctioning or missing parts that need to be secured for a certain process during automotive production. Under normal circumstances, an employee runs or cycles to the warehouse to retrieve a part, which takes 10 to 15 minutes. With a drone, it is possible to fly over the infrastructure and carry out the transport in 3 to 4 minutes. The study states that these results are actual measurements in a car factory. (Markus et al., 2019) The transport of parts between the SEAT factory and the supplier production line described in Section 3.3 is 6 times faster over a distance of 2 km. The original process required 90 minutes; the improved one was 15, while the drone flight time was only 4 minutes.

It is also possible to calculate the savings in labour costs for an employee who transported parts from place A to place B roughly. This work is usually performed by a production operator, and assuming that he works full-time 8 hours a day, the production plant would save approximately 24,340 euros per year. The amount was calculated based on the average salary of an operator at the Kia Slovakia s.r.o. production plant, and therefore, it will vary according to the salary policy of a particular plant. Ultimately, however, the amount will be three times higher because production runs continuously in three shifts, and wages must be paid to three workers. There is also a reduction in costs when transporting parts to the warehouse. These include, for example, fuel costs, driver costs, but the obvious one is the reduction in inventory costs. The drone delivering type C parts and spare parts to the warehouse allows the car manufacturer to follow the trend in Just-in-Time inventory management, i.e. just in time.

Non-economic evaluation. Since the authors proposed incorporating UAVs for various transport options, their non-economic evaluations will also vary. If the drone replaces a motor vehicle (truck or other transfer vehicle), we expect it to contribute to social responsibility in the field of the environment. Transport was the main polluter in terms of CO2 production in 2020. Drones do not pose a burden on the air, as they do not produce CO2 emissions. Thanks to the Just in Time inventory management system, logistics becomes more flexible because transport is carried out when needed, and the necessary parts are always available without downtime in production. The use of vertical space is also an advantage in indoor transport. Air transport brings new possibilities for efficient use of space, which "saves floor space". Employees' original manual transfer of objects from place A to place B was also repetitive and unsuitable for the musculoskeletal system. When transferring protective equipment and parts, a drone acts as an assistant. It can transport the required cargo quickly and reliably, allowing the employee to resume the necessary activity without a long wait.

4.4 Inspection services – technical management of the interior and exterior of the premises in combination with a 3D model

The initial costs of implementing drone inspection services will differ for exterior and interior deployment. The DJI Mavic 2 Pro is a suitable device for interior inspections, the price of which, with the camera and recommended thermal sensors, is approximately 5,560 euros. (Heliguy, 2024, c) We recommend purchasing

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the HELIGUY Mavic 2 drone Cage protective client for 600 euros to ensure the greatest possible security of the drone and property. (Heliguy, 2024, a) We assume the interior inspection drone will be deployed only a few times a year. Therefore, it is necessary to purchase a protective case, which is not a significant item from a cost perspective since its price is around 140 euros. (Dronenerds, 2024, c) We suggest that internal employees conduct internal inspections after the provider has trained them. The cost of training is also an initial cost, which is reflected in the price of implementing the entire solution, which, due to its complexity, cannot be quantified. However, employees must also complete a course to legally fly the drone, which costs 150 euros per employee. (Aprop, 2024) For exterior inspections, we recommend the most advanced technology on the market today, which is the compact DJI M30 drone. Its features are described in detail in recommendation number 5, as it is a suitable candidate not only for exterior inspections but also has the potential to be used for multiple solutions. The DJI M30 costs 9,300 euros, but we recommend purchasing it with the DJI dock, which is also described in subsection 4.5. The total hardware price is 25,000 euros. (DJI, 2024, a) The operating cost for interior and exterior inspections is also the license for the DJI FlightHub Drone Management Software – Advanced, which costs 2,800 euros per year. (Dronenerds, 2024, a)

Benefits. The proposed improved process is a source of time savings for the company. The total time savings for exterior inspections are estimated to be 95%. The car plant will also save the cost of paying external companies that would perform manual inspections for a significantly more extended period. The time savings for interior inspections can be estimated based on data from Ford Dagenheim, which successfully implemented a drone solution into its processes. While the original process took 12 hours to inspect one location, the drone captured the necessary data in 12 minutes. The internal inspection of the entire plant was carried out for 3 weeks, while the drone inspection took only one day. This time saving can be assumed in general for car plants. Another benefit is labour cost savings because employees spend significantly less time conducting inspections. Human labour is also saved in the sense that the improved process requires the cooperation of fewer workers.

The analysis shows that drones reduce labour costs and the costs that result from stopping operations. The amount cannot be precisely quantified, but significant savings can be expected, as the original process required a shutdown of operations for several days. Drone inspection can be performed without a shutdown—time savings where the original process of inspecting one area took 12 hours. The improved process allows for a detailed inspection in 12 minutes. An inspection of the entire manufacturing plant can be performed in one day, whereas in the past, it was performed over three weeks in the summer, during which production was shut down. (Ferris, 2018; Ford Media Center, 2018)

Non-economic evaluation. An automobile plant can expect greater employee health protection from drone inspections. When inspecting high equipment, machines, cranes and roofs, they originally had to overcome dangerous height differences of several tens of meters. Falls from such places can lead to tragic consequences. Thanks to UAVs, employees can monitor the entire process from the safety of the ground and evaluate the data in real-time. The data is displayed in processing software, allowing for more accurate damage identification. Storing photos helps prevent problems associated with workers' different opinions on a given defect and ambiguities during inspection work.

The company can strengthen prevention and conduct interior and exterior inspections more frequently by eliminating complexity. A drone can survey high and hard-to-reach places without building auxiliary scaffolding or various other platforms that need to be dismantled. This complex process requires the cooperation of multiple company resources, while a drone provides a simple solution. The analysis shows that a properly deployed drone is less error-prone than human work. During inspections, an employee may overlook a location or component.

5. Conclusion

The article's purpose was fulfilled by creating recommendations describing possible deployments of drones in automotive plants. The most frequently mentioned benefit is time savings, and the authors see the greatest potential in vehicle inventory in an outdoor parking lot. A significant finding was that the preferred solution is an autonomous, multi-rotor drone from a reliable manufacturer. A device from the technology company DJI

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was chosen for most solutions. The authors believe that unmanned aircraft do not threaten employees' work by replacing them. People are still needed in improved processes. Drones collaborate with them and make their work easier and more efficient. While drones perform monotonous, non-ergonomic and sometimes dangerous tasks, people can focus on work requiring innovation and critical judgment.

It is important to mention that only a small number of drone applications in the automotive industry have been listed. They mainly act as a platform for data collection or as a device capable of transporting objects. Automotive companies, manufacturers and drone service providers are therefore faced with the opportunity to introduce innovations in the form of drone technologies into their processes and thus gain a competitive advantage. In addition to the four main analyses of economic and non-economic evaluation and the benefits of the recommendations, the authors also propose a universal compact drone that can cover multiple activities for the company. The authors are aware that the automotive plant requires a high level of reliability for the solution, so the selection of specific equipment was also adapted. The most reliable solution is a commercially offered drone that meets the company's requirements, and no further modification of the equipment is necessary that could jeopardize the platform's reliability.

The article in question demonstrates that unmanned aircraft have the potential to be used in the automotive industry. The authors assume that with the advancement of technology, current limitations will be overcome, and drones will find their application in more and more processes.

The analysis of drones in the automotive industry is a recent phenomenon with immense potential to revolutionize various production and logistics aspects. Here is a glimpse into how drones are transforming the automotive landscape:

- Inventory Management in Large Parking Lots: Manufacturing plants often have sprawling parking lots for storing finished vehicles. Traditionally, locating a specific car could be a time-consuming manual process. Here's where drones come in. Equipped with RFID technology, drones can efficiently scan and identify vehicles, streamlining the inventory management process and significantly reducing search times.
- Enhanced Safety and Security: Drones can be deployed for security purposes, patrolling manufacturing facilities and perimeters to deter unauthorized access and prevent potential security breaches. They can also be used for aerial inspections of rooftops and other hard-to-reach areas, identifying safety hazards and potential maintenance issues.
- Delivery of Parts and Materials: Large automotive manufacturing facilities often require the movement of parts and materials across vast distances. Drones offer a faster and more efficient solution than traditional ground transportation methods. They can navigate traffic congestion and deliver parts directly to assembly lines, minimizing delays and disruptions in the production process.
- Quality Control Inspections: Drones equipped with high-resolution cameras can be used to conduct detailed inspections of car bodies and painted surfaces, detecting even the slightest imperfections. This can significantly improve quality control processes and ensure the production of defect-free vehicles.

These are the main findings on how drones are transforming the automotive industry. As drone technology continues to evolve, we can expect even more innovative applications to emerge in the coming years.

The novelty of this research lies in its comprehensive exploration of drone applications within the automotive industry, examining both economic and non-economic benefits. The study provides valuable insights into how drone technology can transform various aspects of automotive manufacturing, from inventory management and logistics to quality control and safety inspections. This research contributes to the field in several novel ways:

- Comprehensive analysis: It offers a holistic view of drone applications in the automotive industry, encompassing various aspects of manufacturing, logistics, and management.
- Economic and non-economic perspectives: It evaluates the benefits of drone technology from both economic and non-economic standpoints, considering factors such as cost savings, efficiency gains, environmental impact, and social responsibility.

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- Focus on strategic decision-making: It highlights how drone technology can inform and support strategic decision-making in the automotive industry, enabling companies to optimize operations and gain a competitive edge.
- Real-world examples: It draws on real-world examples of drone deployments in automotive plants, providing practical insights and demonstrating the feasibility of implementing drone technology.
- Specific recommendations: It offers concrete recommendations for automotive manufacturers and drone service providers, outlining potential applications and suggesting suitable drone models and technologies.

By combining a comprehensive analysis, a balanced evaluation, and practical recommendations, this research provides valuable insights for the automotive industry and contributes to the growing body of knowledge on drone technology applications.
However, the research has limitations. The study primarily focuses on the potential benefits of drone technology, with less emphasis on the challenges and risks associated with implementation. The economic evaluations are also based on estimated costs and potential savings, which may vary depending on specific plant characteristics and drone models. For instance, the study does not address potential issues such as:

- Technological limitations: Battery life, payload capacity, and flight range can restrict the types of tasks drones can perform.
- Regulatory hurdles: Obtaining necessary permits and licenses for drone operations can be complex and time-consuming.
- Data security concerns: Protecting sensitive data collected by drones from unauthorized access and cyberattacks is crucial.
- Employee training needs: Operating and maintaining drones require specialized skills and training, which can incur additional costs and time.
- Integration challenges: Integrating drone technology with existing manufacturing and logistics systems may require significant investment and expertise.

Weather dependence: Drone operations can be affected by adverse weather conditions, limiting their reliability and efficiency.
Public perception and acceptance: Concerns about privacy, noise pollution, and safety can impact the public's acceptance of drone technology.
Addressing these limitations in future research would provide a more balanced and comprehensive understanding of drone implementation in the automotive industry.

Further research could investigate the challenges and risks of drone implementation, such as regulatory hurdles, data security concerns, and employee training needs. Additionally, future studies could conduct more detailed cost-benefit analyses using real-world data from automotive plants that have implemented drone technology. Examining the impact of drones on employee roles and the organizational structure of automotive companies could also provide valuable insights. Finally, exploring the potential of drones in other areas of automotive manufacturing, such as research and development, could further contribute to the field.

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A COMPARATIVE ANALYSIS OF SOCIAL NETWORKS CONTENT MODERATION GUIDELINES AND BLOG POSTS*

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Abstract. The study aims to examine the content moderation guidelines of major social media platforms and assess how these platforms communicate their moderation practices through official blog posts. A comparative analysis of Instagram, Facebook, TikTok, Snapchat, LinkedIn and X (formerly Twitter) revealed that while platforms share common moderation goals—such as prohibiting hate speech, misinformation, and harmful content—there are notable differences in the emphasis of these issues in public communications. Blog posts, used as self-representation tools, often focus on specific platform priorities, such as privacy or community protection, which may not always align with the full scope of the guidelines. For example, while misinformation is a formal concern across platforms, it is not always as prominently featured in public messaging. These findings highlight a gap between formal content moderation policies and how platforms publicly communicate their enforcement efforts.

Keywords: social networks; content moderation; blog posts

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1. Introduction

The rapid rise of social media platforms has transformed communication and content-sharing dynamics within society (Wang et al., 2023). This transformation has presented new challenges for platforms, especially regarding harmful content such as misinformation. As platforms evolve, they face increased scrutiny to control the dissemination of harmful content through implementing content moderation systems (Keulenaar et al., 2023). These systems are formalized through community guidelines and policies aimed at regulating the flow of information (Singhal et al., 2023). However, while platforms outline strict guidelines, enforcement often falls short, allowing harmful content to persist (Gruzd et al., 2023; Arya et al., 2024; Shen et al., 2024). Content moderation systems can be broken down into distinct phases. Common (2020) outlines these as the creation of policies, the enforcement of these policies through detection and decision-making, and finally, the response to violations. This study will primarily focus on the creation phase—understanding the formal guidelines

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established by major social media platforms and evaluating how they communicate these moderation strategies through public channels, such as blog posts.

Existing research highlights inconsistencies in how platforms moderate content and define guidelines (Singhal et al., 2023). While certain abusive content, such as hate speech and misinformation, is prohibited across platforms, there is no uniform approach to what constitutes a violation or how platforms address it. Furthermore, prior research focuses primarily on enforcement strategies (Myers West, 2018), discourse analysis (Gillespie, 2010) and labour involved in moderation (Roberts, 2016). However, there remains a need for a more comprehensive understanding of the formal content moderation guidelines and how they are communicated to users.

This **study aims** to address this gap by analyzing the content moderation guidelines of major social media platforms and examining the alignment between these formal policies and the communication of moderation practices through official blog posts.

Objectives of the research:

- To provide a comprehensive literature review on existing research regarding content moderation guidelines across social media platforms.
- To conduct an empirical comparison of the official blog posts of Instagram, Facebook, TikTok, Snapchat, LinkedIn, and X (formerly Twitter) with their stated content moderation guidelines.
- To identify gaps between the platform content moderation policies and their public communication via official blogposts.

2. Literature review

Content moderation on social media platforms such as Facebook, Instagram, TikTok, Snapchat and X (formerly Twitter) has become a crucial research topic due to the complexity of managing harmful content. Despite significant investments in content moderation technologies, platforms continue to face a variety of challenges. Gongane et al. (2022) highlight that these investments are often insufficient, as malicious content remains widespread. Platforms face difficulties detecting and moderating malicious content effectively, with content moderation models unable to handle the diversity and complexity of information across multiple modalities. This often leads to failures in detecting toxic content (Wang et al., 2023). Compounding the issue is the sheer volume of content generated daily, which makes it nearly impossible for human moderators or algorithms to catch everything. Udupa et al. (2023) and Liu et al. (2022) emphasize the scale of this challenge, pointing out that platforms are also pressured to balance user satisfaction and monetization, which can dilute their focus on moderation.

AI-driven content moderation systems have emerged as a popular solution for platforms, yet these systems are far from foolproof. Wang et al. (2023) and Valentine and Dupont (2022) argue that, while AI has the potential to process large amounts of data quickly, it still struggles to understand the nuances of human language and context, particularly when identifying hate speech or misinformation. These systems often fail to differentiate between harmful and benign content, leading to either over-enforcement or under-enforcement. Additionally, algorithmic biases within moderation tools pose another significant problem. Peterson-Salahuddin (2024) discusses how these biases can disproportionately affect marginalized groups, leading to further alienation of already vulnerable communities. Platforms have been criticized for silencing marginalized voices while failing to curb harmful content effectively, suggesting that the algorithms in place are not as effective as they could be (Haimson et al., 2021).

Each social media platform has developed its approach to content moderation, leading to platform-specific challenges and strategies. For instance, Keulenaar et al. (2023) focus on X, showing how its use of modulated moderation aims to create a crisis-resistant speech architecture. This strategy allows flexible content management during high-pressure situations, such as political elections or public health crises. However, these strategies often come under scrutiny, particularly when moderation efforts fail to curb the spread of harmful content in real time. TikTok faces unique challenges in moderating its predominantly video-based content.

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Lookingbill and Le (2024) highlight how TikTok sometimes marginalizes user-generated content in an attempt to maintain community standards. Yet users have found ways to circumvent moderation algorithms by changing keywords or inventing new slang to bypass restrictions, as discussed by Steen et al. (2023). In addition to technological and platform-specific challenges, the ethical implications of content moderation have become a prominent issue in recent research. Franco et al. (2023) emphasize that content moderation systems, while essential, can have unintended consequences on user engagement, particularly when they disproportionately affect fragile and marginalized users.

3. Research methodology

This research utilized a comparative analysis to evaluate major social media platforms' content moderation guidelines and practices (Ragin, 1987; Bennett & George, 2005). Data was collected from official blog posts of Instagram, Facebook, TikTok, Snapchat, LinkedIn, and X (formerly Twitter), covering the period from 2018 to 2024 (with X data extending up to 2022). Comparative analysis enhances decision accuracy and helps generate broader social theories from specific case studies (Przeworski & Teune, 1970). This approach facilitates a deeper understanding of misinformation management and platform accountability. To identify patterns and discrepancies, the study analyzed both content moderation guidelines and blog posts, focusing on themes related to misinformation and harmful content. AntConc, a freeware corpus analysis toolkit, was employed to mine text and identify key themes in blog communications. As blogs serve as a self-representation tool, their analysis offers valuable insights into how platforms publicly discuss and highlight their moderation practices (Gilpin, 2010; Buckley & Schafer, 2022), revealing not only enforcement practices but also evolving platform priorities.

Case selection

The selection of top social media platforms was based on their global popularity and user engagement, which are crucial factors for assessing the effectiveness of content moderation guidelines. The platforms chosen—Instagram, Facebook, TikTok, Snapchat, LinkedIn, and X (formerly Twitter)—represent a broad spectrum of target audiences and content types, allowing for a comprehensive analysis of diverse moderation practices. The selected platforms rank among the highest in terms of daily active users, global reach and content volume (Data Reportal, 2024). The platforms cater to different demographics, from professional networks (LinkedIn) to youth-oriented platforms (TikTok), ensuring that the analysis covers a wide range of moderation challenges.

Data collection

Data was gathered from two primary sources: content moderation guidelines and official blog posts on Instagram, Facebook, TikTok, Snapchat, LinkedIn, and X (formerly Twitter). The current guidelines were scraped from the internet, with guideline lengths varying from 3,000 to 10,000 characters depending on the platform. These guidelines were collected and categorized by themes such as misinformation, hate speech, privacy, and harassment. Additionally, official blog posts published by Instagram (https://about.instagram.com/blog/), Facebook (https://about.fb.com/news/), TikTok (https://newsroom.tiktok.com/en-us), Snapchat (https://newsroom.snap.com/safety-and-impact), LinkedIn (https://www.linkedin.com/blog/member) and X (https://blog.x.com/en_us) between 2018 and 2024 were collected, with X posts analyzed up to 2022. Tech company blogs primarily serve to communicate new policy decisions or initiatives, particularly those aimed at addressing harmful behaviours on their platforms. While the content varies, these blogs typically explain the rationale behind policy changes and emphasize the platforms' efforts to enhance user safety and counteract malicious activities (Watkin & Conway, 2022). All posts were manually reviewed, and only those relevant to the study's focus on content moderation practices were selected. The blog posts were organized into a spreadsheet, documenting the social network, blog title, publication date, URL, and the full text of each relevant post. In total, 917 blog posts were analyzed, with the quantity of posts per platform shown in Table 1 below.

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Table 1. The quantity of analyzed posts

Social network	Analyzed period	Relevant blog posts
Instagram	2018-2024	41
Facebook	2018-2024	541
TikTok	2018-2024	126
Snapchat	2018-2024	112
LinkedIn	2018-2024	28
X (previous Twitter)	2018-2022	69
Total:		**917**

Data analysis

First, the data collected on moderation guidelines and blogposts were analyzed using a qualitative approach through Nvivo, a tool designed for managing and analyzing qualitative data. A bottom-up approach was employed, where inductive codes were created and then grouped into broader themes. Two coders independently coded the data, and their outputs were compared. Discrepancies were resolved by consensus, ensuring consistency in coding. Following the thematic analysis, a quantitative comparison of blog posts and guidelines was carried out, where the frequency of key themes—such as safe usage, community protection, and privacy—was counted and compared across platforms. To further analyze blog post content, the AntConc (https://www.laurenceanthony.net/software/antconc/) tool was used to create wordlists and identify keywords, allowing for the analysis of the context in which key terms were used. This process helped to refine the thematic findings and ensured comprehensive coverage of the moderation topics.

Limitations

Any interpretative techniques in qualitative analysis can introduce subjectivity, even with efforts to mitigate bias through coder comparison. The reliance on official blog posts and public guidelines may not fully reflect real-world enforcement practices, as platforms may curate their communication. Additionally, the focus on data from 2018-2024 limits the scope, potentially overlooking longer-term trends or recent developments in content moderation strategies.

5. Findings

Results of content moderation guidelines analysis

The summary of the key themes in content moderation guidelines across social media platforms is provided in Table 2. The analysis highlights that the core moderation policies are largely consistent across Instagram, Facebook, TikTok, Snapchat, LinkedIn and X (formerly Twitter) despite differences in platform focus and user demographics. The platforms in the sample universally prohibit hate speech, which is defined as content promoting violence or discrimination based on personal characteristics such as race, gender, religion, ethnicity, sexual orientation or disabilities. Similarly, all platforms enforce strict rules against bullying, harassment, and threats, ensuring a safer online environment.

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Table 2. Findings of moderation guidelines analysis

What is not allowed according to content moderation guidelines	Social networks					
	Instagram	*Facebook*	*Snapchat*	*LinkedIn*	*TikTok*	*X (Twitter)*
Harmful content and new types of abuse related to COVID-19	x					
Hate speech	x	x	x	x	x	x
Coordination of harm	x	x	x		x	
Bullying and harassment	x	x	x	x	x	x
Misinformation	x		x	x	x	x
Nudity	x	x	x		x	
Artificially collecting likes, followers, or shares, posting repetitive comments or content, or repeatedly contacting people for commercial purposes without their consent.	x	x		x	x	x
Impersonate others	x	x		x	x	x
Support or praise terrorism, organized crime, or hate groups.	x	x	x	x	x	x
Offering sexual services, buying or selling firearms, alcohol, and tobacco products, drugs	x	x	x	x	x	x
Sharing sexual content involving minors or threatening to post intimate images of others.	x	x	x	x	x	x
Serious threats of harm to public and personal safety.	x	x	x	x		x
Encouraging or urging people to embrace self-injury, suicide.	x	x			x	x
Intense, graphic violence in videos.	x	x		x	x	x
Human Exploitation		x	x			
Privacy Violations		x				x
Attempts to gather sensitive user information or engage in unauthorized access		x	x	x		x
Violation of Intellectual Property		x			x	x
Share harmful or shocking material				x		
Grooming behaviours					x	
Civic Integrity						x
Third-party advertising in video content						x

A significant emphasis is placed on protecting minors, with all platforms adopting a zero-tolerance policy toward child exploitation, including child sexual abuse, grooming, and other harmful activities related to minors. Furthermore, there are clear prohibitions on the sharing of explicit sexual content, particularly non-consensual nudity and child sexual abuse material. In terms of violence, each platform bans content that incites violence or encourages self-harm or suicide. Support for terrorism, hate groups, and organized crime is strictly forbidden across the board. Lastly, user privacy is a critical concern, with platforms prohibiting sharing personal data without consent and cracking down on privacy violations.

Despite these common policies, each platform demonstrates its unique priorities depending on its user base and content focus. While there is a shared commitment to addressing major issues such as hate speech, violence, harassment, and child safety, the scope and focus of content moderation vary significantly according to the nature of each platform. For example, Instagram and TikTok emphasize visual content moderation. Instagram has strict rules concerning graphic violence, nudity, and harmful visual trends, as evidenced by their guideline: *"Post only your own photos and videos and always follow the law. Respect everyone on Instagram, don't spam people or post nudity"* (Instagram, September 2024). Similarly, TikTok applies strong moderation to prevent harmful visual trends, stating: *"To minimize the potentially negative impact of graphic content, we may first include safety measures such as an 'opt-in' screen or warning"* (TikTok, September 2024). This is particularly important on TikTok, given its large younger audience and its focus on short, viral video content.

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On the other hand, LinkedIn emphasizes the importance of maintaining a professional environment, which shapes its approach to content moderation. Its guidelines disallow content that deviates from work-related or ethical standards, promoting a professional and respectful space: *"Only bring safe conversations to LinkedIn. We allow broad conversations about the world of work, but just keep it professional"* (LinkedIn, September 2024). Finally, X (formerly Twitter), given its role as a platform for public discourse, centres its moderation guidelines around regulating abusive speech, civic integrity, and the manipulation of public information. The platform's rules state: *"X's purpose is to serve the public conversation. Violence, harassment, and similar types of behaviour discourage people from expressing themselves and ultimately diminish the value of global public conversation. Our rules are to ensure all people can participate freely and safely"* (X, September 2024).

This analysis underscores the shared responsibilities among platforms to tackle harmful content while highlighting their platform-specific challenges. The differences in content moderation approaches reflect the platforms' varying priorities, influenced by the type of content they host and the audience they serve.

Results of blogpost analysis

Official blog posts provide a narrative directly from the platforms, frequently detailing updates to policies, enforcement strategies and the platforms' positions on critical issues such as misinformation. Analyzing these posts allowed us to understand better how platforms communicate their moderation efforts and the role this communication plays in shaping user behaviour and the spread of misinformation. The analysis using AntConc identified key topics across the social media platforms studied, focusing on themes such as safe usage, community protection, privacy, and misinformation (see Table 3).

Table 3. The main topics of analyzed blog posts

Social network and main topics	Relevant blog posts	Word frequencies
Instagram		
Community protection	19	151 (0.2%)
Safe usage	13	124 (0.2%)
COVID-19, antibullying, hate speech, misinformation	9	94 (0.2%)
Facebook		
Data and privacy	230	1324 (0.7%)
Safety and expression	224	1285 (0.7%)
Combating misinformation	87	356 (0.2%)
Tik Tok		
Important news	13	104 (0.6%)
Community	11	92 (0.4%)
Safe usage	102	315 (0.2%)
Snapchat		
Community	22	116 (0.6%)
Parental tools	18	145 (0.6%)
Safe usage	72	384 (0.7%)
LinkedIn		
Safe usage	14	294 (0.3%)
Updates to community policies	6	94 (0.2%)
Transparency	8	118 (0.2%)
X (previous Twitter)		
Safety	36	224 (0.7%)
Transparency	33	284 (0.4%)

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The blog posts were particularly insightful in revealing how platforms articulate their commitment to safety and moderation while showcasing differences in priorities based on platform demographics and content types. For instance, Instagram primarily focused on creating a safe online environment, with a strong emphasis on community protection and safe usage. Its blog posts frequently addressed efforts to foster a healthy and inclusive space, particularly in response to challenges such as misinformation during the COVID-19 pandemic. The posts highlighted various initiatives to maintain a safe community and combat harmful content trends. Facebook, on the other hand, dedicated significant attention to data privacy and user safety, likely in response to its large user base and its history of privacy-related controversies. The high frequency of posts regarding privacy and safety suggests the platform is actively engaging with these issues. However, while misinformation is a critical topic, its relatively low word frequency (0.2%) in blog posts implies it receives less focus compared to privacy and safety concerns.

The analysis showed that TikTok, given its younger demographic, emphasized safe usage to address potential risks of harmful content. Blog posts highlighted topics such as "Important News" (0.6% frequency), reflecting efforts to combat misinformation and potentially dangerous trends like harmful challenges or misleading content that could endanger users. Similarly, Snapchat, with its younger user base, focused extensively on parental tools and community protection. The high frequency of posts related to safe usage (0.7%) suggests that ensuring safe interactions, particularly with parental supervision tools, is a priority for the platform. LinkedIn's blog posts were centred around maintaining a professional and respectful environment, with a particular focus on safe usage and transparency. The lower volume of discussions compared to other platforms likely reflects its professional nature, where content moderation aims to uphold professionalism rather than mitigate a wide array of content types. Finally, X (formerly Twitter) dedicated a significant portion of its blog posts to user safety and transparency, particularly focusing on improving user trust during its transformation. The relatively high frequency of keywords in these posts reflects the platform's efforts to position itself as a leader in public discourse moderation and misinformation management.

Gaps between content moderation guidelines and public communication

To analyze the gap between formal content moderation policies and how they are represented or discussed in platforms' public communications, we can identify several key themes by comparing the moderation guidelines (Table 2) with the focus of official blog posts (Table 3). Few discrepancies have been identified in this regard.
First, the content moderation guidelines across platforms like Facebook, Instagram, and TikTok clearly prohibit misinformation, particularly on sensitive topics like health (e.g., COVID-19) and civic processes (e.g., elections). This commitment is outlined in their guidelines (Table 2). However, the frequency of blog posts discussing "combating misinformation" is notably lower. For instance, on Facebook, only 87 blog posts (0.2% of the total) mention combating misinformation (Table 3). This discrepancy suggests that, although the platforms have robust guidelines on misinformation, it is not prominently featured in their public communications. This gap between strict policies and their public emphasis may reflect a strategic focus on other issues in their outward communication, potentially diluting their stance on misinformation for broader audiences.

Second, the platforms universally emphasize the need to protect users from harmful content like hate speech, harassment, and violence, as seen in their moderation guidelines (Table 2). However, in their public communications, platforms like X (formerly Twitter) and Facebook tend to focus more on transparency, data privacy, and community safety, as shown by the higher frequency of blog posts discussing these topics. For example, X mentions user safety 36 times in blog posts, while direct discussions on harmful content, such as hate speech, are less frequent. This shift in focus suggests that while these platforms are committed to user safety in their formal policies, the narrative in public communication may prioritize other concerns, such as privacy or transparency, possibly to align with public discourse or regulatory pressures.

Finally, although the content moderation policies are consistent in addressing key issues like misinformation and harmful content, each platform tailors its public communication based on its unique user base. Instagram and TikTok emphasize community protection and visual content moderation in their blog posts, aligning with the visual nature of their platforms. For instance, Instagram's guideline to "Post only your own photos and videos and follow the law" (Instagram, September 2024) underscores the platform's focus on visual content integrity. In contrast, LinkedIn emphasizes professionalism both in its moderation guidelines and public

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communications, reflecting its goal to maintain a respectful and professional environment. This variation shows that while moderation policies may be similar across platforms, the communication strategies vary to reflect platform-specific concerns and user demographics.

The results suggest that while content moderation guidelines are extensive and address a wide range of harmful content, the way platforms communicate these policies publicly, especially through blog posts, reveals gaps. Certain issues, like misinformation or harmful content, may not be as frequently highlighted in public communications as their policies would suggest. This discrepancy highlights a potential gap between the creation of formal content moderation policies and the platforms' public communication strategies, potentially shaped by the need to balance transparency, user trust and regulatory demands.

Discussion and conclusions

After analysis of the existing content moderation guidelines across major social media platforms, the results showed that platforms such as Instagram, Facebook, TikTok, Snapchat, LinkedIn, and X (formerly Twitter) share core moderation policies (bans on hate speech, misinformation, and harmful content), but each platform emphasizes different aspects based on its target audience and operational model. The findings from this research highlight significant insights into how social media platforms formulate, communicate and (to some extent) implement content moderation policies. Despite the existence of clear and robust moderation guidelines across major platforms, there remain critical discrepancies between these formal policies and the themes emphasized in their public communications, particularly in official blog posts.

The analysis of official social media blog posts showed that official blog posts serve as a strategic self-representation tool. The social media platforms selectively emphasize certain aspects of their content moderation efforts. For example, Facebook and LinkedIn focus on privacy and data security, while TikTok and Instagram highlight safe usage and community engagement. Although explicitly prohibited in guidelines, misinformation receives limited attention in blog posts.

One of the most notable gaps identified is the disparity between platforms' stated commitment to combating misinformation and how prominently this issue is discussed publicly. While misinformation is prohibited under formal guidelines, platforms like Facebook and Instagram do not seem to emphasize this issue in their blog posts to the same degree. This gap could reflect a broader strategic focus by platforms on privacy, transparency, and other topics they deem more pressing or publicly favourable. As such, this creates a potential disconnect between what platforms say they are doing to mitigate harmful content and how they publicly present these efforts.

The implications of these findings are twofold. First, the discrepancies identified between formal content moderation policies and public communication suggest that platforms may prioritize certain issues over others in their outward messaging. This could have consequences for public trust, particularly if users perceive that platforms are not being transparent about their efforts to mitigate harmful content. Second, the variation in communication strategies underscores the need for more platform-specific studies when analyzing the efficacy of content moderation.

The novelty of this research is focused on uncovering the disconnect between social media content moderation policies and how these policies are publicly framed, contributing to discourse on digital governance and platform accountability. Also, by utilizing both thematic analysis and frequency-based keyword examination, the study provides a multi-faceted understanding of moderation communication strategies. This study contributes to the ongoing debate on digital platform governance by highlighting the need for increased transparency in content moderation.

The findings align with earlier studies (Singhal et al., 2023; Keulenaar et al., 2023), highlighting inconsistencies in content moderation enforcement. Unlike Franco et al. (2023), who focus on algorithmic challenges, this study emphasizes the role of blog posts in shaping public perception. The results contrast Peterson-Salahuddin (2024), who argues that moderation policies are disproportionately strict for marginalized communities. Instead, this

research suggests that platforms strategically manage their public communication rather than solely enforcing biased policies.

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SOCIAL ENTREPRENEURSHIP: LITHUANIAN CASE STUDY

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Abstract. Social entrepreneurship is a process in which, using business principles, a company is organized and managed in such a way as to achieve social change in society. Whereas a business measures its success solely by the amount of profit, a social business also measures the results of its positive activities in society. The article aims to examine the theoretical aspects of social entrepreneurship and present an analysis of cases of social entrepreneurship in Lithuania. The article analyses the concept of social entrepreneurship, investigates cases of social entrepreneurship in Lithuania, and presents interviews with experts about social entrepreneurship. The aim of the study was to find out the prospects of social entrepreneurship in Lithuania. The study showed that social businesses mainly operate in education, integration into the labour market, and support for children/adults/families. Considering the development trends of the social economy, the development of social business in Lithuania should also take place by encouraging traditional private companies to get involved in solving social problems. Social business focuses primarily on a social mission, while socially responsible business focuses on profit, but with social and environmental impact in mind a socially responsible business deals with the solution of social problems as a short-term one-time/periodic initiative, the solution of social problems is not the goal of the activity.

Keywords: social entrepreneurship; social impact; social problems; social mission; social business model

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Additional disciplines: sociology; educology; information and communication

1. Introduction

Social entrepreneurship is a new phenomenon, so no single, universally accepted definition exists. Perrini et al. (2006) propose to define social business as a process in which business organizations, through innovative activities and principles, initiate or contribute to the creation of positive changes. Social business on an international scale emerged when it began to be realized that business can bring financial and social benefits; the profit obtained can be used as a tool to create changes in society. The emergence of social business was influenced by the emerging social economy sector, which simultaneously creates social and economic value and aims to satisfy human needs, which the existing private and public sectors still do not meet. The topic of social entrepreneurship has been studied by authors such as Dunfee (1991) and Dunham et al (2006). Clarkson (1995), Adler and Kwon (2002), Carroll (1994), Alvarez de Mon et al. (2021), Aparicio et al. (2020), Broccia et al. (2020), Tian and Wang (2022), Azqueta et al. (2023), Daskalopoulou et al. (2023), Rwehumbiza and Hyun (2024).

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2. Social Entrepreneurship concept

Social entrepreneurship is establishing a company whose primary goal is not to maximize economic benefits but to create value for society. Social entrepreneurship consists of meeting social or environmental needs through an enterprise that generates economic benefits and is reinvested in achieving an underlying social goal. The social entrepreneurship concept is presented in Table 1.

Table 1. Social entrepreneurship concept

Author	Highlight
Shin (2018)	The discussion about the openness and innovativeness of social entrepreneurs is limited, and open innovation is essential for the sustainable growth of social and business enterprises.
Cagarman et al. (2020)	Accompanied by economic results and a social mission, social entrepreneurship is defined as a process involving the innovative use and combination of resources to drive social change and/or meet social needs.
García-Jurado et al. (2021)	It is one whose primary mission is to make a transformative impact or create positive social change through a business model or activity that enables the achievement of said mission in a financially sustainable manner using innovative and repeatable business models.
Cardella et al. (2021)	An emerging but rapidly growing field that spans diverse sectors such as innovation, technology, public policy, community development, social movements, and non-profit organizations.
Gigauri et al. (2022)	Social entrepreneurship begins with the characterization of entrepreneurship, which involves innovative activities aimed at creating new social welfare, jobs, and value. It is seen as an engine of economic growth, especially in developing countries.
Kamran et al. (2022)	There are several definitions of social entrepreneurship, which reflect that the social goal is their primary motive, as social entrepreneurship implements continuous innovations, and the entrepreneurs of such social businesses are called entrepreneurs with a mission and social problem solvers.
Monteiro et al. (2022)	Including social priorities such as poverty, unemployment, education, health, local development or the environment.
Coronel-Pangol et al. (2023)	It is relevant because it solves critical issues and social problems that governments have neglected or failed to address. This type of entrepreneurship was seen as a necessary relief mechanism in areas that the private sector considers unprofitable.
Kurata et al. (2023)	Social entrepreneurship aims to solve society's problems and challenges and meet basic human needs through innovative integration of resources.
Talukder and Lakner (2023)	Social entrepreneurship, in contrast to the more common form of entrepreneurship (i.e., the initiative to start a new company or to expand an existing one), emphasizes the creation of social capital more than financial gain, and it does not deny the importance of making a profit.
Azqueta et al. (2023)	Social entrepreneurship research should be included in the framework of existing theories and research models, emphasizing the differences in social entrepreneurship that integrate capitalist logic with social value creation.
Daskalopoulou et al. (2023)	It is the intended outcome of the "social" element of entrepreneurship, which is commonly described in terms of social value, social innovation, social mission, social change, social purpose, social performance, social asset, and social return.
Kruse et al. (2023)	Social entrepreneurship is a new form of entrepreneurship for creativity to its beneficiaries, both as a for-profit and not-for-profit enterprise.
Premadasa et al (2023)	Social entrepreneurship has recently gained popularity as a significant business segment of entrepreneurship. A unique mission and market expectations are the main differences between social and commercial entrepreneurship. The concept of entrepreneurial orientation has become increasingly important in the context of entrepreneurship.
Cruz-Sandoval et al. (2023)	Focused on research on social entrepreneurship education, considering the crucial role of educational institutions in developing the entrepreneurial spirit and providing future entrepreneurs with the skills and tools needed to implement their social projects.
Obi-Anike et al. (2023)	Remains the most effective tool for promoting social entrepreneurship in the economy.
Sampaio and Sebastião (2024)	Involves creating positive societal change through business initiatives focusing on making social value.

In summary, the authors state that social entrepreneurship has become relevant. Figure 1 presents the social entrepreneurship model.

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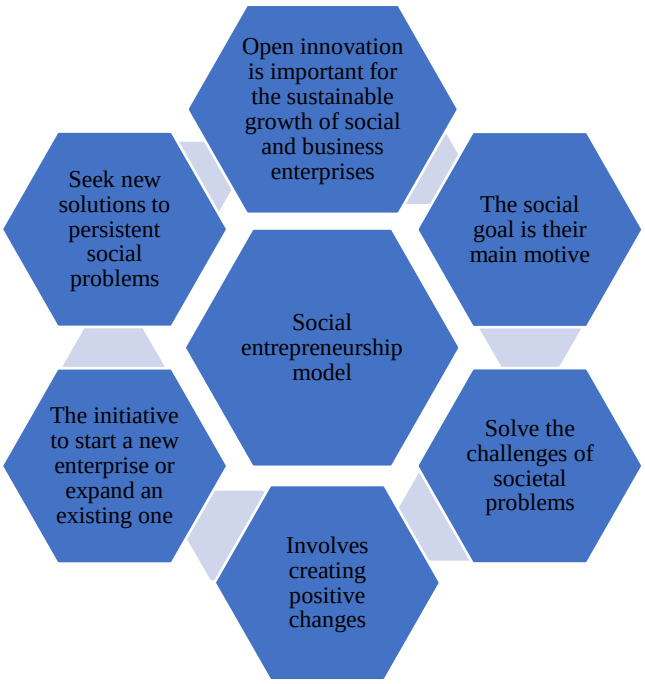


Figure 1. Social entrepreneurship model

Social entrepreneurship solves essential problems and social issues that governments have ignored or failed to solve, it has been considered a necessary assistance mechanism in areas that the private sector considers unprofitable, the social goal is their primary motive, as well as social entrepreneurship, introduces continuous innovations and entrepreneurs of such social businesses are called entrepreneurs, mission, social problem solvers, the goal of social entrepreneurship is to innovatively integrate resources, solve the challenges of societal problems and meet basic human needs, it involves creating positive changes in society.

3. Social entrepreneurship innovation

Dopelt et al. (2023) stated that social entrepreneurship has gained significant importance in recent years as an effective way to address widespread societal gaps. Aparicio et al. (2020) mentioned that essential efforts have been made to analyze social outcomes such as poverty reduction, inequality, inclusive growth and gender equality. Although not as rich as traditional economic growth analyses, this literature confirms that entrepreneurs have a social sense, meaning that their decisions transcend materialism and a money-making mindset.

Ndou (2021) considered that social entrepreneurship aims to solve complex social problems in an innovative, efficient and effective way. Activating powerful knowledge mechanisms that innovate and reconfigure competencies, skills, abilities, attitudes, and knowledge assets becomes imperative for sustainable social development innovations. Therefore, interest in creating and developing social entrepreneurship education has grown significantly.

Broccia et al. (2020) analyzed that innovativeness promotes the long-term competitiveness of an organization; the concept of organizational capability indicator reflects the internal strengths of organizations that can determine how they can gain an advantage over other organizations and thus achieve better results.

Tišma et al. (2022) stated that social entrepreneurship is often associated with social innovation, as social entrepreneurs seek innovative solutions to meet new social needs.

Alvarez de Mon et al. (2021) mentioned that social impact and innovation are essential to any social entrepreneurship project. Alvarez de Mon et al. (2021) research aims to identify the main factors that motivate

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social entrepreneurs to finally create and implement their social entrepreneurship and, more specifically, social enterprises. Beyond this initial goal, Alvarez de Mon et al. (2021) want to understand which of these factors have a more significant impact and a more transformative effect on the final decision of these social entrepreneurs to create their organizations. Alvarez de Mon et al. (2021) also explore the relationship between these factors and the dominant narrative of these social entrepreneurs in their creation.

Bansal et al. (2019) mentioned that the innovative power of entrepreneurs plays a significant role in ensuring a more sustainable future, and entrepreneurs are therefore recognized as drivers of sustainable development. While entrepreneurs are seen as a means to meet (currently) unmet social needs, there has been little academic discourse on how this process will actually play out.

Summarizing the above presented scientific opinion, it can be stated that social innovation is the process of developing and implementing effective solutions to complex and often systemic social and environmental problems to support social progress, and social solutions require active collaboration between government, business, and non-profit entities.

4. Research methodology

Zainal (2007) stated that the case study method allows the researcher to examine data closely in a specific context and most cases. A case study as a research method investigates a contemporary real-life phenomenon by analyzing a limited number of events or conditions and their relationships in detail. It enables qualitative research with or without a particular research tradition. As an independent form of research, the single case study method is not distinguished from other methods, but attention to an individual, single case. An instance can be a person, a group, an episode, a process, a community, a society, or any other element of social life. All relevant and available data are collected. The single-case study method in the context of qualitative research is described as a detailed study of individual cases of a phenomenon in a natural environment (people are observed in their usual environment while communicating in their language) taking into account the perspective of the research participants (explained by direct observation of the participants or by talking to them). A detailed case study is characterized by the fact that quite a lot of data is collected, expressed in words, images, objects, and sometimes in numbers. Such research requires more time, several methods can be used to achieve comprehensive knowledge.

The interview is used and widely applied at various stages of the research to define the problem and specify the research problem. Interviews can also be used to prepare the methodology of extensive surveys, testing, and developing questionnaires. In qualitative studies, the purpose of which is to discover the deeper layers of the problem or phenomenon under consideration and to reveal emotional, experiential or other aspects, the interview can be successfully used as the main method of information gathering. Gaižauskaitė et al. (2016) interview is the most commonly used method of data collection method in qualitative social research. According to Gaižauskaitė et al. (2016), it responds perfectly the assumptions of qualitative methodology allow to delve into the research participants' perspectives to collect abundant data that captures the details and unique nuances of social life. Since this study aimed to obtain answers to the same questions from all respondents, a structured questionnaire is used, which preliminarily formulates open questions and predicts their order. This structure is tried to be followed in the interview, although it is still not as strict as in a quantitative survey. Usually structured, a qualitative interview is conducted when the research aims to compare certain cases or social categories.

5. Social Entrepreneurship Lithuanian case studies

Around 200 small and medium-sized enterprises (SMEs), i.e. micro, small and medium-sized enterprises, are involved in social business in Lithuania. They use more than 50% of their profits to generate social and/or environmental impact. This is an important feature that distinguishes them from businesses as usual. In order to help them develop successfully, Order No 4-532 of 9 October 2024 of the Minister of Economy and Innovation of the Republic of Lithuania approved a description of the procedure for acquiring and losing the status of a social business entity. Its content reveals the above-mentioned use of the profit share, the measurement methodology, the requirements for the independence of a social business entity and the forms of promotion of

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social business. It also provides for the collection of data, information, and declared intentions of companies to become social entrepreneurs by the public body of the Innovation Agency. The Innovation Agency's website https://socialinisverslas.inovacijuagentura.lt is used for information management. By granting social business status, the Innovation Agency collects general information on SMEs and periodically assesses the objectives, target group, business impact and economic performance. Social businesses undertake to measure their social and/or environmental impact and to update the measurement results annually in annual reports, which are made publicly available on the website of the Innovation Agency.

According to the data of the Innovation Agency, at the beginning of 2025, social business enterprises were geographically spread throughout Lithuania. Almost half of the social business enterprises operate in the three largest Lithuanian cities. A quarter of these businesses are concentrated in the capital. Among the regions, Molėtai, Rokiškis, and Anykščiai districts are the most active.

Table 2. Geographical distribution of Social Business Enterprises in Lithuania

Number of social business enterprises,	Lithuanian city/district
52	Vilnius
26	Kaunas
11	Klaipėda, Klaipėdos distr.
10	Molėtų distr.
8	Rokiškio distr.
7	Anykščių distr.
6	Marijampolė, Panevėžys
4	Alytus
5	Mažeikių distr., Utenos distr., Panevėžio distr., Vilniaus distr.
3	Šiauliai, Kauno distr., Kėdainių distr., Ukmergės distr., Zarasų distr.
2	Palanga, Ignalina, Kazlų Rūda, Kaišiadorys, Švenčionių distr., Kretingos distr., Širvintų distr., Pakruojo distr., Šakių distr., Varėnos distr.
1	Birštonas, Druskininkai, Jonava, Alytaus distr., Jurbarko distr., Kelmės distr., Kupiškio distr., Lazdijų distr., Pasvalio distr., Radviliškio distr., Vilkaviškio distr., Šiaulių distr., Šilalės distr., Skuodo distr., Trakų distr., Prienų distr., Plungės distr., Šalčininkų distr.

Source: Made by the authors according to inovacijuagentura.lt, 2025

As part of their mission to address a specific social problem, social businesses operating in Lithuania mainly offer education/informal learning services but also actively contribute to integration/employment and support for children/parents/families. On the other hand, it is observed that social businesses in Lithuania have been slow to emerge in addressing human rights issues and physical health issues.

Table 3. Diversity of services provided by social business enterprises in Lithuania

Content of the social business service	Quantity of services, pcs.
Education/non-formal education	59
Integration/employment	40
Support for children/adults/families	40
Assistance for people with disabilities	33
Environment/sustainability	32
Psychological/emotional health	26
Help for older people	24
Culture/tourism	21

Source: Made by the authors according to inovacijuagentura.lt, 2025

This article examines two cases of social business. These catering companies are well-known in the market and have been successfully operating in Lithuania for many years. The first one is the salad bar – "Mano Guru". The Public Institution "Social Support Projects" was established in 2002 and has been operating for more than 20 years. It aims to create a social business aimed at integrating into the labour market socially excluded people

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with a history of addiction to psychoactive substances, ex-prisoners, disabled people, and homeless people. The company addresses societal issues through a social business in a salad bar called "Mano Guru". It is the first social business established in Lithuania - a catering establishment designed to train the unemployed and the unskilled, provide them with job skills, employ them or find them a permanent job. It is also a place where citizens gather for lunch and socializing. In this way, the business also aims to change society's attitudes towards people who have been excluded. Visitors are socially responsible eaters who come for a tasty meal and to support social business ideas and other people. The longevity of the business demonstrates the viability of the social business model. During the business's long life, around 800 people have been employed here, where they received reintegration services, gained experience, social and work skills, and were trained in professions in demand in the catering sector, such as chef, waiter, and barman.

The company's social worker, psychologist, and, if necessary, psychiatrist dealt individually with each case to determine what services and support each person needed. Based on data from the Okredo Open Data Platform, at the beginning of 2025, the company had 19 employees with an average salary of €1,720.84 (December 2024). This average salary aligns with the national market level and is further evidence of a viable social business model. The company's activities have a clear upward trend, with sales revenues increasing for several consecutive years. Between 2021 and 2024, sales revenue doubled from EUR 167 thousand in 2021 to EUR 538 thousand in 2024. The social business is financially sustainable, has a viable business model, and makes a profit. Profits are reinvested in business development and contribute to solving social problems. The profits earned by “Mano guru” allow the social business to grow and independently finance its activities.

The second case study is about social business – “Pirmas blynas”. This small partnership was established in 2018. It's a pancake restaurant staffed by people with disabilities. In 2018, the restaurant was awarded the Business Gene Award for the best socially responsible business initiative. The aim is to help young people gain confidence, learn responsibility and acquire the skills needed for future professional and personal success. This business allows young people to work while learning a range of vocational skills. This helps them gain work experience and develop social skills that are important for successful integration into the labour market. Young people receive help and support at work and in their daily lives. Mentors and staff help them navigate the working environment, teach communication skills, and help them deal with various personal challenges. The business contributes to social inclusion and reduces social exclusion. Like many social businesses, First Pancake reinvests its profits in its operations and development, ensuring long-term impact and continuity. Funds are often used for additional services, training and projects.

Based on data from the Okredo Open Data Platform, at the beginning of 2025, the company had 11 employees. The company has had a stable team size for the last three years. The number of employees varies between 8 and 11. The average salary of the employees was EUR 1033.83 (December 2024). The average salary aligns with the national market level and is further evidence of a viable social business model. The company's activities have a clear upward trend, with sales revenues increasing for several consecutive years. Between 2021 and 2024, sales revenues more than doubled from EUR 179 thousand in 2021 to EUR 414 thousand in 2024. In 2024, the social business will be financially sustainable, have a viable business model, and make a profit. Like many social businesses, “Pirmas blynas” reinvests its profits in its operations and development, thus ensuring long-term impact and continuity. Funds are often used for additional services, training and projects.

6. Research data analysis

A pilot structured interview method was conducted. The study was carried out in August 2024. Six informants participated in the study. The characteristics of the study participants are presented in Table 4. The age of the research participants ranged from 26 to 62 years. The positions of the research participants varied from the position of project manager to director. Research participants work in the private sector.

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Table 4. Respondents characteristics

Respondents	R1	R2	R3	R4	R5	R6
Age	34	62	57	26	55	41
Gender	Male	Female	Female	Female	Female	Female
Education	Social worker (in the Netherlands)	Master's degree	University degree	University degree	Master's degree	Master's degree
Responsibilities	Founder of a social restaurant.	Deputy Director for Strategy and Development	Head of a project	Head of a project	Director	Director
Field of activity	Restaurant work combined with Social work	education	Banking sector	Private sector	Trade	Publishing (including for the blind), organization of events

Regarding challenges in creating social business, Urmanavičienė et al. (2021) stated that social business organizations are businesses whose social mission is their primary mission and whose primary goal is to find solutions to social problems. Urmanavičienė et al. (2021) mentioned social business organizations choose and implement business strategies in a way that is consistent with and does not contradict their social mission (in the best case, their business model even reinforces the social mission). Kumar and Dwived (2023) mentioned that hybrid legal structures, impact assessment standards, stakeholder engagement, ethical contracting, regulatory advocacy, and legal innovation through collaboration are just some of the existing legal challenges and benefit analysis methods for social entrepreneurship. According to Kumar and Dwived (2023) obstacles remain, such as the inconsistency of hybrid regulatory structures, the difficulty of objectively measuring their impact, the need to balance competing interests when engaging stakeholders, the lack of transparent and enforceable ethical contracts, sufficient resources for regulatory advocacy, and the need for negotiation when pursuing collaborative legal innovation from multiple perspectives. Ferdousi and Abedin (2023). mentioned that for social enterprises that believe in self-reliance and do not rely on donor funds, effective human resource management is one of the most critical factors in their organization's performance. According to Ferdousi and Abedin (2023), managing human resource costs and increasing the impact of their social mission through employees, on the other hand, creates a human resource management paradox. Cato and Nakamura (2022) stated that social business plays an increasingly important role in addressing the social challenges we face today, and many social businesses combine commercial business with a business-related social mission. Cato and Nakamura (2022) mentioned that social entrepreneurs still face difficulties obtaining investment. In addition, those wishing to start business projects often face financial challenges in securing seed funding; therefore, informal investors, including family members, friends and business angels who invest in new companies, are crucial in promoting social entrepreneurship.

Informants were asked (see Table 5) why creating a social business is worth it. The informants said that this is the best way to give hones opportunities to people with disability and solve society's problems. It is worth creating a social business for several reasons: firstly, it is sustainable - it helps to solve environmental problems; secondly - it is a social aspect (it solves society's social issues, such as unemployment, healthcare, etc., and unites the community). Also, public involvement in solving social problems increases positive changes and improves the quality of life.

Table 5. Challenges creating social business, profit in social business

Respondents	Why is it worth creating a social business?
R1	In my eyes, this is the best way to give hones opportunities for people with a disability.
R2	Solve society's problems
R3	It is worth creating a social business for several reasons: firstly, it is sustainable - it helps to solve environmental problems; secondly - it is a social aspect (it solves society's social problems, such as unemployment, healthcare, etc., and unites the community).
R4	It allows for solving social problems, promoting innovation, strengthening communities, and positively impacting society, the state, and the environment.
R5	The burden on the state is reduced, and the problems of the most vulnerable part of society are solved.
R6	Public involvement in solving social problems is increasing. Positive changes in creating a better quality of life.

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Regarding social business, Mu et al. (2024 mentioned that customer expectations have changed, with a clear shift towards ethical consumption and socially responsible business practices. Modern customers increasingly demand transparency, ethical behaviour, and contributions to society and the environment from the companies they patronize. The informants were also asked how to profit at the same time. The informants said creating a profitable and efficient business is essential. However, the profit margin should not be extremely high (as much as it is necessary to expand the activity). The methods of obtaining profit depend on the business area. Suppose it is a business aimed at public health, after selling organic products and/or services. In that case, it is possible to receive a profit, which can be allocated to public health through various programs, part of which can be reinvested in the existing business. The state supports part of social businesses by providing grants and exempting/reducing taxes. Profit can be achieved in social business when the goods or services sold solve social problems and satisfy market needs.

Talking about the difference between social business and socially responsible business, Saatci and Urper (2013) mentioned that the social business model does not do this to maximize profits but to serve humanity's immediate needs. Therefore, the first motive of social business is not profit maximization, and secondly, it does not pay dividends to its investors. It aims to solve social problems by providing products and services at affordable prices or by giving poor and marginalized people ownership of the business and, therefore, allowing them to share in its profits. Social businesses only recoup their initial investment and reinvest their earnings in innovation or further growth to achieve their social goals.

Informants were asked about the difference between social and socially responsible businesses. Informants' opinion is presented in Table 3. Respondent 3 mentioned that social business differs from socially responsible business in its first goal: the goal of social business is not to obtain the highest possible profit, while the goal of socially responsible business (like all other businesses) is to generate the highest feasible profit, while Respondent 4 stated that social business focuses primarily on a social mission, while socially responsible business focuses on profit, but with social and environmental impact in mind and Respondent 5 stated that socially responsible business deals with the solution of social problems as a short-term one-time/periodic initiative, the solution of social issues is not the goal of the activity.

Table 6. Difference between social business and socially responsible business

Respondents	What is the difference between social business and socially responsible business?
R1	Our main goal is the social impact. I never dreamed of opening a restaurant, but I think it is the best way to have a social impact on my target group. This is my main reason to start the business. If I were a socially responsible business, I would have always wanted to have a restaurant and, for example, employ one person with a disability because I also think about the social side.
R2	In the 21st century, all businesses must be socially responsible. Social business also solves sensitive societal problems.
R3	Social business differs from socially responsible business in its first goal: the goal of social business is not to obtain the highest possible profit, while the goal of socially responsible business (like all other businesses) is to generate the highest possible profit. Also, these businesses differ in their operating principles: a social business is created to solve the problems of unemployment, health, education, and environmental protection, while financial indicators measure the success of a socially responsible business and part of the earned profit is directed to the improvement of the social sphere (charity, social initiative - there may be employees for improving work/leisure conditions/health etc.).
R4	Social business focuses primarily on a social mission, while socially responsible business focuses on profit but with social and environmental impact in mind.
R5	A socially responsible business deals with solving social problems as a short-term, one-time/periodic initiative; the solution of social problems is not the goal of the activity.
R6	The purpose of social business is to make positive changes for society, while the purpose of socially responsible business is to make a profit.

Talking about prospects for social business in Lithuania, Andriušaitienė and Vižinytė (2019) stated that Lithuania lacks advertising about what social business innovation is, what its opportunities are, and best practices. Greater dissemination of information and a favourable legal environment could encourage the development of this social innovation and become a significant response to social problems. Respondents were asked what the prospects are for social business in Lithuania. According to R1, a new generation sees more of

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the world than the previous. This gives ideas. With the concept, it starts. R3 stated the prospects for social business in Lithuania are not bad: public education, the new generation of entrepreneurs increasingly delving into sustainability issues, and the efforts of various organizations to create innovative solutions; likely, state support will also be more significant for these companies. R5 mentioned that in a society with many social problems and a big leap in innovation, the prospects for creating a social business are good, but the threat is a small market.

Talking about hindering the development of social business in Lithuania, Andriušaitienė and Vižinytė (2019) mentioned that the most significant obstacles hindering social business: lack of social capital, low interest of entrepreneurs, investors there is no legal basis for regulating social business in the social business model. However, all these reasons are mutually dependent. Andriušaitienė and Vižinytė (2019) the results of the study allow us to propose solutions that can become catalysts for a breakthrough to pave the way for the development of social business: legalization of a flexible social business model in the legal framework and investment in a social advertising campaign. Urmanavičienė et al. (2021) mentioned that disability organizations say the new law does not ensure that government support reaches disabled workers because subsidies are given to companies, not people. Urmanavičienė et al. (2021) stated that social enterprise leaders believe that stricter restrictions on the activities these companies can carry out will drive most of them out of business. Vveinhardt and Kuklytė (2016) considered that there should be more information about the development of social business in Lithuania, which would be prepared and accessible to interested people. According to Vveinhardt and Kuklytė (2016), the awareness of social business models shapes people's perception of social business; a positive attitude towards the application of social innovations and social clusters would have a positive impact on societal values and norms; they encourage public participation, and arouse interest in social business models. Such changes should be announced in the mass media to ensure effective communication and cultural characteristics of the change. Economic, legal and political aspects of the problem can be addressed by adjusting the legal and tax framework.

Respondents were asked what main obstacles they would identify as hindering social business development in Lithuania. R1 stated that Stigma is from the older generation. The ideas mostly come from social people with no business experience; for them to oversee the possible issues and possibilities is difficult. In education, there is almost no overlap in these areas. If there would be, this would be a considerable improvement. R6 mentioned state support is focused on newly created social business companies (start-ups).

In contrast, social business companies operating for more than 5 years do not have such support opportunities. Insufficient public education means the state does not allocate/limit funds for it. Social business enterprises carry out the function of public education voluntarily, accepting interns for practice and using their human resources without remuneration. There are no/small social business support and financing projects.

Table 7. The prospects for social business in Lithuania

Respondents	What do you think are the prospects for social business in Lithuania?	What main obstacles would you identify hindering social business development in Lithuania?
R1	I see it bright; a new generation sees more of the world than the previous. This gives ideas. With the concept, it starts.	Stigmas from the older generation The ideas mostly come from social people with no business experience; for them to oversee the possibilities of the possible issue is complex. In education, there is almost no overlap in these areas. If there would be, this would be a vast improvement.
R2	I can't answer	Society's tolerance and lack of understanding that these problems will need to be solved star_border.
R3	The prospects for social business in Lithuania are not bad: public education, the new generation of entrepreneurs increasingly delving into sustainability issues, and the efforts of various organizations to create innovative solutions; likely, state support will also be more significant for these companies.	The main obstacles preventing the creation of social business in Lithuania are the insufficient maturity of society and entrepreneurs, the absence of a law regulating this activity, and inadequate funding opportunities.

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R4	Growing.	Lack of funding and public involvement.
R5	In a society with many social problems and a big leap in innovation, the prospects for creating a social business are good; the threat is a small market.	Insufficient public education, lack of knowledge, small market, and quality assurance of provided services.
R6	In the creation of social business enterprises, the state support is too low, the process is complicated by the requirements of combining public and private interests.	State support is focused on newly created social business companies (start-ups), while social business companies that have been operating for more than 5 years do not have such support opportunities. Insufficient public education means the state does not allocate/limit funds for it. Social business enterprises carry out the function of public education voluntarily, accepting interns for practice and using their human resources without remuneration. There are no/small social business support and financing projects. The allocation of support to social businesses is not legally distinguished and separately regulated; there are general provisions for allocating support to small businesses. This reduces the opportunities for social enterprises to receive support. The connection with municipalities, Ministries, state institutions, and businesses is weak. A socially responsible business could work in partnership with socially responsible businesses. Social business appears in the Government and business enterprises gap without substantial investment and state support.

Regarding social business initiatives, Missimer and Mesquita (2022) stated that social business sustainability is often treated as an add-on to ecological sustainability, and social sustainability issues are forced to adapt to existing methods and tools without considering the complexity or specificities. Respondents were asked to answer questions about the most critical features society must-have for social business initiatives to be popular. Respondents' opinion is presented in Table 8. Respondents are sophisticated, tolerant, understanding, and proactive and want to create a better, more comfortable, and accessible environment for everyone. They have high social awareness, supportive politics and awareness, understanding, willingness to contribute, and inclusiveness.

Table 8. The most important features a society must have for social business initiatives to be popular

Respondents	What are the most important features a society must have for social business initiatives to be popular?
R1	Educational programs where future social workers, engineers, businessmen & marketing people sit together to create ideas and small products and ideas.
R2	Sophisticated, tolerant, understanding, proactive, who wants to create a better, more comfortable and accessible environment for everyone
R3	For social business ideas to be popular, society must know and understand what social business is. Its role in the welfare of society is to get involved in new initiatives and be ready to create new innovative businesses.
R4	High social awareness, supportive politics and awareness.
R5	In a society with many social problems and a big leap in the field of innovation, the prospects for creating a social business are good; the threat is a small market.
R6	Awareness, understanding, willingness to contribute, inclusiveness.

7. Discussion

Social entrepreneurship is a process where, using business principles, a company is organized and managed in such a way as to achieve social change in society. The results of the case study highlight a good social business says that a social business recognizes a social problem in the immediate environment in which it operates, where its efforts to change something are most effective and useful, where the business has not only customers but also other beneficiaries. Social business is also guided by strong values and the belief that what it does leads to positive social changes. Now, put all these aspects - values, attitude, faith, trust, and the best solutions for society - into one action or activity, and you will get a unique product or service in the market in customers' eyes. Social entrepreneurship includes a business-specific aspiration - to aim for businesses to produce and sell products and services at such a cost price, to which, after adding the desired profit margin, the product would be desirable in the market. Social business includes financing, financial management, human resource management, advertising and communication, sales, reinvestment, and development. Social business is a business, and that

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should not be forgotten. Understandably, social business is a big challenge because it takes extra effort and skills to be successful. So, this type of business is for genuine leaders, and only leaders can strive to implement it.

The authors agree that the social entrepreneurship of Lithuanian private companies is one of the most effective means of maintaining and solving social problems.

The case studies in Lithuania revealed some important aspects: it can be stated that according to Nobel laureate Dr. Muhammad Yunus, the social business mission is to solve a specific social problem in society (through social innovation or adaptation of successful practices). Social business is financially sustainable and has a viable business model. The profit solves a social problem or is reinvested in developing a social business. Social business works in harmony with the environment.

The interview aimed to discover the prospects of social entrepreneurship in Lithuania. The main topics of discussion are the main characteristics of informants, what a social business is, the difference between social business and socially responsible business, information about social business, its opportunities and benefits in Lithuania, and the prospects for social business in Lithuania.

According to respondents, the prospects for social business in Lithuania are not bad: public education, the new generation of entrepreneurs increasingly delving into sustainability issues, and the efforts of various organizations to create innovative solutions; it is likely that state support will also be more significant for these companies. In a society with many social problems and a big leap in innovation, the prospects for creating a social business are good; the threat is a small market. In creating social business enterprises, state support is too low, and the process is complicated by the requirements of combining public and private interests.

Conclusions

Social entrepreneurship is a business model according to which, using the market mechanism, the pursuit of profit is linked to social goals and priorities. It is based on the principles of public-private partnership, and social innovations are applied.

Social business enterprises are geographically spread throughout Lithuania. Almost half of the social business enterprises operate in the three largest Lithuanian cities. Case studies have shown that profit-seeking companies can conduct social business, whose primary purpose of economic activity is social benefit. An extensive range of activities characterizes social business. Case analysis showed that social businesses mainly operate in education, integration into the labour market, and support for children/adults/families. Considering the social economy's development trends, the development of social business in Lithuania should also occur by encouraging traditional private companies to solve social problems. On the other hand, it is observed that social companies in Lithuania have been slow to emerge in addressing human rights issues and physical health issues.

Interview results show that social business differs from socially responsible business in its first goal: the goal of social business is not to obtain the highest possible profit, while the goal of socially responsible business (like all other businesses) is to generate the highest possible profit. Social business focuses primarily on a social mission. In contrast, a socially responsible business focuses on profit but with social and environmental impact in mind. A socially responsible business deals with the solution of social problems as a short-term, one-time/periodic initiative; the solution of social problems is not the goal of the activity.

The prospects for social business in Lithuania are not bad: public education, the new generation of entrepreneurs increasingly delving into sustainability issues, and the efforts of various organizations to create innovative solutions; likely, state support will also be greater for these companies. In a society with many social problems and a big leap in innovation, the prospects for creating a social business are good; the threat is a small market.

Stigmas from the older generation. The ideas mostly come from social people with no business experience; for them to oversee the possible issues and possibilities is difficult. In education, there is almost no overlap in these

areas. If there would be, this would be a considerable improvement. State support is focused on newly created social business companies, while those operating for more than 5 years do not have such support opportunities. The state does not allocate funds for insufficient public education. Social business enterprises carry out the function of public education voluntarily, accepting interns for practice and using their human resources without remuneration.

The essential features a society must have for social business initiatives to be popular, sophisticated, tolerant, understanding, proactive, wanting to create a better, more comfortable, and accessible environment for everyone, high social awareness, supportive politics and awareness, understanding, willingness to contribute, and inclusiveness.

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RESEARCH ON OUTCOMES OF COLLABORATIVE ONLINE INTERNATIONAL LEARNING PROJECT AT VILNIAUS KOLEGIJA/HIGHER EDUCATION INSTITUTION

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Abstract. Large-group collaborative learning approaches are rapidly gaining popularity in undergraduate education, particularly in globalized economies and diverse work environments. This study examines the impact of the Collaborative Online International Learning (COIL) project on developing intercultural competencies and acquiring knowledge about foreign markets. The research focuses on an online collaboration between Vilniaus kolegija/Higher Education Institution and Opole University of Technology, where students engaged in cross-cultural teamwork, discussions, and joint assignments. Qualitative data were collected through student interviews to gain deeper insights into their experiences and perceptions. The analysis revealed that participants significantly improved their intercultural communication skills, developed a deeper understanding of cultural diversity, and enhanced their ability to work in international business settings. Additionally, students expanded their knowledge of foreign markets, trade practices, and business strategies through interaction with peers from different cultural and educational backgrounds. The findings indicate that COIL effectively fosters intercultural competence, promotes collaborative problem-solving, and prepares students for future careers in a globally connected world. By integrating virtual exchanges into higher education curricula, institutions can enhance students' employability, cultural awareness, and adaptability to diverse professional environments. This study highlights the potential of COIL as a valuable pedagogical tool in international business education and beyond.

Keywords: collaborative online international learning; intercultural competence; global business

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JEL Classifications: I21, I23, I25

1. Introduction

The case-based collaborative learning (CBCL) pedagogy was introduced for pre-clerkship teaching at Harvard Medical School in 2015, with subsequent adoption by other medical schools (Besche et al., 2025). This approach highlights the significance of collaborative learning (CL) in modern education. Collaborations between universities and organizations are increasingly essential for societal progress (Inada, 2024). According to Inada (2024), the institutional philosophy of voluntarism, combined with a human-centered approach, servant leadership, and engagement with the younger generation, is pivotal in fostering value creation within community and social entrepreneurship education.

Zhao (2024) emphasizes that collaborative learning traditionally occurs during in-person meetings. However, technological advancements have facilitated Collaborative Online International Learning (COIL), a pedagogy that connects students and lecturers from different countries for joint projects and discussions as part of

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coursework. This concept has gained significant attention among scholars, including Appiah-Kubi and Annan (2020), Aškerc Zadravec (2023), Bienvenido-Huertas and Rubio-Bellido (2022), Borger (2022), Botero-Gómez et al. (2023), Chernova et al. (2024), Dyshko et al. (2021), Esche (2018), and Falkenberg et al. (2023), Zamiri and Esmaeili (2024). These authors underscore that COIL facilitates meaningful global learning experiences by integrating cross-cultural, student-centred collaboration into academic programs. Furthermore, COIL serves as a cost-effective solution for universities to promote international engagement among students.

Despite its growing popularity worldwide, the COIL approach remains relatively novel within the Lithuanian education system. One of the first practical implementations of a COIL project took place at the Faculty of Business Management at Vilniaus kolegija/Higher Education Institution. In this initiative, third-year students enrolled in the International Business study program participated in a COIL project during the Marketing module. Collaborating with peers from Opole University of Technology in Poland, students were tasked with investigating the specificities and unique characteristics of Lithuanian and Polish markets. They aimed to propose practical solutions for introducing new products to these markets.

Although the project was largely successful, several challenges and problematic aspects emerged, particularly regarding the scientific foundation and pedagogical framework of COIL implementation. These challenges underscored the need for a deeper investigation into the integration of COIL within Lithuanian higher education institutions.

The primary **scientific issue** addressed in this study is formulated through the following research question:
What are the challenges associated with Collaborative Online International Learning (COIL) at Vilniaus kolegija/Higher Education Institution?

The **research aims** to investigate the implementation, challenges, and outcomes of COIL at Vilniaus kolegija/Higher Education Institution, focusing on understanding its impact on student learning and internationalization.

To achieve the research aim, the following **objectives** were established:
- To analyze the concept of Collaborative Online International Learning (COIL).
- To examine the application of collaborative online international learning tools, including guerrilla marketing strategies.
- To evaluate the impact of COIL on learning internationalization.
- To investigate the challenges and outcomes of COIL implementation at Vilniaus kolegija/Higher Education Institution.

This research seeks to contribute to the existing body of knowledge regarding COIL by examining its practical application in Lithuanian higher education. By identifying the benefits and challenges of COIL implementation, the study aims to provide insights for educators and institutions seeking to enhance international collaboration and cross-cultural learning opportunities for students.

2. Collaborative online international learning: theoretical aspects

2.1. Collaborative online international learning concept

Collaborative online international learning (COIL) is an innovative pedagogy that allows faculty and students to use technology to collaborate with peers at universities worldwide. COIL takes place over two or more courses taught by professors from different countries and can last from a few weeks to an entire semester. Using a computer or phone with internet access, students meet and communicate in synchronous and asynchronous meetings where they exchange experiences and ideas and work together in teams to complete projects that their respective professors evaluate.

First, collaborative online international learning (COIL) is an educational approach that integrates online technologies to connect students and educators from different countries for joint projects and coursework. Appiah-Kubi and Annan (2020) highlighted that COIL facilitates curriculum internationalization while

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developing students' intercultural competencies, ensuring that all students, not just those participating in study abroad programs, gain international experience. This approach fosters inclusivity and allows students to engage with peers from diverse cultural backgrounds.
Hackett et al. (2023) emphasized that COIL courses typically span from four weeks to an entire semester, involving multicultural student teams engaged in collaborative assignments, where educators play a pivotal role in designing these assignments to promote intercultural learning. Hackett et al. (2023) state that this collaboration aims to expand the student's understanding of the course content and help develop intercultural competencies. Similarly, regarding Gow (2023), COIL encourages students and teaching staff from different cultures to collaborate in class, enhancing their understanding of the subject matter while developing intercultural competencies.

The implementation of COIL offers numerous *benefits* for both students and educators. Dyshko et al. (2021) noted that COIL projects integrate distance learning while providing multilingual students real-time practice opportunities in their native language. This inclusive approach also benefits disadvantaged students who may face technological challenges.

Naicker et al. (2022) further emphasized that COIL enhances students' learning experiences by promoting collaboration, self-directed learning, and intercultural awareness. Romero-Rodríguez et al. (2023) highlighted that COIL fosters internationalization, innovation, and interdisciplinary learning, making it a valuable pedagogical tool for modern education.

Borger (2022) described COIL as an innovative and effective method that promotes students' global intercultural competence (ICC) while using digital teaching methods to create equal learning environments. Similarly, Esch et al. (2018) stated that COIL allows students to develop intercultural competencies through collaborative online communication with peers from diverse backgrounds.

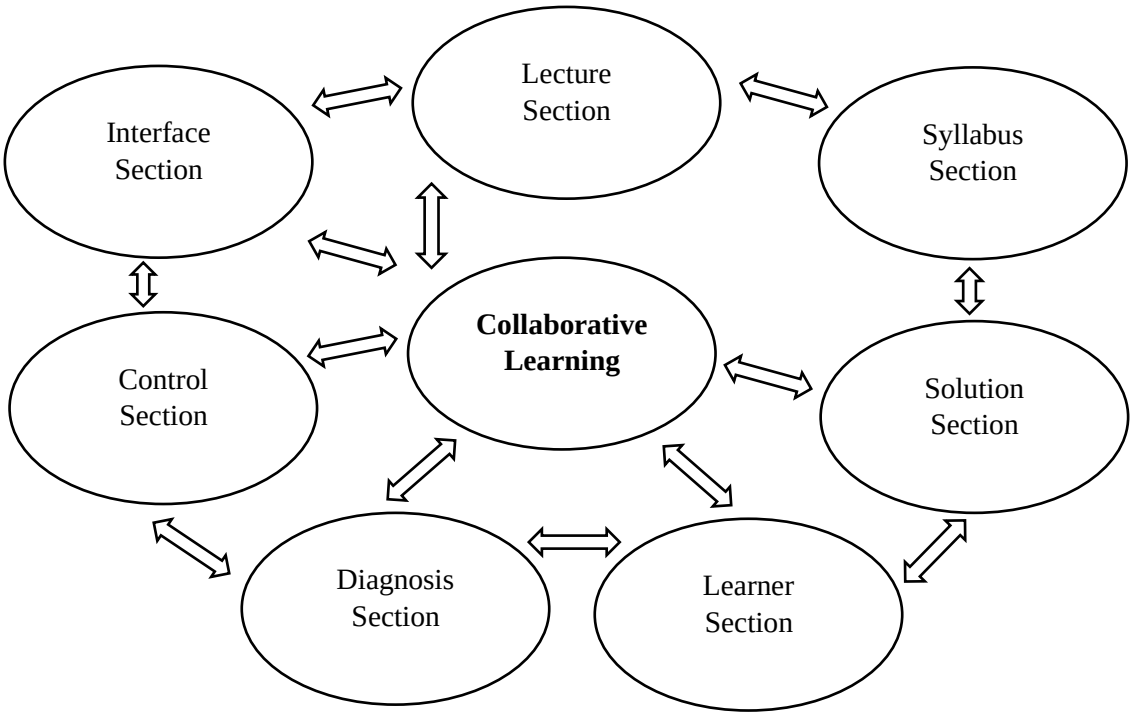


Figure 1. Collaborative learning chart

Source: Barkley et al., 2014

Despite its benefits, COIL presents several *challenges* that must be addressed for successful implementation. Stoten (2024) argued that collaborative learning can pose cognitive and social challenges, as students must

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navigate emotional and motivational factors while working together. This aligns with the control-value theory, which recognizes the emotional context of collaborative learning.

Bach and Tiel (2024) noted that digital interaction can be challenging, requiring high-quality communication among group members to ensure the success of the collaborative learning process. Moreover, Nishio et al. (2020) emphasized that COIL projects can vary in scope, ranging from short-term assignments to semester-long programs, with some involving student mobility and others being entirely online.

According to Barkley et al. (2014), collaborative learning groups are formed and developed in many ways to achieve goals where individuals get together within social contexts, cooperate to perform tasks, or join chosen committees with common interests. Ngatmini (2025) emphasizes several key aspects of *implementing* collaboration-based learning:

- educational materials developed in this program, which include the syllabus and learning implementation plan, taking into consideration both educators' knowledge and experience in related subject;
- learning methods and strategies that must be able to engage students actively, the allocation of available time, and tasks that can improve students' skills, as well as student characteristics;
- lecturers, who are directly involved in the teaching and learning process with real-world experience in good learning relevant to the demands of school-based learning quality.

Moreover, Nishio et al. (2020) emphasized that COIL projects can vary in scope, ranging from short-term assignments to semester-long programs, with some involving student mobility and others being entirely online.

Table 1. COIL definition comparison

Author	Highlight
Roqueta-Vall-llosera et al. (2024)	International online activities that allow you to support transversal competencies in diverse and multicultural environments without leaving home.
Suartama et al. (2024)	Implemented through various formal and informal activities.
Pozzi et al. (2023)	Offer collaborative learning activities to some extent in face-to-face and/or blended environments, as well as entirely online, with statistically significant differences and taking into account the methods adopted and the (technological) tools used.
Rodriguez-Salvador and Castillo-Valdez (2023)	It takes a learner-centred approach where participants work together to acquire knowledge, integrates students into an environment where each body grows through learning, and students constantly exchange knowledge to complete a common task.
Wei et al. (2024)	Students generally perceive collaboration as beneficial and prefer individual research, which indicates their beliefs do not match their learning interests.
Tongal et al. (2024)	It can be divided into two main forms: group collaborative learning and partner collaborative learning.
Ramírez-Marín et al. (2020)	Collaborative online international learning (also known as virtual exchanges, virtual mobility, or telecollaboration) varies greatly in design and implementation and research designs.
Wimpenny and Orsini-Jones (2020)	Students can gain hands-on learning through online dynamics and face-to-face interaction. Such interaction includes the development of critical digital literacy skills, acquiring interactive online communication skills, and, most importantly, an openness to the pluralism of knowledge.
Harris et al. (2021)	The essence of COIL is to rely on willing and like-minded faculty colleagues worldwide who are eager to present classes, projects, and performances together using technology.
Zhua et al. (2023)	Program organizers would focus on cultural gaps affecting these programs and provide additional opportunities for intercultural communication to address cultural gaps.

COIL also contributes to achieving sustainable development goals (SDGs), particularly in providing quality education. Quintana-Ordorika et al. (2024) highlighted that COIL not only internationalizes study programs but also trains future educators to adopt pedagogical approaches that promote global collaboration. This aligns with the goal of ensuring inclusive and equitable quality education for all learners.

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Furthermore, Sally Strand (2020) examined teachers' experiences in teaching international cooperative learning courses and found that COIL-based training programs can support institutional internationalization strategies. This preparation equips students with the skills required for 21st-century global work and citizenship.
Finally, Aškerc et al. (2023) mentioned that online learning positively impacts the social development of study skills, which improves the experience and soft competencies of other students by encouraging them to learn better, as these are essential skills in a digital and intercultural reality.

COIL is an innovative and effective learning method that promotes students' global intercultural communication competence (ICC), provides rich international experiences, and uses new digital teaching methods that promote online collaboration between students and teachers to create equal learning environments that reflect a new approach. COIL definition elements model is presented in Figure 1.

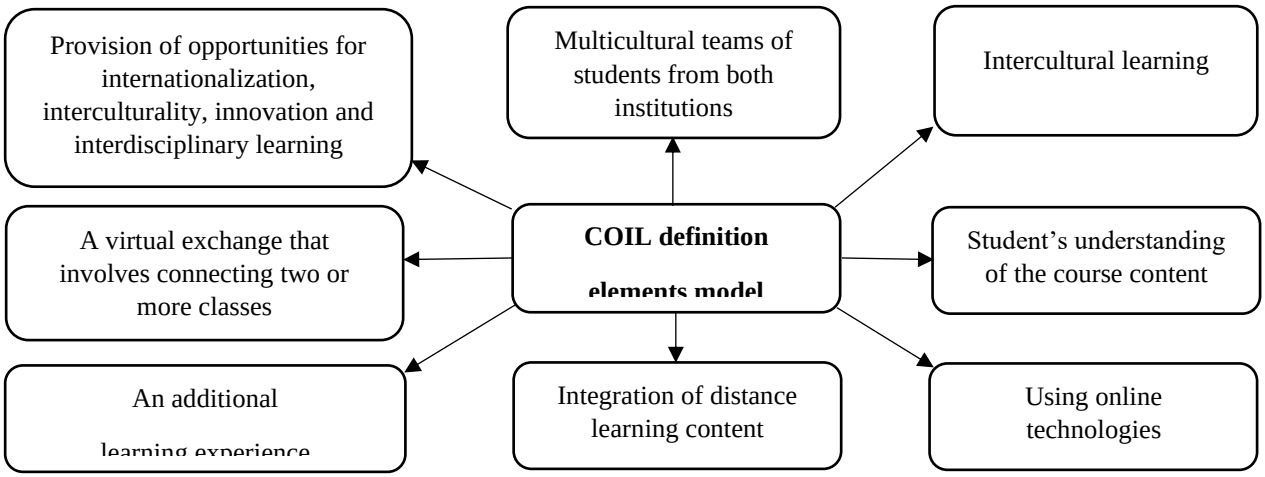


Figure 1. COIL definition elements model

Source: conducted by the authors

In summary, the researchers conclude that a COIL course, which can last from four weeks to an entire semester, typically involves multicultural teams of students from both institutions working on group assignments, with educators consciously designing assignments with intercultural learning in mind and facilitating and promoting this collaborative intercultural learning. This collaboration aims to broaden students' understanding of the course content and help develop intercultural competencies.

Online technologies have become popular in universities worldwide to help internationalize the curriculum. COIL can facilitate students' development of intercultural competencies at home. COIL projects integrate distance learning content and increase opportunities for multilingual students to practice their native language in real time. The project also provides inclusion benefits for disadvantaged students. It offers an additional learning experience where students can interact, collaborate, and take responsibility for their learning, thus expanding intercultural and international learning opportunities.

Collaborative Online International Learning is a method that brings together students and teachers from different cultures to learn, discuss, and collaborate in the classroom. It is a form of virtual exchange that involves connecting two or more classes located in different locations, led by teachers or trained facilitators and has become one of the largest virtual exchange networks in the world.

Collaborative Online International Learning (COIL) is an online technology designed to internationalize study programs and train future educators to apply a pedagogical approach to creators while involving them in international collaborative online learning programs. COIL is an experience developed by academics from various national institutions that aims to provide opportunities for internationalization, interculturality, innovation, and interdisciplinary learning.

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2.2. Collaborative online international learning tools

Collaborative Online International Learning (COIL) relies on advanced digital platforms and tools to facilitate cross-cultural collaboration, enabling students and educators to effectively engage in virtual learning environments. These tools, primarily learning management systems (LMS), provide the necessary infrastructure for course content delivery, collaborative tasks, and student progress tracking.

According to Zabukovšek et al. (2022), e-learning platforms are essential for providing digital learning content and managing the learning process. Universities often integrate multiple systems within their e-learning platforms, including world-renowned LMS platforms such as Blackboard, Canvas, Moodle, and Google Classroom. Of these platforms, Moodle and Canvas stand out as free, open-source systems, making them particularly accessible to educational institutions worldwide.

Moodle is one of the most widely adopted LMS platforms globally. Somova and Gachkova (2022) highlight that Moodle operates in more than 200 countries, is installed on over 170,000 devices, and supports more than 30 million courses for approximately 250 million users. Built on pedagogical principles, Moodle is employed for blended learning, distance learning, flipped classrooms, and other e-learning formats in academic and corporate settings (Sternad Zabukovšek et al., 2022).

The effectiveness of COIL initiatives heavily depends on the design and relevance of the platforms used. Botero-Gómez et al. (2023) argue that creating platforms with relevant content ensures accurate information dissemination and enhances student motivation. Moreover, platforms should incorporate systems for institutional tracking to facilitate continuous improvement. Well-designed LMS platforms enable institutions to deliver specialized training to diverse populations and foster collaborative networks, allowing researchers and educators to exchange insights and broaden their understanding of virtual learning applications.

LMS platforms support various pedagogical activities, enabling individual and collaborative learning. Mikroyannidis et al. (2023) emphasize that these systems allow educators to design, deliver, and assess diverse educational activities while tracking learners' progress. In addition, Nguyen et al. (2024) stress the importance of collaborative learning environments within smart educational ecosystems, where LMS platforms play a central role.

Specific tools such as Padlet also enhance collaborative learning experiences. Lee et al. (2024) demonstrate how Padlet's canvas layout can be employed to organize courses, thereby increasing student engagement and interaction with instructors. Similarly, Ota and Murakami-Suzuki (2022) highlight the value of online problem-based learning (PBL) skill sets, particularly for science and engineering students at technical universities in Japan. These skill sets support collaborative problem-solving while promoting the development of critical thinking and technical competencies.

The integration of COIL tools not only facilitates content delivery but also enhances skill development. Simões and Sangiamchit (2023) examined the effectiveness of virtual global learning approaches, finding that students perceived significant improvements in their skill sets through COIL-based activities. Furthermore, Chernova et al. (2024) underscore the importance of pedagogical processes rooted in sociocultural theory, where virtual platforms provide visibility, structure, and logic to learning activities.

In conclusion, COIL tools encompass a range of online platforms designed to deliver digital learning content, manage the learning process, and facilitate collaborative learning. Platforms like Blackboard, Canvas, Moodle, and Google Classroom form the backbone of COIL initiatives, enabling educators to design engaging, student-centered activities. Well-structured platforms ensure appropriate training and inclusivity, empowering institutions to extend educational opportunities globally. COIL tools play a pivotal role in advancing cross-cultural, internationalized learning experiences by fostering collaborative networks and providing pedagogically sound environments.

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2.3. Learning internationalization in modern education

Learning internationalization has become an essential aspect of modern education, transforming the way students, educators, and institutions approach knowledge acquisition and dissemination. As globalization shapes societies, internationalization offers pathways for cultural exchange, pedagogical advancement, and institutional growth. This chapter explores the multifaceted nature of learning internationalization, drawing insights from recent studies and highlighting its impact on higher education.

According to Fry et al. (2024), internationalization can be categorized into critical, comparative, and comprehensive genres. Critical internationalization examines power dynamics and inequalities in global education, while comparative internationalization focuses on cross-national analyses of educational practices. Comprehensive internationalization, on the other hand, encompasses all dimensions of global engagement, including curriculum design, faculty development, and student mobility.

Perfölz and López-Varela (2022) emphasize the significance of virtual exchanges, enabling students who cannot participate in physical exchange programs to gain international experience. Through online collaboration with foreign peers and instructors, learners can develop intercultural competencies, broaden their perspectives, and enhance their academic skills without leaving their home countries.

Sá and Serpa (2020) highlight how internationalization operates across three institutional levels:

- Macro level, which includes policy-making and decision-making processes that shape international collaborations and institutional strategies.
- Meso level covers curriculum structures and institutional policies promoting cross-border learning and faculty exchange.
- Micro level, which investigates classroom-level learning processes, including internationalized course content and collaborative projects.

These levels collectively shape the global standing of higher education institutions (HEIs), influencing international rankings and funding opportunities.

Xu and Boudouaia (2023) argue that institutions embracing internationalization are more likely to adopt innovative pedagogical approaches. These changes include updated teaching methodologies, digital learning platforms, and cross-cultural course materials. Such advancements not only support internationalization but also enhance domestic learning environments by integrating global perspectives. While institutional policies often drive internationalization efforts, Bienvenido-Huerta and Rubio-Bellido (2022) note that faculty members play a crucial role in shaping international learning experiences. Educators can design new strategies for internationalization, ensuring their sustainability and continuous improvement. This is particularly relevant in postgraduate programs, where specialized content requires tailored approaches to internationalization.

Li and Xue (2022) highlight the contextual nature of internationalization, which varies based on institutional missions, programmatic frameworks, and target audiences. For example, a research-intensive university may prioritize international collaborations for academic publications, while a teaching-focused institution might emphasize student exchange programs. Zhou et al. (2024) advocate developing competitive international study programs, faculty, and disciplines. This involves designing curricula that reflect global trends, recruiting internationally experienced educators, and fostering interdisciplinary collaborations that transcend national boundaries.

Summing up the analysis of the scientific literature, learning is a never-ending process, requiring openness to new ideas and perspectives. The art of learning extends beyond memorization, involving the integration of new knowledge into existing beliefs and values. This process, known as internalization, plays a crucial role in internationalized learning environments. Internalization requires conscious effort and practice, enabling learners to better retain information, apply knowledge, and develop critical thinking and creativity. It empowers individuals to engage meaningfully with global challenges and contribute to cross-cultural understanding.

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In conclusion, learning internationalization is a dynamic and multifaceted process that enriches educational experiences at individual, institutional, and societal levels. Internationalization prepares learners to navigate an increasingly interconnected world through virtual exchanges, pedagogical innovations, faculty initiatives, and contextualized approaches. As higher education evolves, embracing internationalization will remain essential for fostering inclusive, innovative, and globally relevant learning environments.

3. Research methodology and data analysis

3.1. Research methodology

This article presents an analysis of a collaborative cross-cultural project conducted as part of the Marketing curriculum within the International Business bachelor's study program at the Faculty of Business Management of Vilniaus kolegija/Higher Education Institution (ViKo) during the spring semester of the 2023–2024 academic year. The project involved student groups from ViKo and Opole University of Technology, who engaged in a structured, four-week virtual exchange aimed at exploring potential business opportunities between Lithuania and Poland.

The primary objectives of the project were as follows:
▪ To examine main trends in each other's markets (interests, hobbies, preferred leisure activities, shopping behaviours, favourite types of food, favourite brands of clothes, technology, etc).
▪ To compare results and determine to what extent trends are similar/different.
▪ To extend the knowledge of marketing to potential global business opportunities.

Sixteen students from Vilniaus kolegija/Higher Education Institution participated in the project. They formed four groups of 3 to 5 students each and exchanged contact information with representatives from Opole University of Technology to obtain the necessary information for developing their business ideas. All participants were required to formulate specific research questions that would help address the project objectives, with each group's research focus depending on its composition and interests. The conducted research and information exchange aimed to enhance understanding of each other's markets. Based on the research findings, the teams provided suggestions for products and services that could be developed in Lithuania and Poland. As a result, Lithuanian students delivered four presentations introducing new business ideas for the Polish market in the fields of clothing, food, jewellery, and pet products.

At the end of the project, each student was required to submit a 500-word written reflection summarizing their learning experiences and business suggestions by responding to the following questions:
- What did you learn from this project?
- Analyze your interactions with the theories that you have learned.
- How will you be able to use this knowledge in the future?
- What challenges, if any, did you experience?
- Do you have anything else you would like to share?

The provided answers were used for further research when a semi-structured interview was conducted in order to discuss the deeper background of the submitted answers.

3.2. Research data analysis

The analysis of the collected data commenced with its systematic processing into a unified text document, following established qualitative analysis procedures: familiarization with the provided information, data coding, thematic review, and the integration and definition of themes (Tėlešienė, 2005). The qualitative data derived from the iterative search process comprised participants' thoughts and shared insights, supplemented by a semi-structured interview according to established guidelines.

The primary objective of the interviews was to explore key aspects, including the challenges encountered by project participants, the perceived benefits of the COIL project, and experiences related to collaboration with peers. The study sample consisted of 12 students, evenly distributed by gender (6 female and 6 male).

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Table 2 presents the main obstacles encountered by participants, categorized into three sub-categories: lack of information, communication difficulties, and role responsibilities.

Table 2. Challenges faced by project participants

Category	Sub-category	Empirical study statements
Challenges faced by project participants	Lack of information	"COIL assignment was a really rewarding experience, but it also brought some challenges. I needed to adapt to a different work style, which was a bit challenging. There was also a lack of information on how exactly we should implement this project" (I1); "The only problem for me was the lack of information from Polish students about the market in their country. To complete the work, our team had to search for information independently. Perhaps this was influenced by the fact that the Polish students did not understand the task correctly at first" (I5).
	Communication	"There were also other small challenging parts like lack of motivation, but clear communication between both teams and thorough planning helped to overcome them" (I3); "I think we should have been more courageous in communicating with Polish students and asking them for help on certain issues about their market. Working on international projects can bring a wide range of benefits that can be used in the future" (I10); "The biggest challenge in the project was communication with students from Poland; it was difficult for us to communicate; we often did not get answers to the questions we asked, and it took a long time until, in the end, we managed to contact them. For these reasons, another significant challenge immediately followed - to find information about the specific shopping habits of that country. Still, everything was done, although it took a lot of time" (I11).
	Responsibilities	"The biggest challenge that we faced as a team was a lack of thorough understanding of what needs to be done and how it should be done. We also encountered a problem of not agreeing on who was responsible for which part of the project, which took us some time to resolve. Since we just met our Polish and Portuguese groupmates, it is natural that some confusion and misunderstandings appear. At last, once we figured out our roles, we started working like a well-oiled machine" (I12).

Despite the challenges, participants reported several benefits, categorized into improved skills, strong international relationships, and increased flexibility. Table 3 outlines these advantages.

Table 3. Benefits of the COIL project for participants

Category	Sub-category	Empirical study statements
Benefits of the COIL project for participants	Improved skills	"This assignment was a beneficial opportunity to learn new or improve existing skills. The most important thing I improved was teamwork skills. My team and I had to interact with the Polish students to find out what work style would work best for both of our teams. We understood the importance of inclusion and effective team dynamics in achieving project goals" (I1); "This assignment was a very useful opportunity to learn new or improve already existing skills. The most important thing I improved was teamwork skills. My team and I had to interact with the Polish students to determine what work style would work best for our teams. We understood the importance of inclusion and effective team dynamics in achieving project goals. So, with good teamwork skills between both teams, the entire project work was not that difficult. This assignment turned out to be a valuable, interesting and extremely rewarding experience that I think both teams enjoyed" (I3).
	Strong international relationships	"This project not only allowed us to expand our business knowledge but also forged strong international relationships. Collaborating with representatives from various cultures enriched our business analysis and opened up possibilities for future careers, studies, and personal development. From this experience, I learned not only how to analyze business opportunities and work on project tasks with international students but also to appreciate the diversity and importance of cultures" (I3); "Participation in this project deepened my understanding of the Polish market and unveiled its various facets, strengths, and weaknesses. Moreover, it provided a great opportunity to comprehend Poland's marketing structures and methodologies. Understanding the peculiarities of the Polish market enables me to

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		develop my business more effectively and adapt to the unique market needs. This is a crucial advantage when aiming to succeed in international markets" (I2); These lessons are very valuable for me. They have taught me to be more open to different ideas and careful about talking with people from different parts of the world. This experience has given me confidence and skills that I can use in any job where I have to work with a team, especially in international business. It's clear to me now that understanding different cultures and how businesses work in other countries is very important in today's world" (I6); "The lessons learned will undoubtedly shape future endeavours in understanding consumer dynamics and market trends" (I9); "Another useful thing was an opportunity to find out the new market, to monitor and analyze the online store pages of the Polish animal shop, and to broaden its knowledge. However, cooperation with people from different cultures brings long-term benefits in generating inputs and viewing certain things differently. This knowledge will be useful in the future, as this work has provided general sophistication. I had to take an interest in the Polish animal shop market. I became more aware of the Lithuanian market as part of the information needed to be provided to students from abroad. Participation in international projects brings some experience without any need for physical travel" (I10); "The project was beneficial, and I would like to implement more such projects in other countries. It would be nice not only to get to know different markets but also to get to know and try to work with students from other countries and share experiences and insights" (I11); "This project was a great way for me and my friends to get to know Poland, its culture, and its economic and financial intricacies. I learned a lot about Lithuania's and Poland's food markets and the different factors that affect them. My friends and I did a lot of research on how Lithuania's food market is affected by inflation, import and export price fluctuations, the retail sector, Lithuania's economic growth, unemployment rates and changes in consumer spending power. This allowed us to form an impression of the overall state of the current food market. Also, I learned about Lithuania's food market trends and consumer preferences, which helped me get a general view of what influences have a significant impact on preferences for food products and places to eat or to buy products from" (I12).
	Flexibility	"This collaboration also made it clear how crucial it is to be open-minded and flexible. In business, like in life, things often don't go as planned. We had to adapt quickly when we didn't understand each other or found that our usual ways of doing things didn't work. We learned to find common ground, create new solutions together, and always look for the best outcome for our project. These lessons are very valuable for me. They have taught me to be more open to different ideas and careful about talking with people from around the world. This experience has given me confidence and skills that I can use in any job with a team, especially in international business. It's clear to me now that understanding different cultures and how businesses work in other countries is very important in today's world" (I12).

Collaboration with colleagues was another crucial aspect of the project. Table 4 presents the main themes: skill improvement, understanding cultural interaction, and effective information sharing.

Table 4. Collaborating with colleagues

Category	Sub-category	Empirical study statements
Collaborating with colleagues	Improve skills	"I had never done this type of project before, so I learned a lot from it. I learned what it means to do a project with students from different countries, in my case, with Polish students. This assignment helped me improve some valuable and important skills such as English, communication, time management, adaptability and teamwork" (I1).
	Understanding the importance of interaction between different cultures in companies	"Collaborating with colleagues from Poland and Portugal enriched my business knowledge and helped me understand the importance of interaction between different cultures in companies. It was an exceptional experience that allowed me to broaden my horizons and encouraged exploring various business opportunities. This international team became a learning environment and a circle of friends with whom we could share ideas and experiences even after the project's completion. This experience strengthened my belief that teams with diverse cultures are a powerful engine for business innovation and success" (I2);

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		"The COIL task was very interesting, but also a bit challenging. I had never done this project before and learned much from it. I learned what it means to do a project with students from different countries, in my case, with Polish students. This assignment helped me improve some very valuable and important skills such as English, communication, time management, adaptability and teamwork" (I3); "I gained a lot of experience working in a group with students from Poland on a COIL assignment. It was an interesting project; we learned a lot of interesting things about jewellery in our countries and exchanged information on the subject" (I5); "We communicated with the other team through the messenger app, which was the most convenient way for everyone to communicate. We agreed to help each other to find information in our countries first, for example the Lithuanian group searched for the Lithuanian clothing market, the Polish group searched for Poland's clothing market, we wrote down the most necessary points and sent all the useful information to the other group" (I12); "International business consists of many different things, but one of them is cooperation with various foreign countries, which allows us to expand our horizons and to learn about different business models and cultures. Knowing the foreign market is good for anyone who wants to associate their life with international business and have good overall sophistication. I have been involved in the COIL project with students at the Opole University of Technology in Poland. The theme of my Lithuanian team was animal shops, their goods and services" (I10); "Overall, it was a pleasure to work with international students, as they seemed to be nice, smart and hard-working people. I'd say these international projects are a good way for students to learn to work with people from different cultures. And it helps them build their communication and language skills" (I11).
	Sharing information	"From this experience, I learned how important it is to be flexible and to communicate well when working with people from different cultures. We had to find ways to understand each other despite receiving different instructions. This taught me to be open-minded and adaptable. I learned from our lessons that knowing how to manage a project, communicate effectively, and be gentle with different cultures was important. These ideas helped us figure out how to deal with the challenges and make the project better. They also showed that we need clear ways to talk and agreed-upon steps for our work" (I8).

The project facilitated cross-cultural collaboration, enhancing students' understanding of international market dynamics and consumer behaviour. It also provided practical experience in applying marketing theories to real-world scenarios. The students' reflections further contributed to ongoing research on cross-border business development and international marketing education.

Ultimately, this collaborative project demonstrated the value of experiential learning in higher education, equipping students with the skills and insights needed to navigate the complexities of global business environments.

Conclusions

This study contributes to the existing body of knowledge regarding Collaborative Online International Learning (COIL) by examining its practical application within the context of Lithuanian higher education. The findings reveal that COIL is a useful pedagogical approach for enhancing international collaboration and cross-cultural learning opportunities among students. By integrating online technologies, COIL facilitates virtual exchanges between multicultural student teams, typically engaged in group assignments designed with intercultural learning outcomes in mind.

The study highlights several key benefits associated with COIL implementation. Firstly, COIL promotes the development of intercultural competencies without needing physical mobility, allowing students to engage in international learning experiences from their home institutions. This approach enhances students' understanding of course content while fostering cultural awareness and communication skills. Additionally, COIL projects provide a platform for multilingual students to practice their native languages in real time, further enriching their educational experience. Moreover, COIL offers significant inclusion benefits for

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disadvantaged students by providing equitable access to international collaboration opportunities. The virtual nature of COIL projects ensures that students from diverse backgrounds can participate, interact, and take responsibility for their learning. This inclusive approach expands intercultural and international learning opportunities, aligning with the broader goals of curriculum internationalization within higher education.

The findings also underscore the importance of educator involvement in the COIL process. Educators play a crucial role in designing and facilitating assignments that promote collaborative intercultural learning. Their efforts ensure that students not only achieve academic goals but also develop essential global competencies required in an increasingly interconnected world. A notable example of COIL implementation is the collaborative project between Vilniaus kolegija/Higher Education Institution and Opole University of Technology. This project engaged teachers and students from different geographical, linguistic, and cultural backgrounds in collaborative teaching and learning using online communication tools. The study revealed that while students encountered challenges such as language barriers, task formulation, and direct communication between Polish and Lithuanian participants, the project ultimately proved valuable.

The most significant improvement reported by students was the development of teamwork skills. Participants had to collaborate closely with peers from Poland to determine effective work styles that suited both teams. Additionally, the project helped students enhance other essential skills, including English proficiency, communication, time management, adaptability, and collaborative problem-solving. These findings further emphasize the potential of COIL initiatives to equip students with critical skills necessary for success in an increasingly interconnected global environment.

COIL tools encompass a range of online platforms designed to deliver digital learning content, manage the learning process, and facilitate collaborative learning. Platforms like Blackboard, Canvas, Moodle, and Google Classroom form the backbone of COIL initiatives, enabling educators to design engaging, student-centered activities. Well-structured platforms ensure appropriate training and inclusivity, empowering institutions to extend educational opportunities globally. COIL tools play a pivotal role in advancing cross-cultural, internationalized learning experiences by fostering collaborative networks and providing pedagogically sound environments.

In conclusion, learning internationalization is a dynamic and multifaceted process that enriches educational experiences at individual, institutional, and societal levels. Internationalization prepares learners to navigate an increasingly interconnected world through virtual exchanges, pedagogical innovations, faculty initiatives, and contextualized approaches. As higher education evolves, embracing internationalization will remain essential for fostering inclusive, innovative, and globally relevant learning environments.

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THE ROLE AND INFLUENCE OF THE CONSPIRATORIAL NARRATIVE ON THE ACCEPTANCE OF CONSPIRACY THEORIES*

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Abstract: Conspiracy theories have received considerable attention in recent times. Some people consider them the best possible explanations for certain significant social events and believe them more than official reports or explanations. This article, therefore, examines the factors influencing the acceptance of conspiracy theories, paying particular attention to the conspiratorial narrative and the influence of information ambiguity on their acceptance. Based on theoretical foundations, it analyses the relationship between conspiratorial thinking, emotional factors and distrust of official sources, authorities and institutions. The results suggest that information ambiguity is not the primary factor influencing belief in conspiracy theories, but rather the personality predispositions of individuals, their perceived threat and the degree of scepticism towards official explanations of certain events. Conspiracy thinking appears to be a stable cognitive schema resistant to rational counterarguments and often supported by emotional and social factors.

Keywords: conspiracy theories; conspiratorial narrative; conspiratorial thinking

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1. Introduction

Conspiracy theories are currently receiving considerable attention. Some people consider them to be the best possible explanation for specific events and believe them more than official reports or explanations. Belief in conspiracy theories has been shown to have a negative relationship with mental health and is associated with impaired well-being (Chen et al., 2020; van Prooijen et al., 2021a). It is also believed to disrupt interpersonal relationships (van Prooijen et al., 2021b). At the same time, it is quite often associated with attitudes that can have more serious health consequences. Specifically, this concerns the rejection of prevention or treatment based on

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scientific medicine (especially vaccination and chemotherapy) (Jolley & Douglas, 2014; Bertin et al., 2020) and a greater reliance on alternative medicine (Soveri et al., 2021). Belief in conspiracy theories is further associated with distrust in official institutions, science, democratic processes, and also with trivializing serious events or radicalizing attitudes (Lewandowsky et al., 2013; Jolley & Douglas, 2013; Bergmann, 2018). It is assumed that people may be more likely to accept conspiracy theories in ambiguous situations when they do not have clear, unambiguous clues to explain a significant event or when they are plagued by doubts (Douglas et al., 2017). Following this, this article aims to examine the role and influence of conspiratorial narratives on conspiratorial thinking.

2. The problem of defining the concept of conspiracy theory

The problem of researching conspiracy theories begins with the definition of the concept. The term conspiracy theory was introduced into scientific discourse by K. R. Popper (2006) when he wrote about the "conspiracy theory of society". Although a conspiracy is a hypothetical explanation, it is not a theory in the modern scientific sense. It is not a solidly based, consistent, organized, logically elaborated system of concepts, definitions and empirically verified hypotheses based on scientific methodology, which allows predictions of future phenomena. As we will see, they are not always logically coherent explanatory systems. Moreover, conspiracy theories are unfalsifiable. Although they provide simple explanations of phenomena (a group of powerful people is behind everything), many of them suffer from logical inconsistency. This makes it very difficult to empirically verify some conspiracy theories. For others, it is entirely impossible. They, therefore, become more of an object of belief and are essentially pseudo-theories. The definition is complicated because conspiracy theories are complex and extensive. They include theories from the completely unbelievable (e.g. about a flat Earth or reptilian domination), through the rather improbable (about September 11 as part of a US government plan), to the proven (e.g. conspiracy theories before the truth about Watergate was revealed). According to Uscinski (2019), if a conspiracy is exposed and the relevant authorities confirm that it actually occurred, then the explanation for this conspiracy ceases to be a conspiracy theory and becomes a revealed conspiracy. The Watergate affair or the Snowden case are, therefore, not de facto conspiracy theories. In other words, without secrecy, it is no longer a conspiracy theory (Bergmann, 2018). They also include more or less harmless theories (e.g. about the alleged staged deaths of celebrities such as Elvis Presley, Michael Jackson or Princess Diana, who finally wanted to live peacefully without annoying paparazzi and intrusive fans and therefore allegedly faked their deaths), then theories with serious consequences (e.g. that vaccinations cause autism or that vaccines contain nanoparticles with which governments will track us), and even theories that are classified as crimes in some countries (e.g. theories about Holocaust denial). Some conspiracy theories imitate scientific rhetoric (e.g. about so-called chemtrails, a flat Earth or that vaccinations cause autism) and others are related to esoteric, religious or medical topics (Satanists controlling the world, vaccinations cause autism). As can be seen from the examples given, individual characteristics sometimes overlap in specific conspiracy theories.

So, how do we define this concept? Conspiracy theories are most generally defined as a hypothetical explanation that considers a conspiracy to be the cause of a certain event (Dentith, 2014). So, we must first define a conspiracy so we do not go around in circles. A conspiracy is a secret arrangement between two or more actors, usually with bad intentions and illegal or otherwise dishonest purposes, such as great personal, power, political or economic gain (Uscinski, 2019). A conspiracy theory explains past, current or future events or circumstances that cite a small group of influential conspirators acting secretly for their benefit and against the common good (Uscinski, 2019).

This definition is used quite often in several studies. However, upon critical examination, we find that it also applies to potentially plausible conspiracy theories. For example, these are theories in which investigative journalists suspect politicians or other influential people of secret, self-serving and dishonest intentions, which have not yet been proven (for more details, see, e.g. Watergate). Should these real conspiracy theories also be the

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subject of research? Even though this question is rather marginal in the current professional literature, we personally consider it important. And this is because it defines the subject of study. Here, we encounter the issue of definition or, rather, demarcation. The whole situation is further complicated by the fact that the phrase conspiracy theory evokes negative (sometimes even derogatory) connotations. They are usually associated with adjectives such as naive, irrational, stupid, meaningless, absurd, paranoid, etc. Acceptance or advocacy of conspiracy theories is generally perceived as stigmatizing (Harambam, 2020). Some, especially older works, write about conspiracy theories in this vein (although not all of them are primarily offensive and normative) (e.g. Popper, 2006; Hofstadter, 1964; Moscovici, 1987).

Van Prooijen (2018) lists five necessary criteria that conspiracy theories must meet to be the centre of attention. Every conspiracy theory has a scenario (pattern) according to which everything was planned in advance. Behind everything is a sophisticated plan created and executed by a certain powerful actor (agency). The event that the conspiracy theory explains is the result of a deliberate grouping (coalitions) of several actors. If only one actor acted alone, it would no longer be a conspiracy. A coalition of several actors was formed to achieve a malicious (hostile) goal that was detrimental to society. The fact that the secret association of such actors has not been revealed so far is a consequence of continued secrecy. The basic point for the definition of conspiracy theories in research is, therefore, the maliciousness of the intention.

However, the five features mentioned do not completely solve the problem of demarcating conspiracy theories. Therefore, van Prooijen (2018) adds that the conspiracy theories that are the subject of the study proclaim a long-lasting, never-ending secrecy. We all live in constant deception and illusion and are manipulated so that we never learn the truth. This point is also called crucial by other authors (Popper, 2006; Byford, 2011; Uscinski, 2019). Real conspiracies tend to be quickly revealed. According to the mentioned authors, there is something that could be called an inverse proportion to the number of people involved, the length of time and the maliciousness of the plan. The larger the number of people involved in the conspiracy, the more malicious and harmful its alleged impact on society, and the longer the postulated conspiracy is supposed to last, the smaller the chance of its successful fulfilment. And therefore, belief in these conspiracy theories should become a subject of scientific research.

For a more precise definition, some authors (Barkun, 2003; Imhoff & Bruder, 2014; Jolley, et al. 2017) propose adding one more criterion, namely that conspiracy theories express an a priori protest/unofficial position/belief against the official explanation of an event and official institutions. Conspiracy theories appear as an alternative explanation, drawing information from alternative (not always verified or verifiable) sources. Moreover, they express distrust not only in official state authorities, scientific authorities, or mainstream media. They do not trust any official institutions. This criterion largely solves the above-mentioned dilemma of demarcation. Investigative journalists, even if they do not believe the official statement of politicians, do not show a priori distrust of the entire government apparatus (mainstream media, scientists, all politicians). They only exceptionally claim that we will never know the truth because the whole government apparatus is collectively involved in this secrecy. Without this criterion, for example, the official explanation for the events of September 11, 2001, could be a conspiracy theory. A secret group of actors devised and executed a secret, malicious plan with a political purpose to carry out a terrorist attack on the USA (Dentith, 2014, Bashmen, 2011).

Another partial solution is a rough systematization of individual conspiracy theories. The above-mentioned list of several conspiracy theories points to its need. For example, Räikkä (2009) brings a suitable categorization criterion: political versus non-political conspiracy theories. While political conspiracy theories express themselves on societal topics and concern power-political-economic issues, examples of non-political conspiracy theories are, for example, those about the alleged faked death of some famous personalities. Political conspiracy theories are then further divided into local and global, according to the geopolitical impact and seriousness of the event that the conspiracy theory wants to explain (i.e., whether it explains a local or global conspiracy or whether the causes

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and consequences of the event caused by the conspiracy were local or global). He defines the total theory as a third case of political conspiracy theory. In addition to the geopolitical scope, this also adds a historical scope. The total conspiracy theory explains almost the entire course of world history up to the present as a secret political conspiracy of a group of powerful people (Räikkä, 2009). These are "supertheories" that combine several individual conspiracy theories into one large, compact conspiracy theory (Barkun, 2003). Total theories include, for example, conspiracy theories about the Jews, the New World Order, the Bilderberger group or the Illuminati. Political conspiracy theories are the main interest of scientific research, and of these, especially global and total conspiracy theories. Most of the "plausible" conspiracy theories (theories of investigative journalists) are local or global conspiracy theories, never total ones.

3. Conspiracy theories and conspiracy narrative

What fundamentally distinguishes "plausible" conspiracy theories from the conspiratorial subculture that is the subject of research is the specific conspiratorial narrative. It is understood as the rhetorical and argumentative style that is applied in conspiracy theories. It is manifested in its full form in total conspiracy theories (Barkun, 2003; Byford, 2011).

According to Barkun (2003), the conspiratorial narrative is based on three axioms: (a) nothing happens by chance; (b) nothing is as it seems; (c) everything is connected to everything else. The central motif of conspiratorial narratives is secrecy and distrust of authority (Wood et al., 2012; Brotherton et al., 2013). A typical feature of conspiratorial narratives is that they never work with chance. Behind everything is a small, influential group (the elite) that "pulls the strings", and nothing happens without their will (Barkun, 2003). This top-secret elite stands at the top of a large pyramid controlling all spheres of human society: world events, governments and economies of individual states, the global market, religion, education, the army, the media, secret services and organized crime (Bergmann, 2018, Goertzel, 2010). Moreover, because of its power, it also has control over human lives. Because it is always a group of individuals with almost inexhaustible wealth and access to all (scientific and occult) knowledge, they have the means to implement their grand plan (world domination) and their partial goals and control everything that happens in the world. The elite implements its will with the help of a huge machinery of scientists, politicians, mainstream journalists, but also schools and official institutions. It can use not only science, scientific inventions and modern technologies but also paranormal techniques (Byford, 2011).

In this tendency to attribute all world events to a group of powerful individuals, we can detect a fundamental attribution error (Clarke, 2002) and anthropomorphism (Imhoff & Bruder 2014; Douglas et al., 2015). The conspiratorial narrative does not allow for the possibility that significant adverse events can be the product of natural or social forces or the work (result) of simple chance. It claims that they are always intentionally caused by someone (Sunstein & Vermeule, 2009). The conspiratorial narrative also assumes that major events must have a major, non-random cause (Leman & Cinnirella, 2007). Furthermore, Cubitt (1989) notes that the conspiratorial narrative exhibits an associational shift. If someone is considered a participant in the conspiracy, they are attributed very similar attributes to the elite itself. The type of elite and its power also varies depending on the type of conspiracy narrative. In local and some global conspiracy theories, it may be the government, secret services or royal family, whose power may be limited. In some global and especially total conspiracy theories, it is the global elite, i.e. the richest, most powerful people in the world with absolute power. Governments, royal families or secret services are just their puppets.

Byford (2011) believes that a key feature of the elite, its agenda and its minions is the vagueness of their definition. The elite is mysterious and exclusive, its minions are vaguely defined. These are often unidentifiable groups (CIA, Vatican, UN, Wall Street, pharmaceutical companies, multinational corporations, journalists, scientists, etc.), which can include almost anyone. However, the current conspiracy scene also accuses specific individuals, such as Bill Gates or George Soros. However, according to Byford (2011), the essential thing is that

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we almost never learn anything concrete about the activities of the elite or their minions, and we cannot even learn, because they are secret societies. This vague identification perfectly suits the secret and evil intentions postulated in conspiracy theories. Moreover, because of this uncertainty, it is always possible to discover something new, thus confirming the truth of conspiracy theories (Barkun, 2003). It is interesting to perceive some conspiracy theories' internal contradictions and inconsistencies. Although conspiracy theories claim that we will never know the truth, they declare what is said in them true. Moreover, where did they get this mostly secret information if the innermost group is strictly kept secret?

It is the secrecy of the group and its plans that allow for the vagueness of definition that allows the conspiratorial narrative (and the individual conspiracy theories based on it) to persist. Conspiracy theories have been around for ages (Byford, 2011; van Prooijen & Douglas, 2017; Butter & Knight, 2020); they appear across all cultures (Swami, 2012) and even across ideologies and political preferences (Smallpage et al., 2017; Karp et al., 2018). The reason for the universality of the concept of conspiracy theories seems to be that it is not so much the individual conspirators (i.e. the people involved in the conspiracy) or the individual conspiracy theories that matter but rather the general conspiratorial narrative that forms the basis of conspiracy theories (North, 1999).

Conspiracy theories form a simple, coherent, and resilient whole mainly because of the conspiratorial logic with which the conspiratorial narrative works. This logic could be described as follows: When we know nothing about the elite, there is something suspicious about it. There is definitely something that must be discovered. That something is precisely the evil intentions that the elite is trying to conceal. Therefore, camouflage is managed through official institutions. Information about events and the way they are transmitted to us is manipulation. Nothing is as it seems. If we want to find the truth, we must look with common sense beneath the surface of the fabricated news. And because nothing happens by chance, we find a certain pattern beneath the surface of all events in which everything is connected to everything (Ivančík & Nováková, 2023; Ivančík & Andrassy, 2024).

This logic makes the conspiratorial narrative a dogmatic, closed system of unverifiable “truths,” and individual conspiracy theories become a matter of pure faith (Barkun, 2003). Thanks to this logic (and the aforementioned vagueness), the conspiratorial narrative is, on the other hand, able to flexibly respond to any important event and turn it into a piece of a larger puzzle (Hofstadter, 1964). Thanks to this logic, cooperation between mutually incompatible groups (e.g., the CIA – the American secret service and the GRU – the Russian secret service, or the Freemasons and the Catholic Church) is also possible because, in reality, they are collaborators working for the powerful elite (Byford, 2011).

Another important feature of the conspiratorial narrative is the petitio principii (logical fallacy in the proof) – elites are evil because they have evil intentions. Thanks to these factors, almost every conspiracy theory based on the conspiratorial narrative is unfalsifiable (Clarke, 2002; Keely, 2006). Any evidence refuting the conspiracy theory is assimilated by the conspiratorial narrative as confirmation of the theory or is a priori dismissed as a ruse by the opponent (Barkun, 2003).

Byford (2011) gives an example of the defence of conspiracy theories against falsification. Because the elite has control over the dissemination of information, almost no one will learn what the elite does not want to reveal. Most of the evidence that would convict them is destroyed. So, the absence of evidence of a conspiracy can be taken as indisputable evidence of its existence. Conversely, the elite has a large number of false clues created to confuse the public so that they never learn the truth. Barkun (2003) adds in this regard that eventually everything is revealed the way the elite wants it to be revealed or for people to believe it. Therefore, people who try to refute conspiracy theories are considered part of the conspiracy machinery (Lewandowsky et al., 2015) or a blinded herd (Franks et al., 2017). These unfalsifiable conclusions likely manifest cognitive dissonance (Festinger, 1962). Awareness of logical inconsistencies and some contradictions within a particular conspiracy theory may induce a

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state of dissonance in people sympathetic to that conspiracy theory. This state may result in searching for and maintaining one's justification. This justification then reduces the unpleasant feeling of internal dissonance.

Another important feature of the conspiratorial narrative is the interest in presenting "elaborate evidence" (Hofstadter, 1964). The persuasiveness of the conspiratorial narrative lies in its quasi-skeptical (quasi-scientific, quasi-investigative/detective) rhetoric. The careful research of conspiracy theorists and the omission of important evidence during official investigations are often mentioned. Materials supporting conspiracy theories are presented as scientific. Scientific articles, papers, and studies are cited, and professional terms are used. Everything on the surface gives a solid critical impression. The conspiratorial narrative also arouses the tone of scepticism by asking questions confronting the official explanation. It thus arouses suspicion about the event and indicates a hidden "truth" that will be revealed later. However, the arguments of individual conspiracy theories are full of errors, misinterpretations and distortions of facts. Conspiracy theorists' hypotheses are invalid or unfounded, and their stance is dogmatic (Byford, 2011).

Such "careful and conscientious collection of 'evidence' immediately leads to the great leap from the undeniable to the unbelievable," in which the conspiracy theory usually leads to extraordinary conclusions (Hofstadter, 1964, p. 37). A vast amount of detailed 'evidence' is woven into a completely consistent and coherent theory that makes it seem as if "the unbelievable is the only thing to believe" (Hofstadter, 1964, p. 38). Studies have supported this reasoning by showing that people with a higher tendency to believe conspiracy theories commit gross generalization biases (Leman & Cinnirella, 2007; LeBoeuf & Norton, 2011).

Although the conspiratorial narrative imitates critical thinking and presents itself as such, it works with faulty information in addition to dogmatic (unscientific) logic. Sunstein and Vermeule (2009) call the style in which the conspiratorial narrative deals with information crippled epistemology. This is manifested in the fact that the conspiratorial narrative seeks out and prioritizes information that is considered unwarranted, rejected, refuted, or implausible. Barkun (2003) calls this type of invalid information stigmatized knowledge. The conspiratorial narrative also exaggerates unimportant details that are completely irrelevant to the resulting explanation. Keely (2006) calls this errant data.

Since these are unintended by-products of a certain activity or just the consequences of chance or coincidence, these data have not been considered in official explanations. However, since the conspiratorial narrative postulates that nothing happens by chance and everything is connected to everything, conspiracy theorists construct scenarios where these erroneous data are included. Usually, however, at the expense of other, much more substantial data. To incorporate this stigmatized knowledge and erroneous data into a compact explanation, they invent very complicated, intricate, and implausible scenarios (Sunstein & Vermeule, 2009).

The last significant element of the conspiratorial narrative is the Manichaean worldview (Moskovici, 1986). This is a black-and-white vision based on the theory of social identity, or rather on the positive differentiation of one's group. People are divided into good and bad. The bad are part of the elite or minions of the elite (out-group) and the good are simple citizens, victims of the conspiracy (in-group) (Federico et al, 2018; Jutzi et al, 2020). In particular, total conspiracy theories use the Manichaean view to describe the entire history of humanity as a global struggle between good and evil (Byford, 2011). They also assess politics through this simplified view and do not consider the complex negotiations and compromises that are typical of politics, or rather, they consider them as a product of evil or weakness (Byford, 2011; Oliver & Wood, 2014). This is what conspiracy theories have in common with populism (van Prooijen et al., 2015; Bergmann, 2018). The Manichaean view is characterized by the belief that even complex problems have simple solutions (van Prooijen et al. 2015; van Prooijen 2016).

As mentioned earlier, conspiracy theories are dogmatic. It turns out that their acceptance is often associated with confirmation bias (Modgil et al., 2021). Because it is a dogma, people often talk about belief in conspiracy

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theories. Some authors even talk about belief in conspiracy theories as a quasi-religion (Ward & Voas, 2011; Franks et al., 2013). In research, an individual's belief in conspiracy theories is operationalized by two constructs. The first is conspiracy belief, i.e., a person's belief in specific conspiracy theories. It is measured by a questionnaire containing conspiracy theories (e.g., the theory that the moon landing was actually filmed in television studios). A tricky thing about this type of measurement is the existence of several conspiracy theories related to a single event. An individual may believe in specific conspiracy theories but not in those listed in the questionnaire. The second is the more general construct of conspiracy thinking. This is the disposition to look for/see a conspiracy as the cause of every (big, significant) event. A higher tendency to believe in conspiracy theories in general as the (best) explanation for any serious events is particularly evident in people showing higher levels of this latent variable (Uscinski, 2019; Brotherton et al., 2013; Imhof, Bruder, 2014).

4. Conspiracy theory acceptance

According to Douglas (et al., 2017), previous studies show three main motives that fuel belief in conspiracy theories. Specifically, these are epistemic motives (the need to understand one's surroundings), existential (the need for safety and control of one's surroundings), and social (the need to maintain a positive image of oneself and one's social group). Conspiracy theories, through their conspiratorial narrative, saturate these motives. The success of the saturation that results in the acceptance of specific conspiracy theories depends on situational and personality characteristics. It turns out that people tend to accept conspiracy theories in situations where they are (or feel) threatened (Harambam, 2020). Conspiracy thinking is a personality characteristic (general tendency to look for a conspiracy behind significant events as the reason and cause of the emergence of a given situation). It is related to attitudes such as anomie, right-wing authoritarianism, socially dominant orientation, political cynicism, a sense of helplessness, a sense of alienation, Machiavellianism and prejudice (Abalakina-Paap et al., 1999; Imhoff & Bruder 2014; Douglas et al. 2015). However, this is likely a reciprocal influence of situational and personality characteristics. Individual personality traits will be most evident in certain situations and enable the adoption of a conspiracy theory as an individual's reaction to this situation (Bilewicz & Sedek, 2018).

According to the meaning maintenance model (Heine et al., 2006), people constantly need to understand the world in which they live. Therefore, they create mental representations of objects (people, events, etc.), which they then categorize and look for relationships between them to understand their purpose. In doing so, they make the world understandable, orderly, and predictable. These individual mental representations, which arise both as a response to the search for meaning and as a product of interpersonal discursive processes, then determine how they will perceive the world. If people's meaning is somehow threatened, disrupted, or even challenged, or if the creation of meaning is prevented, they respond by searching for and consolidating meanings in areas offered as easiest, simplest, and with which they identify. Motivated reasoning, the tendency to readily accept new information consistent with our current beliefs and critically analyze information that contradicts them (Kunda, 1990), plays a major role in seeking such alternative explanations. This style of reasoning can also serve as an attempt to avoid cognitive dissonance.

Adopting conspiracy theories seems to be a human response to the need to (re)make sense. Hofstadter (1964) came up with this idea when he argued that conspiracy ideas are rooted in a general tendency to rationalize the world and explain it using a coherent set of assumptions. According to Heider (1958), the key factor in creating this coherent set is causal attribution, which allows for a clear detection of the problem, thus making it easy to understand. The conspiratorial narrative offers this clear causal attribution through the paradigm that "behind everything important that happens in the world is a secret and evil conspiracy of a few powerful people." Van Prooijen (2011) also argues that adopting conspiracy theories is a response to the world's complexity. Conspiracy theories provide a simple explanation for complex social events that are otherwise difficult to understand (e.g., assassinations of prominent figures, infectious disease pandemics, plane crashes, or terrorist acts). Simple explanations in the form of various conspiracy theories satisfy individuals searching for meaning in events.

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Empirical research on the role of epistemic motives in the adoption of conspiracy theories is, unfortunately, rare and provides ambiguous conclusions. It has been shown that when it comes to socio-political events, people are not satisfied with chance as an explanation for these events but try to impose meaning on them by searching for patterns. They group individual events, create conditional situations from them, and search for the intentional behaviour of certain individuals. In this way, they construct a causal explanation. And this is the case even when no patterns exist in the events (Zhao et al., 2014).

The acceptance of conspiracy theories is also closely related to the search for meaningful interrelationships between unrelated stimuli through the axiom "everything is connected to everything" (Whitson et al., 2008). Conspiratorial thinking is more associated with the tendency to perceive intentionality in behaviour, even when there is none (Douglas et al., 2015), because conspiratorial thinking appears to be stronger in people who tend to search for and see meanings and patterns in the environment (Bruder et al., 2013) or in ambiguous information (van der Tempel & Alcock, 2015). Some authors mention the tendency of people with higher conspiratorial thinking to see patterns even in a completely random cluster of letters (van der Wal et al., 2018). At the same time, conspiratorial thinking is associated with hasty conclusions (Pytlik et al., 2020), with causal proportionality distortion (big events must have a big cause) (Leman & Cinnirella, 2007; LeBoeuf & Norton, 2012), which also points to an attempt to fulfil an epistemic need somehow.

It seems that by accepting conspiracy theories, people express a need to explain the unexplained or even the inexplicable. The acceptance of conspiracy theories may thus be associated with an epistemic motivation to reduce the ambiguity of the situation. While Marchlewska (et al., 2017) tested a situation where people have not explained a significant situation at all, Miller (2002) believed that what can significantly contribute to accepting conspiracy theories is, on the contrary, multiple explanations. This is especially true when there are two different official explanations, which contradict each other in some information and are presented in a short time sequence. According to him, these cause a wave of doubts and suspicions, which subsequently lead to the acceptance of the conspiracy theory. This statement is quite often cited in the works of several authors (Sunstein & Vermeule, 2009; Swami & Furnham, 2014; Douglas et al., 2017; Swami & Zahari, 2020).

Conclusions

Based on the research and analysis of factors influencing the acceptance of conspiracy theories, it can be concluded that the vagueness or ambiguity of information itself is not the primary determinant of the acceptance of conspiracy narratives. Rather, it appears that the acceptance of conspiracy theories is a complex process influenced by several factors, such as the emotional experience of the situation, the level of conspiracy thinking, and distrust of authorities and official explanations. It seems that individuals with a higher level of conspiracy thinking tend to see a conspiracy even in situations where clear evidence is lacking. This tendency is supported by their general lack of trust in authorities and institutions and their preference for intuitive, quick, and heuristic reasoning. These findings suggest that conspiracy theories are related not only to cognitive distortions but also to individuals' psychological needs, such as the need for control, meaning, and safety in ambiguous situations.

One of the main conclusions is that the acceptance of conspiracy theories may be particularly pronounced in cases where people perceive the situation as threatening or stressful. Existential factors, such as fear, a sense of threat, or a sense of helplessness, appear to be significant variables in predicting belief in conspiratorial narratives. This suggests that not only the quality or quantity of information but also emotional and social factors play a key role in the process of accepting these theories. It is also important to emphasize that although exposure to official explanations of events may, in some cases, reduce the acceptance of conspiracy theories, in individuals with a high degree of conspiracy thinking, it may have the opposite effect – strengthening their belief in

conspiratorial narratives. This finding suggests that communication and education in this area should be very sensitive and consider the individual cognitive predispositions and emotional settings of the audience.

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HUMAN CAPITAL AND ECONOMIC GROWTH IN EU COUNTRIES*

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Abstract. One of the fundamental objectives of any country is to improve its economic performance and ensure stable economic development and sustainable economic growth. Recently, human capital has become one of the most important factors in the growth of national performance, and its importance is growing in the context of the development of the digital economy. To promote economic growth, it is essential to invest in raising the level of human capital, particularly in education, health, science and research. However, it is not only the amount of these investments that is important, but also their efficient use and the government's ability to ensure favourable conditions for their long-term return. This paper aims to identify the evolution of human capital in EU countries by comparing two alternative methods, analysing its level in relation to economic growth and then identifying the dynamics of the patterns of change in these variables across member states. The research was carried out for 2013-2022 and 2023, respectively, based on statistical data from Eurostat and the United Nations Development Programme. The level of human capital was expressed using a multi-criteria method (the standardised variable method) and the Human Development Index. The position of the countries based on the value of the integral indicator calculated by the standard variable method, the HDI and the economic performance measured by the GDP indicator were compared through percentiles. A single-factor analysis of variance was used to assess the dynamics of the development of the indicators under study. The results of our research show that northern and western European countries performed better in both human capital and economic performance assessments than southern and eastern and central Europe, respectively. This is due to the different levels of investment in education, health, culture, research and development, and the different values of the outcome indicators. Sufficient investment in human capital is, therefore, essential for economic prosperity and sustainable economic growth.

Keywords: economic performance; HDI; human capital; human capital indicators; investment

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1. Introduction

Human capital is an important factor for economic growth and one of the sources of competitiveness and competitive advantage for individuals, businesses and society (Jašková, 2022). Yehorova and Drozd (2024)

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interpret human capital as a set of all knowledge, skills, abilities and experiences acquired during a person's lifetime that can be used to create additional economic value. Human capital represents the imaginary engine of an emerging economy that helps sustain the growth and development of developing and emerging countries and developed countries that want to maintain their growth momentum (Pisár, Honzová, 2024). According to Égert et al. (2022), human capital can be considered a complex phenomenon reflecting the knowledge, skills and personal characteristics that make people productive, acquired during formal and informal education. In the context of the development of the digital economy, the importance of human capital is growing, especially in terms of education and skills (Roszko-Wójtowicz et al., 2024; Mugunzva & Manchidi, 2024). As Nezhnikova (2020) states, investments in people and human capital development are key factors of modern economic growth, as they create conditions for sustainable economic growth and continuous adaptation of the socio-economic structure to new areas of scientific and technological progress.

This paper aims to identify and compare the level of human capital and economic growth in EU Member States. The multi-criteria method and the HDI indicator were used to assess the level of human capital, while the GDP per capita indicator was used to assess the economic level of the countries. Subsequently, the aim was to assess the level of human capital in relation to economic growth and to identify the dynamics of the patterns of change in these variables across EU Member States.

The novelty of the paper lies in the use of a multi-criteria method (standardised variable method) and, at the same time, the HDI indicator for a multi-faceted assessment of the level of human capital. The paper is structured as follows: in the literature review, we focus on assessing the current state of research in the field of human capital and its indicators, as well as economic growth and its interrelationship. In the next section, the research methodology is explained. Specific research results, findings, and a discussion and conclusion follow.

2. Theoretical background

The issue of human capital is receiving increasing attention, especially in the context of digitisation and automation, which are changing the requirements for jobs. Due to the rapid pace of technological development, individuals are forced to constantly adapt to the changing demands of the labour market. Human capital thus becomes a flexible element that needs to be continuously developed. According to Bąk et al. (2022), human capital as an element of intellectual capital allows, at an appropriate level, easier adaptation of society to new economic challenges and opportunities. Chernenko (2023) states that human capital is very sensitive to technological changes, macroeconomic shocks and institutional changes that directly or indirectly affect the demand and supply of skilled labour, educational strategies of the population and the structural content of competencies and skills employed in the labour market. In line with the OECD (2007), human capital is defined as the totality of human capabilities formed under the influence of upbringing and education and shaped by an individual's state of health. Widarni and Bawono (2021) classify human capital as the economic value of a worker's experience and skills, including assets such as education, training, intelligence, skills, health, etc.

Whereas physical capital played a much greater role in the past, in the 21st century, human capital is increasingly important. According to a study by Zhang (2023), although physical capital is still an essential element of economic development, its role in supporting economic growth is now less evident than that of innovative human capital. Human capital accumulation is now considered one of the key drivers of economic growth. Sobiech Pellegrini et al. (2024) predict that in most countries, the value of human capital will increase as the skills of younger age groups are significantly higher than those of older groups.

Theoretically and methodologically, there are several approaches to human capital valuation. In line with Abraham & Mallatt (2022), these can be divided into three main approaches: the indicator approach (using indicators such as school enrolment, average years of schooling or adult literacy), the cost approach (based on investment in areas that affect human capital) and the income approach (based on earnings). However, Safonov et al. (2023) report that the investment-based approach is most used in human capital assessment because it provides the most accurate quantifiable estimates of the value of human capital.

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Globally, investment in human capital development is key to sustaining the competitiveness of individuals, businesses and entire economies. Yet different countries approach this differently. According to Plaksiuk et al. (2023), human capital in the Slovak Republic is characterised by polarity; it develops asymmetrically, the dynamics of its development is closely related to the dynamics of GDP development, and its potential is not used efficiently, and therefore human capital in the Slovak Republic is not able to fully ensure a sustainable rate of economic growth of the country. However, as Hippe (2020) points out, there are large regional inequalities in human capital in European countries, which are determined on the one hand by historical development, on the other hand by the geographical location, economic level of countries, or the orientation of government policy. Even though differences in human capital levels across European countries are significant, Dańska-Borsiak (2023) finds that different regions are gradually converging in human capital levels. Still, the pace of the convergence process remains diversified. The interconnectedness of human capital levels with economic levels is also highlighted by Bedianashvili et al. (2024), who find that investment in particular areas affecting human capital levels - such as education, health care and environmental protection - leads to a healthier and better-educated population and hence higher levels of human capital, while it is also true that countries that invest more in human capital tend to have higher GDP per capita. At the same time, countries with rising GDP per capita are more likely to increase their spending on human capital. Similar conclusions are reached by Daňová & Širá (2023), who find that the human capital attributes that significantly affect economic performance and growth vary across economies and depend on the nature of these countries. According to Suparman & Muzakir (2023), higher human capital is associated with higher growth rates and leads to lower unemployment rates; thus, increasing human capital can positively affect overall economic progress. This effect is most visible in less developed countries. Wegari et al. (2023) find that if the share of health spending, education spending, and secondary school enrolment rates increase in Ethiopia, this leads to an increase in economic performance. Research by Widarni and Bawono (2021) showed that increased human capital through the education mechanism affects economic growth in Indonesia.

Yu et al. (2023), examining the relationship between human capital and economic performance in China, find that increasing education spending positively affects economic growth. It is important to use these investments efficiently and, if there is a limited supply of educational opportunities, to solve this problem. Educated individuals within the workforce drive economic growth. In contrast, a workforce with low education can slow innovation adoption, reduce the economy's adaptability to new challenges, and prolong periods of economic stagnation (Carillo, 2024). Even though most studies attribute a significant role to education in raising the level of human capital or in promoting economic growth (Mineeva, 2021; Doré & Teixeira, 2023; Tahsin, 2019), sceptical views also emerge. According to Wolf (2020), the larger, the higher education sector becomes, the less funding per student is likely to be available, which will have a significant impact on quality, and higher education will cease to be a pathway to success, nor will its positive contribution to economic growth be evident.

However, in addition to education, other aspects play an important role in developing human capital, particularly the population's health. Gumbau Albert (2021) considers population health to be one of the main components of human capital, and in his research, he assessed the impact of population health on economic growth. Zheng and Lu (2020) researched the relationship between human capital investment in health and economic growth in China, and their findings show that investment in health can increase economic growth. They argue that investments in health affect labour supply by reducing mortality and increasing life expectancy; they also affect individual labour productivity. Kuchmaeva et al. (2024) health determinants such as the availability of health services or healthy life expectancy explain inter-regional differences in human capital levels, while the availability of educational services has virtually no effect on inter-regional differentials in human capital levels. Also, Şentürk et al. (2023) state that health plays a key role in determining the quality of human capital; there is an interaction between these categories, with health and human capital level variables being important indicators for achieving sustainable development. Although health expenditure shows a causal relationship with GDP development, according to Raghupathi and Raghupathi (2020), its impact on health care in different care areas has different effects on the economy - GDP per capita is most affected by hospital expenditure, followed by personal health care expenditure. Gulcemal (2020) focused on the health status of human capital and its association with extending life expectancy at birth. He found that longer life has a clear positive impact on the economy, as it allows the labour force to stay in employment longer, reducing the financial burden of pension and health care costs for the elderly.

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Although both areas (education and health) influence human capital development, their impact may differ. For example, in the recent past, it has been severely disrupted by the COVID-19 pandemic. Alizadeh et al. (2023) report that the pandemic was the largest crisis since the Second World War, significantly affecting economies worldwide, with seven major domains negatively affected: health, social vulnerability, education, social capital, social relations, social mobility and social welfare. Other studies have also reported the negative impact of the pandemic on health and education. According to Omotayo and Ogunniyi (2024), the disruptions caused by the rapid spread of the pandemic substantially impacted health and education outcomes. Chaabouni and Mbarek (2023) find that while education and health positively affected economic growth before the COVID-19-induced crisis, this positive effect ceased after the outbreak.

Another area that is closely linked to human capital is innovation performance. On the one hand, innovation is largely the result of human creativity, ingenuity and problem-solving skills; on the other hand, innovation creates new jobs and requires new skills, thereby increasing the demand for skilled labour. Human capital influences innovation through its structural condition and, to some extent, through its quantitative condition. Li et al. (2024) find that if human capital does not reach a certain threshold in quantity, it cannot fully manifest its effectiveness, and even its lower level may hinder innovation. Atsu and Adams (2023) also point out the interconnection between the two areas, viewing the promotion of innovation as an important element for the advancement of economies, whereby the innovation capabilities of countries depend on several factors such as the quality of institutions, human capital, the financial system, among others. According to Rakhimzhanova et al. (2024), effective investment in innovation-intensive areas, such as developing and adopting new technologies or developing digital education programs, contributes to increasing competitiveness and promotes sustainable economic development. Brodny and Tutak (2024) conducted a multi-criteria human capital assessment in the EU27. They found that human capital is strongly linked to innovation and various aspects of sustainable development, including economic growth, quality of life and reduction of social inequalities, with countries with more advanced human capital, in particular, tending to have higher levels of innovation, GDP and wages.

Weckroth and Kemppainen (2016) look at human capital from a different perspective - they argue that various linkages characterise the relationship between economic and cultural development; human values do not develop in a vacuum but are the result of historical trajectories of cultural, institutional and economic development, and for this reason, human capital issues find close links with cultural development. The importance of the aspect of culture in human capital development is also highlighted by Bucci and Segre (2011), who argue that investment in culture, like other factors, is an important element of economic growth because culture generates significant economic income and is also a field that produces new ideas, which contributes to the development of human capital in society. Therefore, human capital development cannot be seen in isolation, based on education and health alone, but is also closely linked to other aspects. Cultural values shape individuals' attitudes towards education or work, influencing a society's ability to adapt to new conditions and foster innovation. Culture is important to a country's innovation output (Lee et al., 2022). Thus, innovation results from sufficient skilled, adequately educated workers and a broader cultural and institutional context that either supports or hinders its development.

In this article, we will analyse human capital development in EU countries by comparing two different assessment methods (the standardised variable method and the HDI). At the same time, we will examine its level in relation to economic growth and analyse the dynamics of changes in these variables across EU Member States. As the literature review suggests, although some studies in the field of human capital and economic performance assess entire regions (Hippe, 2020; Dańska-Borsiak, 2023), most of the existing research focuses either on a limited set of countries or on a single country (Wegari et al., 2023; Widarni & Bawono, 2021; Zheng & Lu, 2020; Bozhechkova et al., 2024, and others). In addition, the bulk of studies assess human capital only based on partial aspects or through traditional indicators such as HDI (Şentürk et al., 2023; Gulcemal, 2020; Yu et al., 2023; Tahsin, 2019, and others.) This methodological and empirical gap provides considerable scope for research that would comprehensively cover the issue.

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3. Research objective and methodology

The aim of the paper was to identify the evolution of human capital in EU countries by comparing two alternative methods, analysing its level in relation to economic growth, and then identifying the dynamics of the patterns of change in these variables across member states. The analysis was carried out for the years 2013-2022 and 2014-2023 for human capital, respectively, given the availability of key indicators, using statistical data from Eurostat and the United Nations Development Programme.

To express the level of human capital, we used the standardised variable method as well as the Human Development Index (HDI). We decided to apply the standardised variable method because of the need for a comprehensive assessment of data expressed in different units. We have used this method to express human capital in the past, but at that time, we compared only seven EU countries (Žárská & Smetanová, 2024), and one of our goals for the future was to extend the research to a larger sample of countries. The following relationships were the basis for calculating the normalised scores:

if x_j is the maximising variable: $z_{ij} = \frac{x_{ij} - \overline{x_j}}{s_j}$

if x_j is minimising variable: $z_{ij} = \frac{\overline{x_j} - x_{ij}}{s_j}$

where $\overline{x_j}$ is the arithmetic mean, s_j is the standard deviation.

We then calculated the integral index (normalised score) I_i as the arithmetic mean of the calculated normalised values. The normalised variables have a mean value equal to zero, and their standard deviation is equal to 1. The values of selected sub-indicators were included in the analysis and are shown in Table 1.

Table 1. Indicators for assessing the level of human capital in the standardised variable method

No.	Indicator	Character
1.	share of population with less than primary, primary and lower secondary education	minimising
2.	share of population with tertiary education	maximising
3.	life expectancy at birth	maximising
4.	government expenditure on health	maximising
5.	government expenditure on education	maximising
6.	government expenditure on culture	maximising
7.	gross domestic expenditure on research and development	maximising

Source: own processing

We compared the position of countries based on the value of the integral indicator calculated by the standardised variable method, both HDI and economic performance as measured by GDP, using percentiles, which allow us to quantify what percentage of values in the set are less than or equal to a given value. Specifically, we used the 33rd and 66th percentiles, which allowed us to divide countries into 3 groups:

- countries with low values (values below the 33rd percentile),
- countries with medium values (values between the 33rd and 66th percentile),
- countries with high values (values above the 66th percentile).

Through a single-factor analysis of variance, we investigated whether there were statistically significant changes in the level of human capital and GDP in the EU countries over 2013-2022, respectively. The null and alternative hypotheses were set and tested for each of the examined indicators. The results of this analysis were intended to provide information on whether the evolution of the variables under study in the EU countries is relatively stable or whether there are more significant fluctuations in the level of human capital and GDP.

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4. Results

As a first step in the analysis of human capital development, we calculated the average value of the integral indicator (normalised score) over the entire observation period. We displayed the results in a bar chart (Figure 1), which allowed us to visually compare the level of human capital between EU countries or to capture what level of human capital each country exhibits compared to the average.

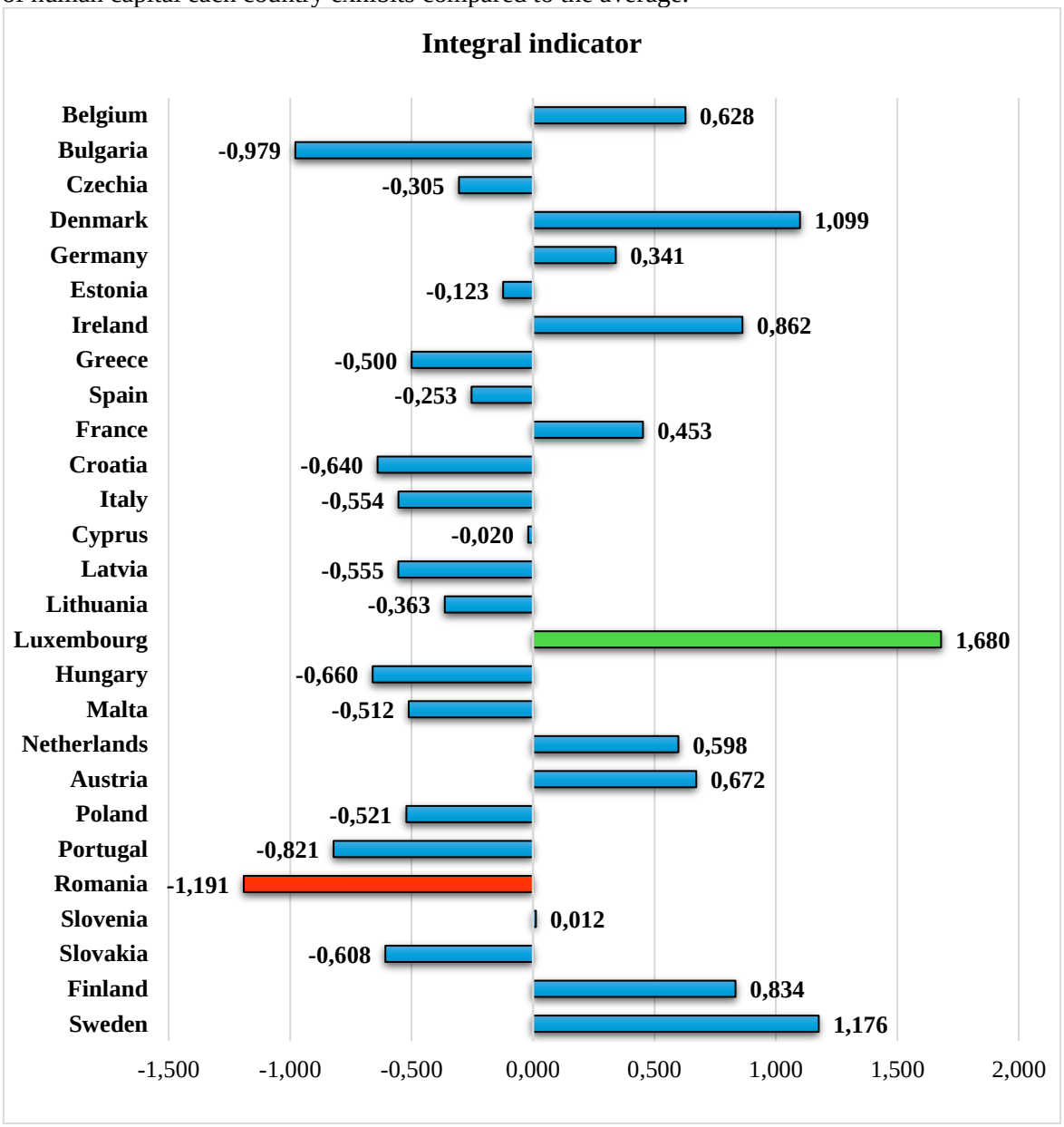


Figure 1. Human capital - average value of the standardised score for 2013-2022
Source: Eurostat, own calculating

The values shown in the graph are a dimensionless number resulting from a comparison of seven areas affecting the level of human capital in all 27 EU countries. The values shown are positive or negative depending on how each country scores compared to the average. As the scores are expressed as deviations from the EU average, this makes it possible to clearly identify countries with above- or below-average human capital development. Out of the 27 EU countries, 11 showed positive values, and the remaining 16 showed negative values. The highest value of the integral indicator (1.680) and, thus, the highest level of human capital was recorded in Luxembourg, significantly outperforming the remaining countries. Significantly above-average scores of over 1 were also reported by Sweden (1.176) and Denmark (1.099), which, although lagging Luxembourg in the

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ranking, still significantly outperformed the remaining 24 EU countries. It can be concluded that these countries have the best conditions for the development of human capital within the EU countries, investing heavily in its development, which is also reflected in their position within the result indicators. The relatively high share of the population with less than secondary education in countries with high human capital scores, especially Luxembourg and Denmark, is somewhat surprising. This phenomenon would require further analysis to identify its causes and consequences. This is an indicator where Sweden scores only slightly above average, and Luxembourg and Denmark are even below average. Countries with a positive overall value for the integral indicator also included Ireland (0.862), Finland (0.834), Austria (0.672), Belgium (0.628), the Netherlands (0.598), France (0.453) and Germany (0.341). Slovenia (0.012) also showed a very low but still positive value.

These countries are characterised by relatively high levels of education, longer life expectancy, and relatively significant investments in education, health, culture and research. The other countries surveyed lag the average in terms of conditions for human capital development. However, we consider it necessary to point out that a negative score is not indicative of the absolute level of human capital but of its relative level compared to the EU average. Thus, countries with lower scores do not necessarily underperform in all areas of human capital development but, on the contrary, may perform relatively well in some areas.

For example, Italy and Malta have the longest life expectancy at birth among all EU countries, while Lithuania, Cyprus and Estonia have a high share of tertiary-educated population. Lithuania, Poland and Slovakia have the lowest proportions with less than primary, primary and lower secondary education. Looking at the value of the integral indicator, Cyprus (-0.020) and Estonia (-0.123) are slightly below average, with the potential to improve in the relatively short term. Several other countries show more significant deficits in human capital levels, such as Spain (-0.253), Czech Republic (-0.305), Lithuania (-0.363), Greece (-0.500), Malta (-0.512), Poland (-0.521), Italy (-0.544), Latvia (-0.555), Slovakia (-0.608), Croatia (-0.640) and Hungary (-0.660). Although these countries show satisfactory results in some sub-areas, they should pay more attention to human capital development in all its aspects. Portugal (-0.821), Bulgaria (-0.979) and Romania (-1.191) show the lowest negative scores, with Romania being the only one to score below -1, indicating a significant lag for the rest of the EU in human capital development. These countries will face the biggest challenges in the future if they want to gradually catch up with the rest.

We divided the values of the integral indicator in the EU countries into 3 groups through the 33rd and 66th percentiles and applied the same procedure to the HDI, which allowed us to compare the results obtained using the standardised variable method with the HDI values.

The aim was to find out whether different methodological approaches to human capital assessment yield the same or similar results or whether there are more significant differences when the level of human capital is expressed in different ways. This comparison (Table 2) makes it possible to assess the extent to which the results are influenced by the choice of methodology and indicators used to measure human capital. It also provides a more detailed insight into whether the standardised variable method is an appropriate complementary indicator to traditional ways of expressing human capital, such as the HDI.

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Table 2. Distribution of EU countries by level of human capital

Percentile	HDI		Integral indicator of human capital	
	HDI value	Countries	Integral indicator values	Countries
0.33	HDI < 0.875	Bulgaria, Croatia, Lithuania, Latvia, Hungary, Poland, Portugal, Romania, Slovakia	I_i < - 0.516	Bulgaria, Croatia, Latvia, Hungary, Poland, Portugal, Slovakia, Romania, Italy
0.66	0,875 ≤ HDI ≤ 0.901	Cyprus, Czechia, Estonia, France, Greece, Malta, Slovenia, Spain, Italy	-0,516 ≤ I_i≤ 0.359	Cyprus, Czechia, Estonia, Greece, Lithuania, Malta, Germany, Slovenia, Spain
1	HDI > 0.901	Belgium, Denmark, Finland, Netherlands, Ireland, Luxembourg, Germany, Austria, Sweden	I_i > 0.359	Belgium, Denmark, Finland, France, Netherlands, Ireland, Luxembourg, Austria, Sweden

Source: own calculating

The table below compares the countries of the European Union based on two different methods of assessing the level of human capital. This makes it possible to analyse their degree of consistency and to identify possible differences depending on the indicators used. According to the UNDP (2024), the HDI is influenced by life expectancy at birth, years of schooling for adults aged 25 and over, expected years of education for children, and the gross national income per capita. In contrast to the HDI, the integral indicator reflects government spending on several key areas affecting human capital development. However, like the HDI, it includes outcome indicators on health and education. Countries with low HDI human capital scores include Bulgaria, Croatia, Hungary, Latvia, Lithuania, Poland, Portugal, Romania and Slovakia. According to the standardised variable method, this is the same group of countries, except for Lithuania, with Italy in this category instead. This discrepancy may indicate that although Italy achieves a relatively higher HDI due to its higher economic level or longer life expectancy, its lower level of public investment in areas important for human capital development has resulted in a relatively lower ranking in the normalised score. In the context of historical development, it can be noted that the group with low scores mainly includes post-communist countries. The countries with medium HDI human capital scores include Slovenia, the Czech Republic, Estonia, Greece, Spain, France, Italy, Cyprus and Malta. We find the Czech Republic, Greece, Germany, Estonia, Spain, Cyprus, Lithuania, Malta and Slovenia using the normalised score. There is, therefore, some inconsistency between the chosen assessment methods. The fact that Germany has a high HDI but is only in the middle group in the integral indicator may indicate lower spending in areas important for human capital development compared to Northern European countries and lower values for the outcome indicators. The countries with high levels of human capital in the HDI include Denmark, Germany, Ireland, Luxembourg, the Netherlands, Austria, Belgium, Finland and Sweden. The countries in the standardised score group are Austria, Belgium, Denmark, Ireland, France, Luxembourg, the Netherlands, Finland and Sweden. Thus, according to the HDI, Germany belongs to the group of countries with a high level of human capital. Still, according to the normalised score, it belongs only to the group of countries with a medium value. In contrast, Belgium and France, which are medium according to the HDI, are high according to the normalised score, indicating higher investment in human capital, as the normalised score was largely based on a cost approach.

The two methods of human capital assessment produce consistent results, and there is considerable overlap but no complete overlap. Countries with high HDI may have relatively lower spending on human capital, resulting in a lower value of the integral indicator there, as 4 of the 7 sub-indicators on which the calculation of the normalised score was based were based on the level of spending. Conversely, countries with lower HDI may record higher human capital expenditure. In addition, high government spending on education and a relatively high share of the population with tertiary education do not necessarily imply a high level of human capital, especially if the country also has a high share of the population with low educational attainment, which may

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negatively affect the final score. Based on the findings, it can be concluded that the choice of methodology and indicators may influence the assessment of human capital levels. Still, given the relatively consistent results, the standardised variable method may be a suitable complementary method to traditional methods such as the HDI.

In the next step, we also divided countries into 3 groups based on the level of GDP per capita in 2014-2023 (Table 3). We compared the results with the previous division of countries by human capital level to identify correlations between these variables. The intention was to see whether higher levels of human capital in EU countries are associated with higher economic performance in those countries or whether there are exceptions that would suggest that the impact of human capital on economic growth is not clearly evident and that economic growth is more dependent on other factors.

Table 3. Distribution of EU countries by level of GDP per capita

Percentile	GDP	
	GDP value	**Countries**
0.33	GDP <18 957	Bulgaria, Greece, Croatia, Latvia, Lithuania, Hungary, Poland, Romania, Slovakia
0.66	18957 ≤ GDP ≤ 36567	Czechia, Estonia, Spain, France, Italy, Cyprus, Malta, Portugal, Slovenia
1	GDP > 36 567	Belgium, Denmark, Germany, Ireland, Luxembourg, Netherlands, Austria, Finland, Sweden

Source: own calculating

The low-GDP countries are Bulgaria, Croatia, Greece, Hungary, Latvia, Lithuania, Poland, Romania and Slovakia. Most of these countries fall into low HDI and standardised human capital score categories. The exception is Greece, which is in the middle category for both HDI and standardised scores but is one of the countries with low GDP per capita. The group of countries with medium GDP is made up of the Czech Republic, Estonia, Spain, France, Italy, Cyprus, Malta, Portugal, Slovenia and Spain. Most of these countries fall into both the medium HDI category and the medium standardised human capital score category. The exceptions are France, Portugal and Italy. France has a high normalised score, i.e. a high level of human capital. Despite being one of the economically stronger countries, Portugal shows low human capital scores in both cases. This is also the case in Italy, but only in the standardised human capital score, which, in addition to lower spending in some areas, is also because the share of the population with tertiary education is the lowest in the EU. Conversely, the share of the population with less than primary, primary and lower secondary education in Italy is among the highest in the EU. Belgium, Denmark, Germany, Ireland, Luxembourg, Luxembourg, the Netherlands, Austria, Finland and Sweden are among the most economically productive countries. Most of them also have high HDI and standardised scores, confirming the assumption that countries with developed human capital also have higher economic performance. Germany has a high GDP and HDI but a lower standardised score, probably because, although spending in each area is relatively high, it lags behind Luxembourg, Sweden or other countries.

A significant correlation exists, but not a perfect match, between GDP and HDI or the integral indicator. Countries with higher HDI and standardised scores generally tend to perform better economically, as a higher level of human capital is one of the prerequisites for ensuring economic growth. The results of both methods of human capital assessment yielded similar results. This suggests that regardless of whether the level of human capital is assessed based on outcome indicators or expenditure indicators, the resulting country classifications are broadly comparable.

The comparison showed that the Northern European countries performed best in terms of human capital and economic performance. Western European countries also performed similarly and, in some cases, maybe in the middle category when assessed by either method. Interestingly, Luxembourg and Ireland showed much higher GDP values per capita than other countries, but their HDI was similar to that of other Western European countries. Southern and Eastern European countries lag the North and West in terms of both human capital levels and economic performance, but some are gradually beginning to catch up. Therefore, it is clear from the

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above that human capital development is an important prerequisite for economic growth but is also influenced by other factors not examined here, such as historical development, economic policy, institutional environment, etc.

Since we have been able to show that the economic level of countries shows a large degree of correspondence with the level of human capital in them, we have captured the dependence between the 2 sub-indicators of human capital and the economic performance of countries in the following graph (Figure 2). Among the sub-indicators, the share of the population with tertiary education was selected for comparison, as education is considered the most important factor in human capital development. The second indicator is per capita expenditure on research and development, as this area is characterised by a high proportion of the workforce with a university degree and plays an important role in the knowledge economy. This analysis is intended to show the extent to which the educational structure of the population and investment in research and innovation affect the economic performance of individual countries.

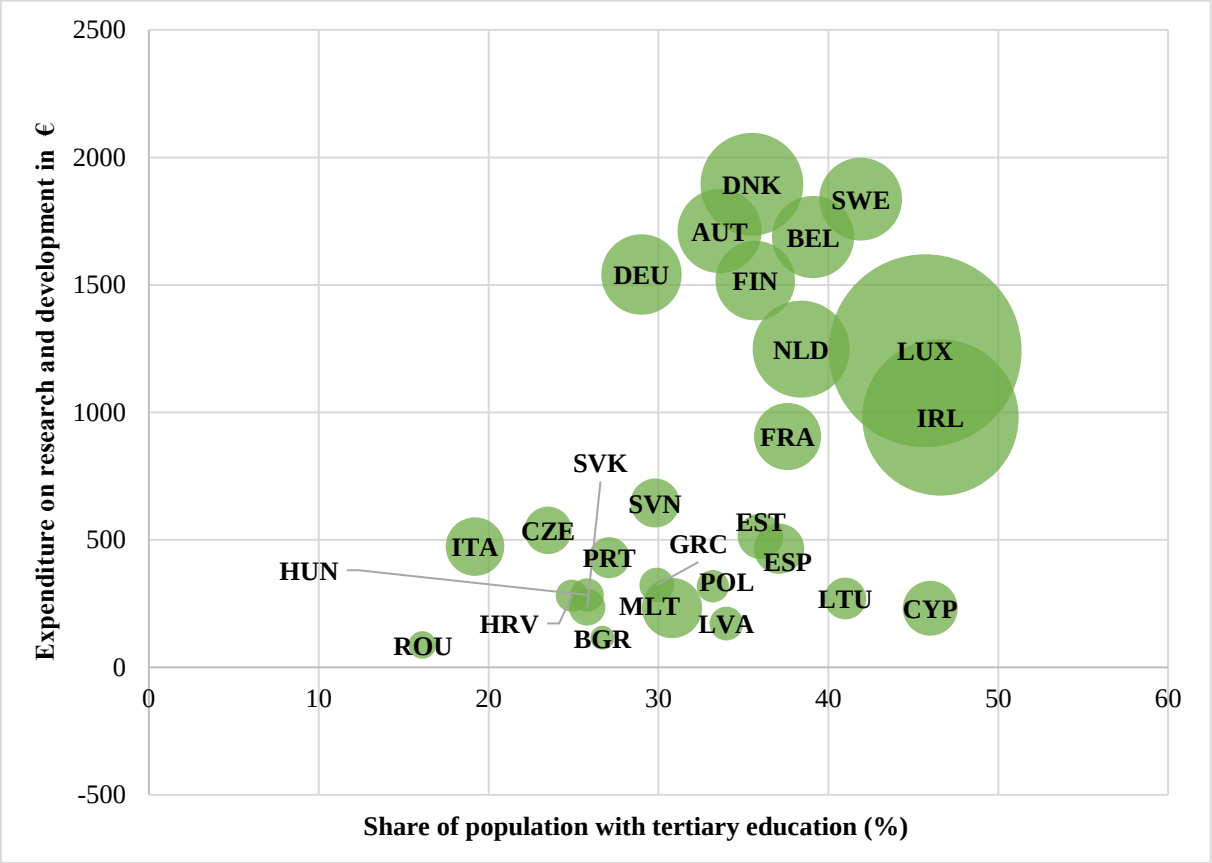


Figure 2. The relationship between the share of the population with higher education, research and development spending, and the economic performance of countries
Source: own processing

The y-axis shows how much each EU country invests in R&D per capita, the x-axis shows the share of the population with tertiary education in those countries. The bubble size represents the GDP per capita, reflecting the economic level of the countries. Countries such as Luxembourg and Ireland are characterised by high GDP per capita but are outperformed in R&D investment by countries with lower, though still relatively high, GDP per capita, such as Denmark, Sweden, Austria, Finland, Belgium, etc. These are countries which, in addition to high investment in research and relatively high GDP, also have a high share of the population with tertiary education. On the other hand, countries such as Bulgaria and Romania are at the bottom of the chart with low R&D expenditure, lower tertiary education shares and low GDP per capita. This may indicate that these countries have problems in economic development and promoting areas important for human capital development. We consider it worth noting that in addition to these countries, which show lower values for all

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three indicators, we also find at the bottom of the graph countries such as Cyprus and Lithuania, which tend to have lower GDP, underinvest in research, but have a high share of the population with tertiary education. This may suggest that although education is often considered the most important prerequisite for human capital development, it may not be sufficient to ensure economic growth and development if it is not accompanied by adequate investment in R&D and other relevant areas.

As we have observed differences in the examined indicators between countries, we decided to identify the dynamics of their development in more detail. For this purpose, we used the single-factor analysis of variance (ANOVA) method to test whether there are statistically significant changes in their levels for HDI, normalised human capital score and GDP. First, we assessed the dynamics of the evolution of the normalised score. We tested the following hypotheses:

H0: There is no statistically significant change in the level of human capital as measured by the standardised score in EU countries between 2013 and 2022.
H1: There is a statistically significant change in the level of human capital as measured by the standardised score in s EU countries between 2013 and 2022.

Table 4 captures the results of the single-factor ANOVA through which we examined the changes in the level of human capital as expressed by the normalised score in the EU countries over 2014-2023.

Table 4. ANOVA - standardised human capital score

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.192338	9	0.021371	0.037322	0.999994	1.915995
Within Groups	148.8766	260	0.572602			
Total	149.069	269				

Source: own processing

The between-group variability (0.1923) is very small compared to the overall variability (149.069), but the within-group variability (148.877) is almost identical to the overall variability. This signals that most of the variability in the data examined comes from differences between countries within years, rather than from differences between years themselves. The results of the univariate analysis of variance, where the F-statistic took on a very low value (0.0373), which is less than the critical level of significance (1.916), suggest that the differences between the mean human capital values across the years under study are not large enough to be statistically significant. The p-value is very high (0.999) relative to the significance level set ($\alpha = 0.05$), indicating that there is insufficient evidence to reject the null hypothesis. We, therefore, accept the null hypothesis and conclude that there is no statistically significant change in the level of human capital in EU countries between 2014 and 2023. Individual EU countries have maintained a stable level of human capital throughout the period under study. As we did not observe a statistically significant difference between the years, we can assume that the factors affecting human capital within the EU did not undergo substantial changes during this period.

We have also identified the dynamics of HDI development. We tested the following hypotheses:
H0: There is no statistically significant change in the level of human capital as expressed by the HDI in EU countries between 2013 and 2022.
H1: There is a statistically significant change in the level of human capital as measured by the HDI in EU countries between 2013 and 2022.

Table 5 shows the results of a single-factor ANOVA to examine the changes in the level of human capital as measured by the HDI in EU countries over the period 2013-2022.

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Table 5. ANOVA - HDI

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.012966	9	0.001441	1.002435	0.438424	1.915995
Within Groups	0.373659	260	0.001437			
Total	0.386625	269				

Source: own processing

The results show that the variability between groups (EU countries) is very small (0.013), suggesting that the differences in mean HDI values between EU countries are not statistically significant. This is confirmed by the F-value (1.002), which is lower than the critical value of F crit (1.916). However, the within-group (within-country) variability is much larger (0.374), indicating that there are within-country differences in HDI between the surveyed years. This may be due to various external factors, such as the COVID-19 pandemic or changes in policies aimed at human capital development. The p-value (0.438) is higher than the established significance level ($\alpha = 0.05$), indicating that there is insufficient evidence to reject the null hypothesis that the mean HDI values between EU countries do not differ significantly across years. Thus, even if there are differences in HDI values between EU countries, these differences are statistically considered to be random and do not show a consistent and statistically significant trend over time. The evolution of the level of human capital as measured by the HDI is, therefore, relatively stable and homogeneous across EU countries.

Having identified the dynamics of human capital development, we also identified the dynamics of GDP development. We tested the following hypotheses:
H0: There is no statistically significant change in the level of GDP in EU countries in 2014-2023.
H1: There is a statistically significant change in the level of GDP in EU countries between 2014-2023.

Table 6 shows the results of the single-factor ANOVA through which we examined the changes in the level of GDP in EU countries over the period 2014-2023.

Table 6. ANOVA - HDP

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4642681913	9	515853545.8	1.134637	0.338461	1.915995
Within Groups	118 207 000 000	260	454641879.5			
Total	1 228 511 000 00	269				

Source: own processing

The variation between EU countries (4.64 billion) is lower than the variation within countries (118.2 billion) over the years studied. The F-value (1.135) is lower than the critical value of F crit (1.916), implying that there are no statistically significant differences between EU countries in GDP over the period under study. The p-value (0.336) exceeds the established significance level ($\alpha = 0.05$), indicating insufficient statistical evidence to reject the null hypothesis. As with HDI, although there are differences in HDI values between EU countries, these are statistically considered random. Thus, economic growth in EU countries is subject to some changes over time, but these changes are not large enough to create significant differences between countries in the long run.

5. Discussion

In line with Kwon (2009), 3 approaches are used to measure human capital: revenue-based, cost-based, and outcome-based. The HDI, which we have used as one of the possible approaches, is primarily based on outcomes or indicators. The second method we used to express the level of human capital was the standardised variable method, one of the multi-criteria methods. This method integrates three outcomes and four cost indicators. The choice of the indicators included in it was based on the findings of Safonov et al. (2023), who suggest that the investment-based approach is the most commonly used in quantifying human capital, as it provides the most accurate quantifiable estimates of its value. Although multi-criteria methods allow for a more comprehensive view of human capital assessment, several authors (Ivanova & Masárová, 2018; Laifa & Benhassine, 2023)

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point out their subjectivity, as the final results may be influenced by the choice of indicators included in the assessment. Similarly, Balcerzak (2016) points out that the greatest weakness of using multi-criteria analysis is the great sensitivity of the final results to differences in the selection of potential variables. Still, despite this shortcoming, a multi-criteria analysis can show the structure and long-run path of the development of the phenomena under evaluation well. In order to minimise subjectivity, we compared the ranking of EU countries on the basis of the level of human capital as expressed by the HDI and the standardised variable method. Despite several outliers, we found a significant association between the HDI and the normalised score. While the choice of methodology and indicators may impact the assessment of human capital levels, given the relatively consistent results, the normalised score may be a suitable complementary method to the traditional ways of expressing human capital levels.

Countries in Northern and Western Europe performed better on human capital and economic performance measures than those in Southern, Eastern, and Central Europe, respectively. This is consistent with Hippe (2020), who states that there are large regional inequalities in human capital across European countries. According to Ederer et al. (2020), the level of investment in technological development and knowledge creation is too low in Central and Eastern European countries, which is reflected in low government spending on education, health, culture, as well as low spending on R&D in these countries compared to the rest of Europe. According to Minhaj & Ahmed (2023) investment and human capital development are key to achieving a favourable economic growth rate. This was confirmed as countries that fell into the higher human capital category generally also reported higher GDP. Conversely, countries that fell into the low human capital category generally reported lower GDP. Even though EU countries develop human capital to different degrees and are at different stages of economic development, Vaitkevicius et al. (2015) suggest that they may share the same pattern of human capital development. However, an examination of this issue would require a deeper analysis.

When assessing the level of human capital in individual countries, it is important to consider the specificities and differences in each area. The overall assessment may not always reflect the absolute structure of the individual factors that influence it, as some areas may be developing more dynamically, while others may be lagging behind. Thus, countries with relatively lower levels of human capital may not lag in all areas. They may even perform better than countries with the highest levels of human capital in some areas. Conversely, some countries with high human capital scores may lag more significantly in certain areas. Examples include Italy and Malta, which have the longest life expectancy at birth among all EU countries, while Lithuania, Cyprus and Estonia are among the countries with a high share of tertiary-educated residents. Conversely, some economically advanced countries such as Sweden, Denmark and Luxembourg have a relatively high share of the population with less than primary, primary and lower secondary education. However, this is often considered to be an obstacle to economic development. According to Carillo (2024), a poorly educated workforce can slow down the process of innovation adoption, which weakens the potential contribution of individuals with high levels of human capital and thus reduces the overall economic effect.

The contribution of this paper is that we have compared two different methodological approaches to measuring human capital, which provides a more comprehensive view of the issue. In addition to the traditional indicator, which is the HDI, we have used the normalised variable method to express the level of human capital, which is rarely used for this purpose but, with regard to its construction, can be a suitable complementary tool. While several studies have examined the correlation of variables through causal analysis, we used a comparative analysis based on the division of countries into three performance groups based on percentiles.

6. Conclusions

The paper aimed to identify the evolution of human capital in EU countries by comparing two alternative methods, analysing its level in relation to economic growth, and then identifying the dynamics of the patterns of change in these variables across member states. The stated objective was met. The two different methods of expressing the level of human capital (integral indicator, Human Development Index) showed consistent results. Minor variations may have been due to countries with high HDI scores having relatively lower human capital expenditure, resulting in a lower normalised score for the integral indicator. Conversely, countries with a lower HDI may have recorded higher human capital development expenditures. Thus, the methodology used to assess

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human capital, including the choice of indicators through which it is assessed, may, influence the results obtained. However, given the high degree of agreement in the classification of countries into different groups, an integral indicator based on the standardised variable method may represent a suitable complementary method to the traditional ways of expressing the level of human capital. The analysis further revealed that there is a significant relationship, but not a perfect correspondence, between economic performance as measured by GDP and the level of human capital as measured by the HDI, or integral indicator. Countries with higher HDI and higher integral indicators tend to be more economically productive, as higher levels of human capital are one of the basic prerequisites for ensuring economic growth. However, regional disparities have been observed across EU countries. Most countries in Northern and Western Europe performed better on human capital and economic performance measures than in Southern and, Eastern and Central Europe, respectively. The results of the single-factor analysis of variance showed that the level of both human capital and economic performance in the EU countries is relatively stable. Although there were changes in the HDI, normalised score or GDP values in the years under study, these changes were not large enough to be considered statistically significant. Relatively stable levels of both human capital and economic performance may be a good indicator that the most developed countries are doing well and are not experiencing a decline in these indicators. However, this may challenge the lagging countries as they should aim to converge towards the most developed countries.

In addition to the shortcoming we have previously pointed out - that the use of multi-criteria methods is associated with a significant risk of subjectivity (Balcerzak, 2016; Ivanová & Masárová, 2018; Laifa & Benhassine, 2023), we also cite other limitations that may have constrained our research. While the analysis shows a relationship between human capital levels and economic performance, it is not possible to say conclusively whether higher levels of human capital lead to higher GDP, whether richer countries have more resources to invest in human capital, or whether the effect of both variables is synchronous in the long run (Boztosun et al., 2016). The ANOVA results showed that the level of HDI, normalised score and GDP did not show statistically significant differences between years, which may indicate stability. However, this may also be due to the statistical method used, which may not be sensitive enough to capture minor differences. Another limitation of the research carried out is the selection of the research sample, which includes only the countries of the European Union. Thus, the values of the standardised human capital scores are only meaningful for comparisons between these countries and do not allow for an assessment of their position in the global context.

Given these limitations, as well as the nature of the overall research, future research could aim to improve the methodology of human capital assessment through the standardised variable method to minimise subjectivity and increase the accuracy of the results. Given the increasing importance of technological progress and digitalisation, an indicator from this area should be added to the sub-indicators used. It could also be useful to compare the results of EU countries with those of developed countries in other regions, e.g. North America. As the research has only focused on assessing the current position of countries, further research could identify the extent to which countries with lower levels of economic development and human capital can follow the progress of developed countries.

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ON SOME PROCESSES AFFECTING BELIEF IN CONSPIRACY THEORIES*

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Abstract. This study examines some of the processes influencing belief in conspiracy theories. They have gained considerable popularity among the public in recent years. They react more and more often to several socially significant events taking place around us while coming up with an alternative explanation, especially for events connected to popular personalities from the world of show business, politics, sports, etc., or concern a more significant number of people. Due to the rapidly progressing internalization, informatization, and digitalization of human society, as well as the dynamic development of information and communication technologies, systems, and means, conspiracy theories penetrate the field of mass media, especially new media. Today, social networks are the medium with the most incredible spread of conspiracy theories. It is one of the primary reasons why conspiracy theories have become the subject of our scientific interest. With the use of relevant methods of qualitative theoretical scientific research, in this work, we present our research findings and an insight into some processes affecting belief in conspiracy theories to readers from the professional and lay public.

Keywords: human society; people; events; conspiracy theories; processes; social issues

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Additional disciplines: Security

1. Introduction

In recent decades, conspiracy theories have increasingly drawn attention as a significant sociocultural phenomenon affecting public perceptions, political attitudes, and social behaviour (Douglas et al., 2019; van Prooijen & Douglas, 2018). Defined broadly as explanatory beliefs attributing events or circumstances to secret plots by powerful entities (Keeley, 1999), conspiracy theories thrive in environments of uncertainty, distrust, and rapid information dissemination (Uscinski et al., 2020). Although conspiracy theories have existed historically (Pigden, 1995), the proliferation of digital media platforms and social networks has significantly amplified their

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reach and influence (Wood & Douglas, 2013; Roberts & Risen, 2022; Shields, 2022; Cassam, 2023; Muirhead & Rosenblum, 2023; Strömbäck et al., 2024; Prims, 2024; Littrell et al., 2025; Salvati, 2025).

The rise of conspiracy theories is particularly notable following pivotal or traumatic events, such as terrorist attacks, pandemics, political upheavals, or sudden social crises (van Prooijen & Douglas, 2018). Notably, incidents such as the COVID-19 pandemic (Uscinski et al., 2020), the conflict in Ukraine, or major electoral processes have recently illustrated how rapidly conspiracy narratives can emerge and gain traction among the general population. Such theories offer simplified explanations for complex events, providing individuals with psychological comfort by reducing uncertainty and attributing clear causes to distressing phenomena (Marchlewska et al., 2017).

Research into conspiracy theories has identified several psychological, social, and cognitive factors contributing to their acceptance and proliferation. Psychological predispositions, including cognitive biases, intuitive rather than analytical reasoning (Swami et al., 2014), and a heightened need for cognitive closure (Leman & Cinnirella, 2013), significantly influence the susceptibility of individuals to conspiracy beliefs. Moreover, the interplay between media consumption patterns, political polarization, and motivated reasoning further complicates the dynamics surrounding belief formation in conspiracy theories (Miller et al., 2016; Saunders, 2017).

Despite the growing body of international literature examining the causes and consequences of conspiracy beliefs, research addressing this issue from specific regional or cultural contexts remains relatively sparse (Douglas et al., 2019). This gap in the literature highlights the need for continued investigation, particularly concerning how societal and cultural variables shape conspiracy thinking across diverse contexts. Therefore, the present study aims to provide an in-depth analysis of selected processes influencing belief in conspiracy theories, contributing to the broader discourse by examining factors relevant to both theoretical and practical implications in contemporary society.

2. Materials and Methods

2.1 Defining Conspiracy Theories and Related Concepts

Conspiracy theories are typically described as alternative explanations for significant events involving powerful actors or institutions operating in secrecy to achieve hidden goals (Keeley, 1999; Douglas et al., 2019). These theories challenge conventional narratives and often emerge in contexts of uncertainty, fear, and declining institutional trust. While such narratives have long existed – dating back to the Middle Ages – they have evolved dramatically in their content, spread, and sociopolitical function, especially with the advent of mass media and digital communication.

Unlike verified conspiracies, which involve clandestine actions that are later supported by empirical evidence (e.g., the Watergate scandal), conspiracy theories are usually speculative and rely on perceived inconsistencies, gaps in knowledge, or distrust in authority (Clarke, 2002; Barberio, 2020). This distinction is essential: while conspiracies are factual and provable, conspiracy theories often remain in the realm of suspicion and hypothesizing without clear substantiation.

Notably, the academic discussion of conspiracy theories has yielded multiple definitions emphasizing different dimensions of the phenomenon. Keeley (1999) frames conspiracy theories as explanations centred on the actions of groups operating in secret. Sunstein and Vermeule (2009) argue that such narratives often involve influential individuals who act to obscure their involvement in shaping events. A broader sociopolitical definition provided by Douglas et al. (2019) interprets conspiracy theories as efforts to attribute significant political or social outcomes to intentional manipulation by elite actors.

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Another critical conceptual distinction lies in the differentiation between "conspiracy belief," which denotes a person's acceptance of a specific theory, and "conspiracy mentality," which reflects a general disposition to interpret events through a conspiratorial lens. Imhoff and Bruder (2014) and Sutton and Douglas (2020) argue that conspiracy mentality can be considered a stable individual trait that predicts susceptibility across multiple, even contradictory, conspiracy beliefs.

Contemporary research also highlights the role of contextual triggers – such as sociopolitical crises, health emergencies, or natural disasters – as catalysts for the emergence and popularization of conspiracy theories. The COVID-19 pandemic is a contemporary case study of how global uncertainty can create fertile ground for misinformation and conspiracy narratives (Uscinski et al., 2020). From claims about the virus being manufactured in laboratories to suggestions of global elite manipulation, conspiracy theories surrounding COVID-19 reflect broader social anxieties and a need to assign agency to chaotic events.

Digital media environments further compound the problem. The Internet and social media provide unprecedented tools for rapidly disseminating and normalizing conspiratorial content, allowing these narratives to reach global audiences and foster online communities that reinforce shared beliefs (Wood & Douglas, 2013). These dynamics underscore the importance of distinguishing legitimate scepticism from conspiratorial thinking, which can erode social cohesion and public trust in science and institutions.

Ultimately, the definitional framework for understanding conspiracy theories must remain flexible to account for the fluid nature of such narratives across historical, cultural, and political settings. While unified definitions may be elusive, scholars widely agree that conspiracy theories function as explanatory frameworks that are compelling under conditions of low trust, ambiguous evidence, and high emotional arousal.

2.2 Conspiracy Beliefs and Psychological Determinants

Psychological research has consistently demonstrated that belief in conspiracy theories is associated with a variety of cognitive and motivational factors. At the core is "conspiracy thinking"—a tendency to attribute the causes of events to secret plots and hidden agendas, often by powerful actors (Imhoff & Bruder, 2014). Individuals high in conspiracy thinking are more likely to interpret ambiguous information as evidence of malevolent intent, particularly when personal or collective uncertainty is heightened and traditional explanatory frameworks seem insufficient.

One major psychological factor is the need for cognitive closure, defined as the desire for definite answers and an aversion to ambiguity (Leman & Cinnirella, 2013). Individuals with a high need for closure are more likely to gravitate toward simplified, emotionally appealing narratives that provide resolution – even at the cost of accuracy. Conspiracy theories fulfil this role by offering coherent explanations for distressing or complex events, thereby reducing psychological discomfort and uncertainty (Marchlewska et al., 2017), especially when official sources fail to provide satisfactory or timely information.

In parallel, cognitive style – particularly the balance between intuitive and analytical thinking – plays a significant role. Studies have found that individuals who rely more on intuitive thinking (fast, automatic, emotion-driven) are more prone to endorsing conspiratorial explanations, whereas those with stronger analytical reasoning abilities are more likely to reject unsupported claims (Swami et al., 2014; Pytlik et al., 2020). This suggests that strengthening analytical reasoning and critical thinking skills may reduce vulnerability to conspiracy beliefs and foster more evidence-based evaluation of complex social phenomena.

Another robust psychological mechanism involved in conspiracy belief is motivated reasoning, which refers to the selective processing of information to support existing attitudes and worldviews. In politically charged environments, people may adopt conspiracy theories that align with their ideological preferences while dismissing

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contradictory evidence (Hartman & Newmark, 2012; Enders & Smallpage, 2018). Motivated reasoning thus reinforces polarization and reduces openness to corrective information.

Moreover, feelings of powerlessness, alienation, and perceived loss of control have been strongly linked to conspiracy beliefs. When individuals feel marginalized or excluded from decision-making processes, they are more likely to believe that unseen forces exert control behind the scenes (van Prooijen, 2017). In such cases, conspiracy theories can provide explanations and a sense of agency or empowerment by identifying a perceived enemy responsible for one's misfortune.

Finally, emotional factors such as fear, anxiety, and anger also influence conspiracy belief formation. Emotional arousal can impair critical evaluation and increase susceptibility to simplistic explanations. This makes conspiracy theories particularly compelling during periods of social upheaval or collective trauma. Effective interventions must, therefore, consider the emotional and psychological needs that conspiracy theories fulfil, not merely their informational inaccuracies.

Understanding these psychological determinants is crucial for developing effective countermeasures—whether through education, communication, or policy—that aim to reduce belief in harmful conspiracy theories without alienating individuals who hold them.

2.3 Social and Cultural Factors in Conspiracy Beliefs

Social and cultural factors also play crucial roles in the proliferation and acceptance of conspiracy theories. Political polarization is a notable social factor amplifying conspiracy theory dissemination, as individuals adopt narratives aligning with ideological or partisan affiliations (van Prooijen & Douglas, 2018). Conspiracy theories involving electoral fraud, political scandals, or significant societal events often reflect ideological divisions, intensifying societal fragmentation and distrust toward democratic institutions.

Cultural contexts influence susceptibility to conspiracy theories. Communities marked by social alienation, mistrust toward authorities, or perceived powerlessness provide environments conducive to conspiracy beliefs (van Prooijen, 2017). Furthermore, media environments, particularly social media, significantly amplify conspiracy theory dissemination by facilitating rapid spread and reinforcing pre-existing beliefs through algorithmically driven content recommendations. Online echo chambers reinforce conspiratorial beliefs, reducing exposure to contradicting information (Uscinski et al., 2020).

Historical and regional contexts shape societal predispositions toward conspiracy beliefs. Societies with histories of political oppression, authoritarian regimes, or significant social disruptions frequently display elevated levels of conspiratorial thinking, driven by collective trauma and persistent distrust toward state or institutional narratives (Butter & Knight, 2020).

Conclusively, conspiracy theories represent complex phenomena shaped by intertwined psychological, social, and cultural determinants. Effective understanding requires multidisciplinary approaches integrating insights from psychology, political science, sociology, and media studies. Ongoing research should further unravel these interrelationships, offering deeper comprehension of conspiracy theories and contributing to interventions mitigating their potentially harmful social consequences.

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3. Results

3.1 Processes Affecting Belief in Conspiracy Theories

Today, it is evident that conspiracy theories have gained a more expansive space for their search, communication, and dissemination with the development of the Internet and social networks. In the current period, which is closely connected with the aggressive war led by Russia against Ukraine or with the consequences of the coronavirus pandemic, we can observe how many conspiracy theories only about the conflict in Ukraine or about the coronavirus and the COVID-19 disease have appeared during the past months. This proves that people explain events that are unexpected and crises for them using conspiracy theories and belief in them. Therefore, conspiracy theories are mainly created in connection with such events as, for example, wars, terrorist attacks, murders of important personalities, epidemics/pandemics, large-scale fires, floods, or accidents. It is precisely for this reason that it is not only interesting but also necessary to study and investigate the processes affecting belief in conspiracy theories. Many reasons contribute to a stronger belief in conspiracy theories, so in the following subsections of the article (also due to the limited space), we will focus on some of these processes.

3.2 Motivated Reasoning

Motivated reasoning is included among the psychological processes that influence whether or not a person believes in conspiracy theories. This may be because a relatively large number of conspiracy theories are created or spread about events that touch on political topics and are, therefore, political (Miller et al., 2016). Thus, motivated reasoning is most often associated with such political factors as party preferences or ideological beliefs (Miller et al., 2016; Saunders, 2017; Douglas et al., 2019). Therefore, the authors sometimes speak directly about party-motivated reasoning (for example, Smallpage et al., 2017).

Motivated reasoning affects the approach to information processing, namely in such a way that people who support different ideologies will perceive the same information differently (Douglas et al., 2019). This is because each ideology promotes specific values and attitudes. If a person supports one ideology, he supports the values associated with that ideology and thus forms his opinion on everything happening around him through ideological conviction. He processes information based on these values and views within the ideological or party preference framework. This can lead to preconceived or incorrect information, resp. To believe in conspiracy theories (Hartman & Newmark, 2012). Taber & Lodge (2006) came up with the term motivated scepticism based on the mechanism of motivated reasoning) or to accusations of manipulation (Hajdúková, 2023). As part of motivated reasoning, there is a strengthening of already-held attitudes and opinions or an idea of how a specific situation should look or be solved. However, Smallpage et al. (2017) point out that it is not a conscious process because people who make decisions in motivated reasoning do not perceive that they are processing information biased. According to these authors, this is an automatic psychological process.

However, the reactions mentioned above are not the only manifestations and consequences of motivated reasoning because, in addition to confirming one's opinions and creating ideal ideas about the functioning of the surrounding world, motivated reasoning also involves attacking the other side with different views, precisely through conspiracy theories. Such examples can be conspiracy theories that refer to the act of another political actor, most often a political opponent (Miller et al., 2016). Typically, we can observe this phenomenon in American politics between the two main camps, the Democrats and the Republicans, when these two political directions also debate whether one side is more prone to believe in conspiracy theories than the other. However, the agreement on whether there is an assumption of a higher susceptibility of a particular ideology or party to belief in conspiracy theories is not uniform, except for political extremism. Thus, even in motivated reasoning, asymmetry is discussed in connection with ideological preferences (Enders & Smallpage, 2018; van der Linden et al., 2020).

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Thinking and processing information through motivated reasoning, such as global warming, is more expected among Republican voters and supporters (Saunders, 2017). Theories about global warming and climate change can also be influenced by the ideological affiliation of scientists who confirm global warming. If such scientists are assigned to the left current, their claims can be rejected based on this information (Douglas & Sutton, 2015). However, this does not mean that the propensity for motivated reasoning does not apply to people with democratic preferences because they, too, can protect their attitudes through this psychological process (Saunders, 2017). These are primarily works and statements related to American politics that are necessary. In his work, Saunders (2017) talks about trust and, subsequently, that trust can moderate belief in the claim that global warming is a hoax. Therefore, he mentions increasing confidence as one of the options to combat such beliefs. He adds, however, that it is easier to spread false and unsubstantiated information because the opposite trend is more likely to occur. Based on the mentioned information, there is a strong connection between the processes of motivated reasoning, belief in conspiracy theories, and a person's ideological or party preferences. Van der Linden et al. (2020) also discuss the connection with denialism in these contexts, i.e., denial of scientific evidence in general, not only according to party preferences.

Conspiracy theories about Barack Obama and his place of birth are very often mentioned as a typical example of party-motivated reasoning. This is the so-called "birthers" movement (You can find more about this movement in Pham, 2015), which disputes the origin and place of birth of former US President Barack Obama. Hartman and Newmark (2012) point out that something similar was not avoided even by liberal and democratic supporters, specifically in the case of the presidency of George W. Bush when, according to the authors, there were various accusations against President Bush which were not true in all cases. Based on the logic of motivated reasoning, one might expect that people who preferred values other than President Obama's and, therefore, disagreed with him would be more likely to believe the conspiracy theories that were spread about his birthplace. And this belief in the "birthers" theory is thus supported by their different views on public events. In this case, these mainly promote conservative and republican values (Pasek et al., 2015). Pasek et al. (2015) argue that such people will perceive any further negative information about President Obama as much more credible than those who agree with and support his policies.

The link between conspiracy theories and motivated reasoning can also be seen in another type of conspiracy theory. Specifically, these are theories associated with electoral fraud (Edelson et al., 2017). Edelson et al. (2017) indicate belief in electoral fraud as a widespread consequence of conspiratorial thinking and motivated reasoning. As part of motivated reasoning, the already mentioned process occurs in which people will not believe the theories about the fraud committed by their preferred party. Instead, it will react indignantly to the party they perceive as an opponent of their political party. For example, Enders and Smallpage (2018) discuss defensive motivated reasoning, a defensive psychological information processing process. According to them, this defence process is precisely related to whether a person is exposed to a conspiracy theory that is in line with his views or, on the contrary, in line with his views.

Overall, people are more prone to fall into motivated thinking when their party is not in power or after losing elections (Duran et al., 2017). And this can lead, through motivated reasoning, to a higher belief in conspiracy theories as long as the preferred party is not in power. This may not only apply to the short post-election period and accusations of electoral fraud but to the entire period when the supported party is not in power.

At the same time, however, the negative consequences of motivated reasoning may not be present in every individual who sympathizes with an ideology or political party (Miller et al., 2016). And that's because there are different types of motivated reasoning. For example, in his work, Nir (2011) writes about different types of motivated reasoning, which differ according to their consequences in thinking through motivated reasoning. He talks, for example, about two types already mentioned by Kunda (1990: 480), namely (a) motivated reasoning to be accurate and (b) motivated reasoning with directional goals.

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Specifically, with motivated reasoning that focuses on accuracy, people may search for and believe information that does not confirm their belief or opinion. On the contrary, the so-called directional motivated reasoning is the type in which information processing occurs, as indicated above. In other words, a person with this reasoning looks for and receives information close to his opinion, thus maintaining his belief in the given question (Nir, 2011). This directionally motivated reasoning, considered a thought mechanism associated with ideological preferences, leads to belief in conspiracy theories and their spread (Craft et al., 2017). Craft et al. (2017) further investigated media literacy's influence on belief in conspiracy theory through motivated reasoning. They found that media literacy skills can positively reduce belief in conspiracy theories across the political spectrum.

3.3 The Need for Cognitive Closure

Conspiracy theories are related to the cognitive processes involved in processing the information we receive from our surroundings. Cognitive closure is cited as one of the processes that can impact belief in conspiracy theories. In the original wording, we can come across the term "need for cognitive closure" or a shortened version of the name of this psychological process "need for closure" (Leman & Cinnirella, 2013; Marchlewska et al., 2017). Specifically, cognitive closure refers to a person's motivation to process and evaluate information. People want to get answers to questions about problems that interest them. They want to avoid confusing and ambiguous information, which can lead to ambiguous conclusions regarding the events being explained. This means that people are willing to use any easily accessible information to get satisfactory final answers about an event to achieve cognitive closure. Later, however, it is difficult to leave the first answer received and re-evaluate one's opinion based on new information (Marchlewska et al., 2017).

According to Leman and Cinnirelli (2013), two tendencies occur within cognitive closure. The first tendency is that people try to get the necessary answers quickly to conclude the given event as soon as possible. The second tendency that the authors mention in their text is the tendency to freeze or retain a solution regarding the explained event. Thus, cognitive closure is needed mainly when the official explanation is insufficient or completely absent (Douglas et al., 2019). People resort to the psychological process of cognitive closure mainly because of the feeling of uncertainty that stems from this unsatisfactory or absent explanation of the event (Marchlewska et al., 2017).

However, the need for cognitive closure does not always have to be the same, as we can observe different values of the need for cognitive closure. Specifically, people may have a higher or lower level of need for closure or the need to obtain an explanation for a specific event. An increased need to conclude some explanation can occur when we are under cognitive load (Leman & Cinnirella, 2013) or time pressure (Klein & Webster, 2000). As part of the high need for cognitive closure, heuristic information processing and strengthening one's opinions occur (Leman & Cinnirella, 2013). On the contrary, with a lower need for cognitive closure, there is a more thoughtful and extensive information processing, which continues longer than those with higher values of the need for closure. At a lower need for closure, pre-held beliefs do not have as much influence as they might at a higher value (Klein & Webster 2000). For example, a characteristic such as a person's high level of responsibility can help lower the need for closure (Leman & Cinnirella, 2013). In their work, Leman and Cinnirella (2013) also investigated the link between feelings of alienation and conspiracy belief, the relationship between trust and faith in conspiracy theories, and the link between the type of evidence evaluation and the need for cognitive closure. The relationship between belief in conspiracy theories, feelings of alienation and low interpersonal trust was confirmed in their research.

In contrast to the above-described text by Leman and Cinnirella (2013), in the following research, it was assumed that the need for cognitive closure would support the explanation of events through conspiracy theories or the belief in conspiracy theories. This text also focuses on whether a conspiracy explanation for a certain event already exists and is spreading or, on the contrary, such an explanation is absent. If conspiracy theories about a particular event are widespread, the need for cognitive closure is more likely to support belief in conspiracy

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theories. On the contrary, if there is also a good official, non-conspiracy explanation for the given event, the need for cognitive closure will not significantly impact the individual's thinking. The assumption of the expected relationship between belief in conspiracy theories and cognitive closure has been confirmed in research (Marchlewska et al., 2017). However, Marchlewska et al. (2017) point out that the relationship between belief in conspiracy theories and the need for cognitive closure needs further attention, as direct evidence to confirm this relationship needs to be found. In addition to the already presented research, they also mentioned the influence of cognitive closure on relations between groups and competitive behaviour in their text. Cognitive closure can affect how people will cooperate. However, this connection means a higher need for cognitive closure is associated with higher support for competitive behaviour and the resulting competitive struggles.

Conspiracy belief can be connected with party or ideological preferences, as indicated in this article. And that through motivated reasoning and the feeling of defeat or trust in state institutions. In their work, Kossowska and van Hiel (2003) claim that sympathy for a political party or ideology also affects the process of the need for cognitive closure.

3.4 Intuitive and Analytical Thinking

One of the psychological processes often mentioned in several works precisely in connection with the fact that it can influence the belief in conspiracy theories is the style or type of thinking. For this reason, we deal with the analytical or intuitive thinking style in this subchapter. Several authors have been able to confirm in various research the claim that analytical or, conversely, intuitive thinking has an influence on whether a person believes explanations of events through conspiracy theories (Swami et al., 2014; Douglas et al., 2016; van Prooijen, 2017; Mao et al., 2020). As indicated above, we distinguish two thinking styles, namely analytical and intuitive thinking styles. Analytical thinking is described as rational, in which information is processed slowly, consciously, and deliberately. In general, one could talk about critical thinking ability in this case. On the contrary, in the case of an intuitive thinking style, the information presented to us is processed quickly and spontaneously (Dagnall et al., 2015).

Some authors talk about paradoxes concerning analytical thinking and conspiracy theories. According to them, conspiracy theories are often built on very complicated claims; therefore, belief in such theories should also include analytical information processing. However, as they point out, empirical evidence confirms that conspiracy theories are more related to an intuitive thinking style. This means that belief in conspiracy theories is, on the contrary, based on emotional, mostly negative processes, which relate to the intuitive thought process. As mentioned above, spontaneous and automatic information processing is also associated with an intuitive thinking style, like emotional states (van Prooijen & Douglas, 2018).

If a person has acquired analytical thinking skills, he will likely be able to reject false and fake news based on carefully considered information (Douglas et al., 2016). Douglas et al. (2015) also investigated whether gender affects conspiracy theory beliefs. They tried to see if it was possible that men or women would be more prone to believe in conspiracy explanations of events. Still, they found no difference between perceptions of conspiracy theories based on gender. Therefore, based on the claim that analytical thinking can reduce conspiracy beliefs, it is possible to infer that an intuitive thinking style will support belief in conspiracy theories (Pytlik et al., 2020). Swami et al. (2014) confirm this thesis in their research. Analytical thinking can help an individual find inaccuracies often occurring in conspiracy theories. The results indicated that lower analytical thinking elicited stronger belief in conspiracy theories, while stronger conspiracy thinking was associated with a more intuitive thinking style. This is also because conspiracy theories are associated with intuitive information processing since they do not require much cognitive effort and evoke emotions. For this reason, conspiracy theories can appeal more to people who want to find accurate information about a given event but lack the cognitive tools to obtain accurate information through critical and analytical thinking (Douglas et al., 2019).

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How a person thinks and processes information also affects other characteristics and factors. For example, according to the authors, a paranormal thinking style is a trait that can be linked to an analytical thinking style. Specifically, it is assumed that this is a negative relationship, which means that a higher analytical thinking ability will be associated with a lower belief in paranormal phenomena. Conversely, an intuitive way of thinking will be accompanied by a higher belief in such phenomena (Douglas et al., 2016). With motivated reasoning, the need for cognitive closure, and an intuitive thinking style, there can be a connection between ideological and party preferences (van der Linden et al., 2020). For example, Talhelm et al. (2014) investigated the relationship between party sympathies and thinking style. They found differences in thinking style based on which ideological or party line a person prefers. Specifically, they concluded that more analytical thinking led to a more liberal view of public events and vice versa.

Another factor related to the processes affecting the belief in conspiracy theories is the lower social status of a person, in which the level of education is associated with the style of thinking. The lower the level of education, the more an individual is expected to seek simple solutions and explanations for events and thus be prone to believe in conspiracy theories. Belief in simple solutions is given by the relationship between education and analytical thinking (van Prooijen, 2017; Mao et al., 2020). Higher education supports analytical or critical thinking, leading to slower but more thorough information processing. This then results in a lower probability of the individual believing the explanation of events through conspiracy theories. Van Prooijen (2017) confirmed this expected relationship in his research.

Some authors also discussed the possibility of limiting conspiracy belief within the framework of the relationship between thinking style and belief in conspiracy theory. For example, Swami et al. (2014), based on their work, propose the possibility of combating conspiracy theories, which prove harmful, by strengthening the ability to think analytically. However, other authors point out that we should not focus purely on the fight against conspiracy theories through education but instead on strengthening analytical and critical thinking in education (Douglas et al., 2016) because even the automatic judgment that every conspiracy theory is a misleading and incorrect conclusion. Based on examples from practice, we know that even a conspiratorial explanation of an event can eventually be confirmed. A perfect example of such a theory is the Watergate case.

4. Conclusions

The present study provided an extensive examination of the multifaceted processes influencing belief in conspiracy theories, highlighting psychological, social, and cultural factors integral to understanding their persistence and popularity in contemporary societies. Conspiracy theories, characterized by alternative explanations that challenge official accounts, emerge notably during periods of uncertainty, crisis, or political polarization, as underscored by historical and contemporary examples.

Our analysis identified key psychological mechanisms central to conspiracy beliefs, particularly the role of conspiracy thinking, cognitive biases such as the need for cognitive closure, intuitive versus analytical reasoning styles, and motivated reasoning. Individuals prone to conspiracy beliefs demonstrate heightened suspicion, exhibit intuitive information processing, and frequently interpret events through ideologically motivated lenses. Understanding these psychological dynamics offers crucial insight into the cognitive mechanisms that drive individuals toward conspiratorial thinking, thereby providing a foundation for developing more effective educational and communication strategies to counteract misinformation.

Additionally, this research underscored the significance of broader social and cultural contexts influencing conspiracy theories. Political polarization emerged as a substantial determinant, with individuals more likely to endorse conspiratorial explanations congruent with their political identities, thus exacerbating societal divisions. Cultural factors, including collective historical experiences of oppression, mistrust towards authorities, and social

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alienation, also proved pivotal, fostering environments in which conspiracy theories can thrive as alternative frameworks for interpreting reality.

The impact of digital media, particularly social networks, represents a contemporary challenge, amplifying conspiracy beliefs through rapid dissemination and reinforcement within echo chambers. This highlights the urgent need for policymakers, educators, and media platforms to develop coordinated responses that address misinformation effectively, promote transparency, and enhance public trust in credible sources. In this regard, digital literacy and critical thinking education should be prioritized to foster resilience against disinformation, encourage evidence-based reasoning, and equip individuals with tools to critically evaluate sources of information in a rapidly evolving media landscape.

Conclusively, addressing the complexities of problems related to conspiracy theories necessitates a multidisciplinary and integrative approach, bridging psychological insights with sociopolitical analyses. Further empirical research, therefore, could focus on exploring these interdisciplinary interactions more deeply, providing a robust evidence base for policies and interventions designed to counteract potentially harmful effects of widespread conspiracy beliefs on society. It is equally important to engage with communities most vulnerable to misinformation, build trust through inclusive dialogue, and ensure that public health and policy communication is culturally sensitive, accessible, and transparent.

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PROSPECTS OF THE EU ELECTRIC CAR MARKET*

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Abstract. The electrification of the transport sector is pivotal in achieving the European Union's climate neutrality objectives, given its substantial contribution to greenhouse gas emissions within the region. Furthermore, this initiative aligns with the broader Sustainable Development Goals (SDGs) 9 and 11, which underscore the critical importance of fostering sustainable transport systems. However, there is a pressing need for a comprehensive index that robustly correlates with advancements toward the SDGs in general, and more specifically, the electrification of transport. Such an index would facilitate a nuanced analysis of these processes. This article introduces the Sustainable Development Green Index (SDGI), a multifaceted analytical tool that encompasses educational, economic, political, societal, and environmental dimensions. The findings presented in this study support the efficacy of the SDGI and demonstrate its significant potential for analyzing current trends while emphasizing its strong correlation with progress in transport electrification within European Union member states.

Keywords: electric car; sustainable development; green economy; SDGs

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1. Introduction

The notion of sustainable development gained significant prominence in the latter part of the 20th century, propelled by a growing awareness of the interrelatedness among economic, social, and environmental dimensions. This holistic approach to development was notably influenced by the 1987 Brundtland Report, which articulated sustainable development as the capacity to fulfill present needs without undermining the ability of future generations to satisfy their own needs (Mitra, 2016). The report served as a catalyst for global dialogue, underscoring that economic growth should not occur at the cost of environmental degradation, thereby

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establishing the foundation for what subsequently developed into the Sustainable Development Goals (SDGs) endorsed by the United Nations in 2015 (Gracia-de-Rentería et al., 2023; Dobson, 2024).

The European Union's dedication to the SDGs exemplifies a wider movement toward sustainable economic policies that emphasize social equity and environmental sustainability alongside economic growth (Ricciolini, 2023). The EU's sustainable development strategy is fundamentally based on its international commitments as outlined in the SDGs. A significant initiative in this regard at the EU level is the European Green Deal (EGD) (Kiełczewski, 2021; Gołąbeska, 2023; Gomez-Olmedo et al., 2024). To actualize the principles of the EGD, the European Commission has aimed to reduce net greenhouse gas emissions by at least 55% by 2030, with a target for the European economy to achieve climate neutrality by 2050 (European Commission, 2021).

Threats such as noise pollution, air pollution, traffic congestion, stress, etc., pose serious risks to the environment and human health. About 75% of air pollution in cities globally is attributable to transportation activities, primarily emanating from vehicular emissions (Meydani et al., 2023). In response to this issue, the transport sector has implemented significant measures, most notably the adoption of electric vehicles as a viable alternative to traditional gasoline-powered cars. Electric vehicle is considered as a promising solution to reduce pollutant emission (Victor et al., 2019; Zhang et al., 2023; Subbotin et al., 2023), increase risks to human health (Nieuwenhuijsen, 2018; Sisani et al., 2022; Golinucci et al., 2023), save fuel consumption (Mazur et al., 2023; Roca-Puigròs et al., 2023). Research indicates that the extensive implementation of electric cars can substantially mitigate urban air pollution and decrease greenhouse gas emissions (Hofbauer & Maier, 2022; Kurc, et al., 2024; Jędrzejczak-Gas, 2024).

In 2020, global EC sales saw an increase of 43% compared to 2019, with the market share for electric cars reaching a record 4.6%. The following year, 2021, marked a significant milestone in ECs sales, which doubled from the previous year to total 6.75 million units. Remarkably, the number of electric vehicles sold within a single week in 2021 surpassed the total sales recorded for the entire year of 2012. The year 2022 continued this upward trajectory, setting new records as electric vehicle sales exceeded 10 million units, representing 14% of all new car sales – an increase from 9% in 2021 and below 5% in 2020. This growth resulted in over 26 million electric vehicles on the roads worldwide by 2022, reflecting a 60% increase from the previous year (Virta, 2024).

The most visible benefit of using electric cars is the absence of exhaust fumes in cities and a reduction in the amount of exhaust fumes globally. The argument often put forward that drawing energy from the grid produces the same amount of carbon dioxide is pure demagoguery. First of all, EC has greater efficiency – it doesn't waste energy to generate large amounts of heat, doesn't have a lot of moving parts, and implements regenerative braking. Secondly, the energy can come from various power plants, including nuclear, hydroelectric, wind, etc., which certainly can't power combustion cars. Third, most of the energy consumed by ECs in the future will come from wind turbines (Abdelrahim et al., 2022), water (Kubiak-Wójcicka et al., 2022) and photovoltaic panels (Vu et al., 2022). In recent years, electrification has emerged as a progressively vital component in numerous transportation modes. This is influenced by the increase in economic competitiveness, technological advancement and model availability of electric cars (Al-Saadi et al., 2022; REN21, 2022, 2024; Dirma et al., 2024).

Various indices have been developed to measure progress in this area, reflecting the multifaceted nature of green growth. This interest has precipitated the development of various indices designed to assess advancement toward this objective, alongside the realization of the SDGs. These indices integrate an array of factors that encapsulate the complex interrelationships between economic growth, ecological integrity, and social equity, thereby providing a multifaceted tool for evaluating progress within this paradigm.

2. Literature review

A variety of indices exist to evaluate the progress made toward establishing a green economy and achieving the SDGs. These indexes integrate an array of factors that encapsulate the complex interrelationships between economic growth, ecological integrity, and social equity, thereby providing a multifaceted tool for evaluating

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progress within this paradigm. In the context of the increasing urgency to transition towards sustainable development, Ryszawska (2015) work of on green economy indicators is particularly significant. Ryszawska (2015) research contributes to the understanding of how indicators can be utilized to measure the progress and effectiveness of green economy initiatives. This comprehensive analysis not only delineates the theoretical underpinnings of green economy indicators but also provides practical frameworks for their implementation across various sectors and regions. The researcher's work begins by establishing a clear definition of what constitutes a green economy. The author asserts that a green economy is characterized by enhancements in human well-being and social equity, coupled with a substantial reduction in environmental risks and ecological scarcity. This definition is in harmony with the overarching discourse surrounding sustainable development, which underscores the necessity for economic growth that does not jeopardize planetary health or the welfare of future generations. Ryszawska's Green Economy Index encompasses various elements, including natural capital (biodiversity and ecosystems), economic factors (waste, pollution, emissions, and resource consumption), political dimensions (policies and environmental strategies), and social considerations (social inequalities and poverty). By framing green economy indicators within this context, Ryszawska underscores their role as essential tools for measuring progress towards sustainability (Ryszawska, 2015).

Kasztelan (2017; 2018) employed the methodology established by the Organization for Economic Cooperation and Development (OECD, 2017) as a foundation, utilizing its Green Growth Indicators. These indicators encompass various metrics such as low-income levels, GDP per capita, inequality, material productivity, environmentally adjusted multi-factor productivity, CO2 productivity, environmentally related innovation and taxation, and exposure to air pollution (Organization for Economic Co-operation and Development, 2017).

Kasztelan's work on the Hellwig's Pattern Model serves as a methodological framework for assessing green growth across OECD nations. This model facilitates the evaluation of various indicators that reflect the interplay between economic performance and environmental sustainability (Kasztelan, 2017; Kasztelan, 2018). By employing such models, researchers can identify the effectiveness of green growth strategies and their impact on sustainable development. By employing such models, researchers can identify the effectiveness of green growth strategies and their influence on sustainable development. The integration of natural capital into economic development processes is crucial, as it provides an extensive understanding of the role that environmental assets play in fostering economic prosperity (Kasztelan, 2021).

Another important enhancement to the evaluation of progress in the green economy is the Green Economy Index (GEI). The index includes more than 20 detailed indicators covering environmental quality, resource efficiency, and social equity. Godlewska and Sidorczuk-Pietraszko (2019) highlight that such composite indices are instrumental in assessing the transition to a green economy across different regions, including Poland. As nations continue to grapple with pressing environmental challenges, the GEI will play a crucial role in guiding policy decisions and fostering a more sustainable and equitable global economy (Godlewska & Sidorczuk-Pietraszko, 2019). Alekna and Kazlauskienė (2020) highlight that the GEI incorporates a range of indicators, including environmental quality, resource efficiency, and social equity, providing a holistic view of green economic development. This comprehensive approach is essential for understanding the multifaceted nature of sustainability and the interconnections between economic, environmental, and social dimensions.

Within the framework of Germany's transition toward a green economy, Lutz et al. (2017) emphasize the necessity of a multi-dimensional framework that incorporates natural resource use, environmental quality of life, and institutional measures. This approach is crucial for effective policymaking and resource allocation, as it enables an in-depth understanding of sustainability allows for a comprehensive understanding of sustainability. The integration of various dimensions of sustainability into the assessment process is essential for addressing tackling the complex challenges associated with environmental degradation and resource depletion. Wagner et al. (2017) note that while environmental issues are often discussed politically, their perceived importance among the populace may not align with the urgency of the situation, particularly in regions where past environmental crises have been mitigated.

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All these researches in assessing the transition to a green economy has represented essential milestones in the development of analytical frameworks for assessing the green economy within the paradigm of sustainable development, recognized by both researchers and policymakers. However, the indices referenced previously do not capture the full range of sustainable development dimensions, and their frameworks have not been employed to evaluate their relationship with progress on the SDGs, particularly in the European Union. At this background, this paper proposes the implementation of a new Sustainable Development Green Index (SDGI), developed by the authors, which includes educational, economic, political, societal and environmental dimensions of sustainability (Lavrinenko et al., 2022; Rybalkin, 2022). SDGI is based on the quintuple helix model of sustainable development. This model consists of five subsystems: economy, policy, society, education, and environment. Each subsystem consists of 10 indicators (see Annex 1). The EEPSE index effectively correlates with various SDGs, thereby providing a comprehensive framework for evaluating the performance of different countries in their transition to a green economy. This index is particularly useful as it allows for a nuanced understanding of how specific policies and initiatives align with broader sustainability objectives. Shao et al. further elaborate on the importance of monitoring progress over time, arguing that static composite indices may not adequately capture the dynamic nature of green development (Shao et al., 2022).

The research aim of the paper is to examine the relationship between electric car adoption and sustainable development in EU countries. It focuses on analyzing how the SDGI correlates with the growth of the electric car market, providing insights to enhance policies for sustainable transportation. The research questions of the paper include:

- How does the SDGI) correlate with electric vehicle adoption across EU countries?
- What role do economic, educational, and environmental dimensions play in influencing electric car market growth?
- How can policymakers leverage sustainability metrics to enhance electric vehicle infrastructure and incentives?
- What regional differences exist in electric vehicle adoption within the EU, and what factors contribute to these variations?

3. Materials and Methods

The sales of electric car cannot be regarded merely as an economic factor, given that the electrification of transportation is a complex phenomenon. Moreover, electric cars continue to exhibit significantly higher costs in comparison to traditional alternatives (even though there are positive developments in this respect). Therefore, in order to enhance their adoption, it is essential to implement subsidies and state support (political subsystem), such as tax discounts, low-interest loans, and benefits related to road usage and parking. Additionally, it is imperative to establish the necessary infrastructure, including charging stations. Besides that, electric cars sales are obviously stimulated by high level of ecological awareness (societal subsystem) and developed green education (educational subsystem) (Ginavičienė & Sprogytė, 2021; Zamfir et al., 2022).

The abovementioned considerations necessitate the integration of economic, educational, environmental, societal, and political factors into the analysis, thereby establishing the foundation for employing the Quintuple Helix model in this research (Rybalkin, 2022). The Quintuple Helix model is characterized by both interdisciplinary and transdisciplinary aspects, as the complexity inherent in the five-spiral framework demands ongoing engagement from the entire spectrum of academic disciplines, spanning from the Natural Sciences (due to the inclusion of the natural environment) to the Social Sciences and Humanities. This collaboration fosters the visualization and promotion of a system interlinking knowledge, expertise, and innovation for sustainable development (Carayannis et al., 2012). A visual representation of the model is illustrated in Figure 1. As indicated in the figure, the Quintuple Helix model comprises five helices: the educational system (represented by academic and higher education institutions), the economic system (including industries, banks, and services), the political system (comprising public authorities along with their plans, laws, and ideologies), the media and cultural sectors, and the natural environment (Grundel & Dahlström, 2016). These five helices function as subsystems facilitating the circular movement of knowledge among them.

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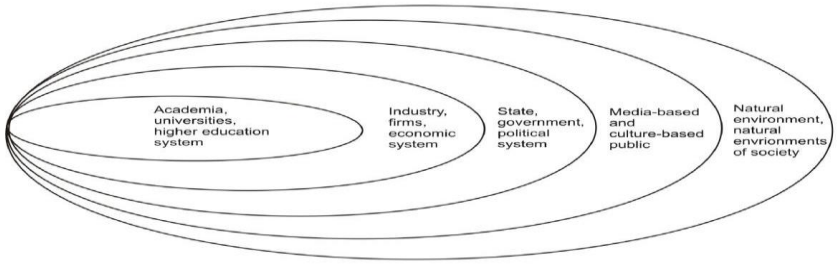


Figure 1. The subsystems of the Quintuple Helix model.
Source: Carayannis et al. (2012), as modified from Etzkowitz, Leydesdorff (2000)

Moreover, the implementation of the Quintuple Helix Innovation Model in the context of sustainable development, and specifically the Sustainable Development Goals (SDGs), has already been undertaken (Barcellos-Paula, 2021). The role of institutional differences among countries in achieving the SDGs is underscored by Maya, who notes that effective governance and the promotion of knowledge transfer between universities and businesses are critical for fostering social innovation (Maya, 2022). The Quintuple Helix model supports this by encouraging collaboration among multiple stakeholders, thereby enhancing the capacity for innovative solutions that address sustainability challenges.

The environment subsystem encompasses the status of environmental conditions and resources, including indicators such as changes in forest cover and levels of water and air pollution. The educational subsystem pertains to the degree of ecological education and research and development activities. The economic subsystem focuses on the proportion of renewable energy sources and per capita CO2 emissions. The political subsystem examines governmental incentives for the advancement of a green economy and international partnerships addressing climate change. The societal subsystem addresses issues of social and gender inequality as well as community engagement in matters related to the green economy. Now that the basis for the proposed Index (i.e., the Quintuple Helix Model) has been defined, to make necessary calculations of SDGI an equal number of indicators (Grundel & Dahlström, 2016) were assigned to each of the subsystems (Kasztelan, 2018), 50 indicators in total (see Annex 1). All indicators were standardized. The average values of the (SDGI were calculated as the arithmetic means of the respective indicators. The composite SDGI was derived as the arithmetic mean of the values of five subsystems.

4. Research results

The Sustainable Development Green Index, including its subsystems, was computed utilizing data from European Union member states. The subsequent analysis was conducted using SPSS software.

According the results, Sweden leads the SDGI index with a score of 58.97, benefiting from its strong performance across the educational (57.39), economic (64.58), and societal (58.45) dimensions, indicating a balanced approach to sustainable development. Denmark follows closely with an overall SDGI score of 57.75, marked by strong educational (55.42) and political (61.73) subsystems, though lower performance in the economic sector (55.42). Germany demonstrates a notable strength in the educational subsystem (69.28), but has lower scores in economic (51.72) and societal (51.28) dimensions, suggesting a potential area for improvement despite its high SDGI index rank – 56.42 (Table 1).

Table 1. Sustainable Development Green Index calculated for the EU countries in 2020

Country	Sustainable Development Green Index subsystems					SDGI
	Educational	Economic	Political	Societal	Environmental	
Sweden	57.39	64.58	59.59	58.45	54.83	58.97
Denmark	55.42	59.56	61.73	56.65	55.38	57.75
Germany	69.28	51.72	54.71	51.28	55.09	56.42
Finland	53.08	56.02	60.92	57.32	52.73	56.02
France	63.88	51.41	54.06	50.47	53.64	54.69
Netherlands	58.33	51.71	56.45	53.86	51.55	54.38
Austria	52.37	52.67	51.22	50.35	54.48	52.22

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Luxembourg	44.93	51.78	53.31	55.92	54.77	52.14
Spain	57.32	48.43	47.83	51.36	51.90	51.37
Estonia	44.28	52.62	51.21	54.42	52.83	51.07
Italy	56.68	50.12	50.19	47.16	49.96	50.82
Belgium	52.84	46.91	52.60	52.54	47.85	50.55
Ireland	46.19	51.91	48.77	55.59	47.92	50.08
Slovenia	45.63	47.89	49.50	47.36	52.58	48.59
Portugal	47.67	49.08	53.73	51.35	40.53	48.47
Latvia	40.90	52.23	51.79	48.16	48.37	48.29
Lithuania	41.58	51.32	47.93	48.68	49.61	47.82
Greece	47.26	42.15	48.31	51.88	48.40	47.60
Czech Republic	45.63	47.89	49.50	47.36	52.58	48.59
Slovakia	42.33	46.92	45.58	44.98	49.93	45.95
Croatia	42.32	49.50	45.24	40.85	49.76	45.53
Malta	42.52	49.82	43.70	47.28	43.98	45.46
Romania	42.17	49.09	43.06	42.91	49.02	45.25
Hungary	45.15	45.42	43.57	42.76	47.83	44.94
Cyprus	42.52	40.34	43.57	51.63	39.42	43.50
Bulgaria	42.24	43.40	42.14	42.67	46.85	43.46
Poland	47.55	40.72	37.50	44.68	45.61	43.21

Source: authors' calculations in SPSS software using statistical data

This group with higher values of the SDGI includes following countries as Finland (56.02), France (54.69), Netherlands (54.38), Austria (52.22), Luxemburg (52.14), Spain (51.37), Estonia (51.07), Italy (50.82), Belgium (50.55), Ireland (50.08). A lower level of values of the SDGI characterized other countries – Slovenia (48.59), Portugal (48.47), Latvia (48.29), Lithuania (47.82), Greece (47.60), Czech Republic (48.59), Slovakia (45.95), Croatia (45.53), Malta (45.46), Romania (45.25), Hungary (44.94), Cyprus (43.50), Bulgaria (43.46), Poland (43.21) (Table 1).

Statistic data show that Sweden leads the way with 46.0%, indicating a significant shift towards electric cars. Denmark and Finland also show high registered electric car rates at 34.5% and 31.8%, respectively, suggesting a growing preference for sustainable transport solutions in these countries as well. Countries like Germany (26.9%), Netherlands (29.7%), and France (17.6%) fall in the mid-range category. These are significant markets in the EU, and their shift towards electric cars can be a strong indicator of future trends. Eastern and Southern European countries tend to have lower adoption rates. Estonia, Slovakia, and Cyprus show the lowest percentages with 3.2%, 2.1%, and 0.8%. This might reflect economic factors, infrastructure challenges, or a slower policy push towards electrification (Table 2). Overall, the data points to a significant variation across the EU in electric car adoption, highlighting both the successes of certain regions and the opportunities for growth and development in others.

Table 2. Sustainable Development Green Index, newly registered electric cars and GDP per capita in the EU countries

Country	**SDGI**	**Newly registered electric cars (% of all cars registered)**	**GDP, euro per capita, 2021**
Sweden	58.97	46.0	44820.0
Denmark	57.75	34.5	50010.0
Germany	56.42	26.9	35480.0
Finland	56.02	31.8	37280.0
France	54.69	17.6	32530.0
Netherlands	54.38	29.7	41860.0
Austria	52.22	20.0	36950.0
Luxembourg	52.14	21.5	84490.0
Spain	51.37	5.7	23450.0
Estonia	51.07	3.2	15750.0
Italy	50.82	9.3	26710.0
Belgium	50.55	19.6	35960.0
Ireland	50.08	16.0	70530.0
Slovenia	48.59	4.3	21310.0
Portugal	48.47	19.9	18050.0
Latvia	48.29	3.9	12970.0

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Lithuania	47.82	5.0	14820.0
Greece	47.60	6.9	17610.0
Czech Republic	48.59	3.2	18020.0
Slovakia	45.95	2.1	15920.0
Croatia	45.53	4.3	13780.0
Malta	45.46	20.5	22300.0
Romania	45.25	7.6	9550.0
Hungary	44.94	7.0	13690.0
Cyprus	43.50	0.8	25480.0
Bulgaria	43.46	4.4	6950.0
Poland	43.21	3.6	13760.0

Source: authors' calculations according to statistical data (European Environment Agency, 2022; Rybalkin, 2022).

Analyzing the provided table showing GDP (per capita in euros) for various European countries in 2021 reveals several observations regarding economic performance and disparities among countries. **Luxembourg** stands out with an exceptionally high GDP per capita (84.490), which is significantly above all other countries listed. Next follows **Ireland** with (70.530). **Denmark** (50.010), **Germany** (35.480), and **Netherlands** (41.860) are within the high range of income. **Bulgaria** (6.950) and **Romania** (9.550) show the lowest GDP per capita figures (Table 2).

Now that the SGDI has been defined for the EU member-states, it is suggested to test empirically its correlation with new registrations of electric cars in these countries and in a broader sense – with SDGs 9 and 11, which imply promoting sustainable transport (European Statistical Agency, 2022). Previously a strong correlation between SDGI and Plug-in Electric Car Share of Market in the EU countries has been revealed (Rybalkin, 2022). Recently new data have been published, showing a significant increase in the uptake of electric cars and vans in the EU-27 (European Environment Agency, 2022). Further, it appears necessary to find out if there is a correlation between the new data and SDGI, and to compare it to the correlation with such conventional metrics as GDP per capita.

To test this hypothesis and find out, which interrelation is stronger, a correlation analysis was performed with SPSS software. The results were as follows (Table 3).

Table 3. Results of Pearson correlation analysis between new electric cars registrations and SDGI, GDP per capita.

	SDGI	**GDP per capita**
Electric cars registration	**0.824****	**0.624****
	0.000	0.001
	27	27

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

The correlation analyses show the strong positive correlation between newly registered electric cars (as percentage of all cars registered) and SDGI (0.824), which suggests countries with high sustainable development scores (as captured by the SDGI) are more likely to promote new electric cars registrations. This could be due to different factors (Table 3).

The correlation coefficient between electric car registrations and GDP per capita is 0.624. This value suggests a moderate positive correlation, meaning that as GDP per capita increases, the number of new electric car registrations tends to increase as well (Table 3).

5. Discussion and conclusions

Traditionally electric cars are seen as one of pillars for transition towards green economy (International Energy Agency, 2021). At the same time, still there is a big field for studying the electrification as one of the strategies for promotion sustainability in the transport sector.

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The objective of this study to investigate the relationship between the adoption of electric car and sustainable development in European Union countries was achieved. It emphasized the analysis of how SDGI is associated with the expansion of the electric car market, offering insights to inform and improve policies related to sustainable transportation.

The results of the Pearson correlation analysis emphasize a strong, statistically significant relationship between electric car registrations and the SGDI in the EU countries. This finding highlights the importance of sustainability efforts in promoting electric car adoption. Policymakers and stakeholders should take these correlations into account when designing strategies to improve both the sustainability profile of their regions and the transition to electric mobility. Further research could explore the causal mechanisms behind this relationship and assess the impact of specific policies on electric cars uptake. The Pearson correlation analysis results presented indicate a significant relationship between new electric car registrations and GDP per capita in EU countires. Other research results also show that a strong economy stimulates demand for electric vehicles and supports the development of charging infrastructure (Shao & Mišić, 2023).

While the correlation suggests a positive relationship, it is important to note that higher GDP per capita does not automatically guarantee higher electric vehicle registrations. Researchers mention different factors such as regional policies, availability of electric car models, consumer preferences, and cultural attitudes toward electric cars and even cost of electricity (Hofbauer, 2021) also play critical roles. Hidayati underlines that public perceptions play a significant role in the adoption of electric cars. Research indicates that positive public perceptions can enhance ridership and support for sustainable transport policies (Hidayati, 2023). Scientists Qiu and Bindhya indicate that while there is a growing interest in electric cars, challenges such as range anxiety and the availability of charging infrastructure continue to represent considerable impediments to the widespread adoption of electric cars (Qiu, 2024; Bindhya, 2024); Hofbauer, Vylegzanin (2022) and Schvartz et. al. (2024) survey findings also reveal that factors such as accessibility of charging infrastructure and maintenance considerations are primary determinants that influence the purchasing decisions regarding electric cars. Government initiatives aimed at promoting electric cars through incentives and subsidies are crucial in addressing these concerns and enhancing consumer confidence (Budiono, 2024).

The novelty of the findings lies in its use of the SDGI to analyze the impact of sustainability efforts on electric car adoption across EU countries. This approach provides a unique perspective on how different dimensions of sustainability – economic, educational, environmental, societal, and political – influence the growth of the electric car market. By linking SDGI scores to electric car registrations, the study offers valuable insights for policymakers aiming to foster sustainable transportation solutions.

The practical implications of the article are significant for advancing electric car adoption in the EU. It provides guidance for policymakers on creating effective incentives and infrastructure plans. The study highlights the necessity of expanding charging networks, emphasizing the importance of robust infrastructure to support increased electric car usage. Economic incentives such as tax breaks and subsidies are recommended to make electric vehicles more affordable and attractive to consumers. Additionally, the paper underscores the significance of raising public awareness about the benefits of sustainable transportation and suggests that tailored solutions should be implemented to address specific challenges and opportunities in different EU regions.

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Annex 1
Indicators used for each of the subsystems of the Quintuple Helix

Subsystem 1. Education:
S_1_1 Research institutions prominence 0–100 (best) (Global competitiveness report (further – GCR) 2019);
S_1_2 Scientific publications score (GCR, 2019);
S_1_3 Gross expenditure on R&D, % of GDP (Global Innovation Index, 2020);
S_1_4 Total number of documents in Scopus, Environmental science, cumulative, 1996 – 2019 (SJR — SCImago, 2021);
S_1_5 Citable documents, 1996 – 2019 (SJR — SCImago, 2021);
S_1_6 Citations (SJR — SCImago, 2021);
S_1_7 Self-citations (SJR — SCImago, 2021);
S_1_8 Citations per document (SJR — SCImago, 2021);
S_1_9 h-index, (SJR — SCImago, 2021);
S_1_10 Patents by origin/bn PPP$ GDP (Global Innovation Index Report, 2020);
Subsystem 2. Economic aspects:
S_2_1 GDP per unit of energy use (Global Innovation Index Report, 2020);
S_2_2 ISO 14001 environmental certificates per bn PPP$ GDP (Global Innovation Index Report, 2020);
S_2_3 Resource efficiency index (The global sustainable competitiveness index, 2020);
S_2_4 Greenhouse gas emissions score (Climate Change Performance Index, 2021);
S_2_5 Share of renewable energy in gross final energy consumption by sector, % (Eurostat, 2019)
S_2_6 The global sustainable competitiveness index (2020);
S_2_7 Circular material use rate, % of material input for domestic use (Eurostat, 2019);
S_2_8 Efficiency sectors (Global Competitiveness Report, 2019);
S_2_9 growth of innovative companies 1–7 (best) (Global Competitiveness Report, 2019);
S_2_10 Energy transition index (Energy transition index 2020 by World Economic Forum);
Subsystem 3. Political system:
S_3_1 Stringency of environmental regulations, index (Travel and Tourism Competitiveness Report, 2019);
S_3_2 Enforcement of environmental regulations, index (Travel and Tourism Competitiveness Report, 2019);
S_3_3 Environment-related treaties in force count (out of 29 possible) (Global Competitiveness Report, 2019);
S_3_4 Climate policy, index – covers both national and international climate policy performance (Climate change performance index, 2021);
S_3_5 Climate Change Performance Index (Climate change performance index, 2021);
S_3_6 Environmental performance, index (Global Innovation Index, 2020);
S_3_7 Environmental tax revenues, % of GDP (Eurostat, 2018);
S_3_8 Intellectual property protection 1–7 (best) (Global Competitiveness Report, 2019);

S_3_9 population covered by the Covenant of Mayors for Climate & Energy signatories – percentage of total population (Eurostat, 2019, for the UK – 2018);
S_3_10 Renewable energy regulation 0–100 (best) (Global Competitiveness Report, 2019).
Subsystem 4. Civil society:
S_4_1 Attitude of European citizens towards the environment – percentage of population who consider environmental issues to be important (Eurobarometer, 2017);
S_4_2 World Press Freedom Index (Reporters without borders, 2020)*;
S_4_3 Democracy index (The Economist Intelligence Unit, 2020);
S_4_4 Civil liberties (The Economist Intelligence Unit, 2020);
S_4_5 Social Capital Index (The global sustainable competitiveness index, 2020);
S_4_6 Incidence of corruption 0–100 (best), (Global Competitiveness Report 2019);
S_4_7 Internet users % of adult population, (Global Competitiveness Report, 2019).
S_4_8 People at risk of poverty or social exclusion, Eurostat (2019), except for Ireland, Italy, the UK (2018);
S_4_9 Share of busses and trains in total passenger transport, % of total inland passenger-km (Eurostat, 2018);
S_4_10 Females employed with advanced degrees, % (Global Innovation Index, 2020).
Subsystem 5. Natural environment:
S_5_1 Environmental performance index (Environmental performance index report, 2020);
S_5_2 Air quality (Environmental performance index report, 2020);
S_5_3 Water resources (Environmental performance index report, 2020);
S_5_4 Biodiversity and habitat (Environmental performance index report, 2020);
S_5_5 Forest cover change, % (The Travel & Tourism Competitiveness Report, 2019)*;
S_5_6 Wastewater treatment, % of total (The Travel & Tourism Competitiveness Report, 2019);
S_5_7 Total protected areas, % of territory (The Travel & Tourism Competitiveness Report, 2019);
S_5_8 Natural capital (The Global Sustainable Competitiveness Index, 2020);
S_5_9 Ecological sustainability, index (Global Innovation Index Report, 2020);
S_5_10 Agriculture (Environmental performance index report, 2020);
** a negative indicator (inverse relationship with sustainable development).*

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CHANGES IN LABOUR MARKET INDICATORS UNDER THE INFLUENCE OF INTERGENERATIONAL DISPARITIES IN VALUE ORIENTATION*

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Abstract. The labour market simultaneously encompasses multiple generations—Baby Boomers, Generation X, Millennials (Generation Y), and Generation Z. Each of these generations is characterised by distinct values, attitudes, and expectations, which, in combination with rapid technological progress and changing social conditions, accentuate their differences. The diverse preferences of each generation may have a significant impact on the labour market and its indicators. This study aims to examine the effect of generational shifts on selected labour market indicators, such as employment, labour productivity, long-term unemployment, and mobility within the conditions of the V4 countries. The primary analytical method applied is the Seemingly Unrelated Regression (SUR) model, with the analysis based on available statistical data from Eurostat. SUR models allow for a more detailed examination of the specific characteristics of individual generations in the labour market and their influence on the aforementioned indicators. The study tests a set of four hypotheses, each addressing statistically significant differences between generations in the context of: (1) employment by sector, (2) labour productivity by sector, (3) long-term unemployment, and (4) labour mobility. The interpreted results present a summary of findings across all V4 countries (Czech Republic, Poland, Slovakia, and Hungary) and are subsequently compared with findings from other regions, particularly Western Europe and the United States. The main findings indicate that the generations differ statistically significantly in relation to the selected labour market indicators. Since the V4 region has remained relatively underexplored in this research domain, the acquired findings expand existing theories on intergenerational disparities and their impact on the labour market.

Keywords: Generational shifts; labor market; SUR analysis; V4

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JEL Classifications: J11, J21, J24

1. Introduction

Intergenerational disparities in value orientation represent a process that influences not only societal values and preferences but also the structure and functioning of the labour market (Kalleberg, 2020). Each generation enters the workforce with distinct experiences, education, work habits, and technological literacy, creating both new challenges and opportunities for employment and economic productivity (Visser et al., 2018). While older

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generations may struggle with adapting to digitalisation and automation, younger generations bring innovative approaches, flexibility, and greater mobility within the labour market (Abou Assi & McGinnis Johnson, 2021). A review of the literature identifies three key factors contributing to intergenerational disparities in relation to the labour market: (1) Demographic differences, leading to an ageing workforce and labour shortages (Jiang et al., 2024; Coliander, 2023; Giannini et al., 2022; Tan et al., 2022); (2) Changes in skills, which have become more pronounced due to technological advancements (Mahmoud, 2024; Abbasi et al., 2024; Calvo-Porral & Pesqueira-Sanchez, 2020); (3) Shifts in value orientation, referring to changes in attitudes toward the labour market, employers, and workforce preferences (Czerwińska-Lubszczyk & Jankowiak, 2025; Kupczyk et al., 2024; Lee et al., 2023).

This study focuses on identifying the impact of these intergenerational disparities in relation to the labour market, particularly on selected indicators such as sectoral employment, sectoral productivity, labour mobility, and long-term unemployment. The geographical scope of the study is limited to the V4 countries. This region remains relatively underexplored in terms of labour market research, despite significant disparities between generational cohorts due to regional factors. These claims are supported by Hu and Hang (2023), who examined generational differences and found that studying such disparities at the geographic regional level is crucial, as they vary significantly across regions. Within the V4 countries, Yen et al. (2023) argue that social evolution in Eastern Europe, influenced by cultural, economic, and social factors, has significant implications for understanding the decision-making processes of different generations. Their research confirms that regional differences persist and continue to shape the behaviour of generational cohorts based on region-specific factors.

Given this context, an in-depth examination of the V4 region is considered highly valuable for expanding knowledge on generational disparities and their effects on the labour market. Among the total number of indexed studies published in the last ten years (n = 117), only four studies on this topic from Eastern European countries are currently indexed in Web of Science, all of which originate from the Czech Republic (Kyzlinkova & Stastna, 2018; Gurrutxaga, 2020; Egerova et al., 2021; Bicakova et al., 2023). These studies addressed unemployment among Generations Y and Z, student employment, demographic changes, and fatherhood in the context of declining birth rates.

An analysis of these studies reveals a lack of large-scale empirical research focusing on generational differences and their impact on the labour market in this region. Most existing studies originate from Western Europe and the USA, making their findings difficult to apply directly to Eastern Europe. This discrepancy is highlighted by Mahmoud et al. (2021) and Fuchs-Schündeln and Schündeln (2020), who argue that generational cohorts in Western countries and Eastern Europe exhibit significant differences rooted in historical and political factors, particularly the legacy of socialism. The communist ideology has contributed to disparities between generational cohorts in Eastern Europe and other regions and within generations raised during the Soviet era versus those raised after its collapse (Sagituly & Guo, 2023). This conclusion is further supported by Hu and Hang (2023).

Although these studies highlight specific aspects of generational differences in employment, a more comprehensive analysis of their impact on the labour market in the V4 countries remains absent. Poór et al. (2025) emphasise that one of the key challenges in the region is the ageing workforce and the migration of younger generations to economically stronger Western European countries, leading to a shortage of skilled labour in specific sectors. Similar trends were identified by Nešpor and Večerník (2023), who analysed intergenerational mobility and concluded that while the economies of the V4 countries are gradually converging with Western Europe, significant differences in working conditions and career prospects persist.

The shortage of skilled workers in certain sectors may lead to further structural problems in the labour market, especially if effective measures are not implemented to support intergenerational cooperation and adaptation to new technological challenges (Stojanova & Raguž, 2024). In this context, it is crucial to develop policy strategies that consider the differences between age groups and ensure effective integration between older workers' experience and younger generations' technological competencies.

Moreover, Woźniak-Jęchorek and Pilc (2024) emphasise that political and institutional factors play a significant role in shaping the labour market, with V4 countries facing challenges related to labour market flexibility and

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productivity across different sectors. The findings of these studies provide essential insights for developing effective employment policies that address the specific characteristics of generational cohorts and support long-term labour market stability in the region.

2. Theoretical background

The value orientation of generations in the labour market is changing, with each generation possessing specific attitudes, skills, and values that influence employer selection, labour market dynamics, and its indicators (Lissitsa & Laor, 2021). As generational cohorts in the labour market evolve, meaning that older generations leave and are replaced by younger ones, changes occur that employers and states must be able to adapt to. Since Generation Y has become the most numerous in the labour market, followed by Generation Z, these generations are considered the most significant. Therefore, researchers and employers have shown increased interest in these generations.

Intergenerational perception in the workplace plays a vital role in the collaboration of different age groups. While this diversity can benefit creativity and innovation, it also increases the risk of conflicts, particularly regarding work methods, communication, and management approaches. Employers strive to understand these differences and create an inclusive work environment where each generation can contribute to collective success (Kuyken & Costanza, 2024; Hans et al., 2023).

According to Elstad et al. (2021), value differences between generations are caused by global transformational processes, including technological advancement, economic cycles, and social movements. Additionally, Šestáková (2023) identified four key factors shaping generational disparities: (1) life cycle effects – values change over a lifetime due to experiences; (2) period effects – major historical events (wars, crises, technological innovations) shape generational attitudes; (3) technological impact – digitalisation and automation influence work habits across generations; (4) cohort effects – belonging to a particular generational group affects an individual's value system.

Post-war prosperity, the Cold War, and increasing political engagement shaped the Baby Boomer generation. This generation is known for its strong work ethic and preference for career advancement over financial rewards, holding higher status values towards the company compared to younger generations (Kinger & Kumar, 2023; McCrindle, 2018). In the workplace, they often advocate for hierarchical structures and formal communication, which can lead to generational conflicts in the modern, flexible economy.

Generation X, also called the "MTV Generation," grew up during the oil crises, digitalisation, and rising divorce rates. It is characterised by a sceptical approach to authority, individualism, and an emphasis on work-life balance (Heys, 2024). This generation began to recognise the importance of flexibility and independence in the workplace.

Generation Y (Millennials) was influenced by globalisation, the rise of the internet, and European Union integration. This generation is technologically proficient, focused on self-development, and prefers transparent communication (Jacobsen et al., 2023). In the workplace, they are characterised by teamwork, multitasking, and high expectations regarding job benefits.

As Generation Z enters the labour market, a significant portion of recent research focuses on studying generational cohorts. Generation Z grew up in the digital age and during the climate crisis. In the workplace, they emphasise rapid career growth, digital skills, and sustainability values (Lissitsa et al., 2022). This generation also prefers hybrid work models and flexibility, perceiving traditional hierarchical structures as outdated.

According to Dania et al. (2023) and Egerová (2021), Generation Z is the most educated but the least experienced, as many of its members choose higher education. A key difference from previous generations is their low loyalty to employers—if dissatisfied, they are willing to change jobs quickly. Their job mobility is

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also supported by higher language proficiency and broader international employment opportunities (Dania et al., 2023).

Based on these characteristics, each generation has different expectations from the labour market, which can influence mobility, productivity, and long-term employment. Overall, intergenerational differences in values and work preferences significantly impact labour market indicators. While older generations (Silent Generation, Boomers) prefer stability and hierarchical management, younger generations (Y, Z) emphasise flexibility, self-development, and meaningful work (Eyoun et al., 2020).

In the interconnectedness of these generational characteristics and current global changes, the modern labour market is undergoing fundamental transformations due to technological progress, affecting not only the demand for labour but also inequalities between sectors and regions. According to Manning & Petrongola (2024), employment concentration in traditional industrial sectors is declining, leading to changes in wage policies and demand for skills. Companies are forced to seek labour outside the local area or beyond their original sectors, with increasing emphasis on transferable skills (Giupponi & Machin, 2024). One of the most significant variables in this process is digital skills, which are a key factor in employability and socio-economic development. Bejaković & Mrnjavac (2020) emphasise that due to rapid technological development, governments and employers must develop strategies to promote digital inclusion, ensuring a new generation of IT specialists and the overall adaptation of the workforce to technological changes.

In the context of generational differences, it is important to note that younger generations (Y and Z) generally have a higher level of digital competencies, whereas older generations (Boomers, X) often have lower technological literacy, which can deepen disparities in employment opportunities. This trend may lead to the necessity of lifelong learning and retraining of older workers to maintain their competitiveness in the labour market (Giupponi & Machin, 2024).

From the perspective of direct intergenerational changes in value orientation related to the labour market, studies most often focus on several key trends: (1) Generations Y and Z are more frequently employed in the technology and creative industries, whereas older generations dominate in traditional sectors such as manufacturing, agriculture, administration, and healthcare (Klopotan et al., 2020); (2) Differences in job mobility – younger generations are more mobile and change jobs more frequently, while older generations remain loyal to a single employer. This occurs mainly due to established job security but also as a result of globalisation and the opportunities it brings (Yinhui et al., 2020); (3) Long-term unemployment – older generations face greater difficulties in finding new employment after a job loss, whereas younger generations have lower long-term unemployment rates due to broader digital skills (Balytska et al., 2023; Vasilescu et al., 2020).

In addition to the aforementioned changes and differences between generations, which lead to labour market transformations, demographic indicators among generational cohorts are also evolving. This makes understanding intergenerational disparities in the labour market even more crucial. Demographic changes influence the labour market in terms of labour supply and overall macroeconomic development. Gagnon et al. (2021) analysed the impact of population ageing and generational changes on GDP. They concluded that demographic factors directly impact economic growth, interest rates, and workforce composition. Their models indicate that generational shifts cause fluctuations in the economy, with the primary factor being the decline in the labour force due to the ageing of Baby Boomers and declining birth rates. A significant element is the change in consumer behaviour – while older generations prioritise stability and savings, younger generations invest more in technology, education, and experiences (Yang et al., 2023). According to Sum et al. (2020), demographic differences are also reflected in varying demands for jobs across different sectors.

Rentería et al. (2024) state that demographic changes represent one of the greatest challenges modern societies will face in the coming decades. Changes in the population's age composition pose a threat to the socio-economic structures of social and democratic states. According to the European Commission report (2024), monitoring demographic changes is becoming increasingly important, as shifts in population composition significantly affect the labour market and the economic development of the European Union.

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Based on the aforementioned literature analysis, generational shifts and their impact on the labour market are based on three main factors – differences in skills, values, and demographic structures. Changes in the labour market due to generational transitions thus constitute a broad and complex issue. In the context of these demographic changes, it is even more essential to understand generational differences at a regional level, which can yield significant insights for labour market adaptation in the V4 countries.

Integrating generations in the workplace is challenging, particularly for human resource management. Maan and Srivastava (2022), and Smeak (2020) emphasise that understanding employees' needs and preferences is key to ensuring their satisfaction, productivity, and stability in the workplace. Identifying these differences enables employers to respond effectively to generational disparities and contribute to the long-term sustainability of the labour market by securing the necessary workforce.

4. Research objective and methodology

Intergenerational changes in value orientation and their impact on the labour market represent a complex research area that requires a regional examination. Given that the issue of generational cohorts in connection with the labour market in the V4 region has not been sufficiently explored, this study aims to examine the impact of generational exchange on selected labour market indicators such as employment, labour productivity, long-term unemployment, and mobility in the conditions of V4 countries.

Several hypotheses are set to achieve this main objective:

H1: There are statistically significant differences between generations in terms of employment by sectors in the labour market.
H2: There are statistically significant differences between generations in terms of productivity by sectors in the labour market.
H3: There are statistically significant differences between generations in terms of long-term unemployment in the labour market.
H4: There are statistically significant differences between generations in terms of labour mobility in the labour market.

The SUR analysis (Seemingly Unrelated Regressions) method will be used to clarify the stated objective and the hypotheses set for it. This method represents an econometric analysis of multiple regression equations simultaneously while considering the mutual interactions of variables. A similar method in examining demographic or generational changes was used in the research of Temsumrit (2023), who applied it to analyse the impact of older individuals (aged 65+) on state expenditures. The author of this study describes that the GMM model is more useful for such research; however, regarding data interconnectivity, SUR (or SURE) analysis is a better modelling approach. Compared to Temsumrit's study, the presented research will not work with the share of older individuals but rather with data on the percentage representation of each generation in the labour market. The significance level at which a statistically significant correlation between the generational cohort and the examined variable was identified is set at 0.05 (5%). Since modelling certain relationships requires as many observations as possible (n-variables), the analyses will be conducted collectively for the V4 countries. Incorporating these countries will significantly increase the number of observations studied. As mentioned, the V4 countries share similar economic, demographic, social, historical, and political contexts, reducing variability that could distort the analysis results. This homogeneity allows for a better identification of specific relationships between the studied variables. Analysing data from V4 countries can reveal regional trends and patterns specific to this region and may differ from the rest of Europe. Combining data from multiple countries increases the number of observations in the analysis, which is crucial for enhancing the statistical power of the model. A more significant number of observations enables a more reliable identification of relationships between variables. Statistical data were obtained from Eurostat for the years 1998–2020.

Summary of Examined Variables in this Analysis:
(1) Labor productivity (variables y1–y10): Agriculture, industry, manufacturing, construction, trade and services, logistics, hospitality, ICT, administration, arts; (2) Employment by sector in the labour market

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(variables y11–y18): Agriculture, industry, manufacturing, construction, trade and logistics, ICT, public administration, arts; (3) Other labour market indicators (variables y19–y21): Long-term unemployment, mobility, part-time employment; (4) Control variables (variables K1–K5): GDP, inflation, unemployment, public debt, value-added, government expenditures; (5) The percentage share of a given generation in the labour market (variable X). The total number of observations for each indicator is n-96 (n-24 per each V4 country).

When selecting indicators, the statistics' availability and relevance for the analysed period were considered. The main variables include labour productivity (PP) by sector, reflecting employee efficiency in production and service provision, and employment (Z), which allows for tracking structural changes in the labour market and workforce distribution among industries. Additional indicators include long-term unemployment, labour mobility, and part-time employment, which, according to literature analysis, are particularly significant for younger generations and show an increasing trend.

The control variables include GDP, reflecting macroeconomic development; inflation, affecting purchasing power and labour market demand; and unemployment, indicating shortages. Also included are public debt and government expenditures, which are linked to fiscal policy and impact the labour market and economic development. These control variables help minimise bias and account for macroeconomic factors that may influence the analysed dependent variables. For the accuracy and reliability of the models, verification tests were considered, including (1) the Normality test – Doornik-Hansen test; (2) the Heteroskedasticity test – Breusch-Pagan test.

Given the robustness of multiple analysed models for each generation and the necessity to consider econometric verification tests, several models were processed. Due to their extent, the research section will present only the final models meeting all set conditions. These models will include variables (Y and K) that demonstrated statistical significance with variable (X – generational group) at the established significance level.

5. Results and discussion

Each generational cohort entered the labour market during a specific period, with its attitudes, skills, and values shaped by the circumstances of that time. These circumstances may include technological advancements, socio-economic factors, globalisation, and changes in the education system concerning labour market needs within a given timeframe. Based on this, it can be assumed that each generation in the workforce will have specific preferences that influence labour market indicators at different levels.

Table 1. Description of the final model for determining the relationship between the Boomer generation and selected labour market indicators

Dependent/independent variable		const	**Boomers**	**Log Boomers**	GDP	Unemployment	Public debt	Added Value	Government Expenditures	R^2 / adj.R^2
			x1	**l_x1**	K1	K3	K4	K5	K6	
l_y11 (Employment in Agriculture	coefficient	3,57256	**−0,0284743**	-	-	0,120479	0,0070162	-	−0,0392360	0,793476
	p-value	1,22e-09 ***	2,23e-05 ***	-	-	6,70e-025 ***	0,0007 ***	-	0,0002 ***	0,784398
l_y15 (Employment in Trade and Logistics)	coefficient	−44,0809	**0,229288**	-	8,23371	−0,334906	-	-	5,45793	5,56348
	p-value	9,07e-019 ***	9,29e-028 ***	-	6,66e-024 ***	0,0199 **	-	-	1,50e-014 ***	0,0619307
y19 (LTU)	coefficient	−109,914	-	**0,990043**	0,172772	1,4724	-	-	−0,799230	0,621262
	p-value	0,0081 ***	-	5,15e-06 ***	0,136	8,22e-07 ***	-	-	4,71e-06 ***	0,604614
l_y20 (Mobility)	coefficient	88,3775	-	**−0,486812**	0,192963	-	-	−0,0604441	−0,261430	0,891911
	p-value	1,64e-013 ***	-	2,97e-07 ***	9,32e-06 ***	-	-	0,0920 *	0,0177 **	0,88716

Source: own processing

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The exit of the Boomer generation from the labour market in V4 countries will significantly impact multiple sectors. The most substantial effect is expected in agriculture, where their declining share may lead to a shortage of experienced workers. These findings align with Martin and Ottemann (2016) and Marchand and Minni (2019), who highlight the decreasing proportion of older employees in the primary sector. The departure of the Baby Boomer generation from the workforce will fundamentally shape the labour market, with an anticipated shortage of experienced workers in traditional industries (Kirchnera, 2024). In contrast, the trade and logistics sector is experiencing employment growth. This trend may improve labour supply in the sector but also requires adjustments to working conditions to meet the expectations of younger cohorts.

The results also indicate a correlation between the decline of Boomers in the workforce and an increase in long-term unemployment, suggesting that younger generations (Y and X) are more vulnerable in this regard. This phenomenon may be linked to different work values, lower employer loyalty, and higher demands for work-related benefits. Furthermore, it appears that Boomers played a crucial role in stabilising labour mobility—their long-term job commitments contributed to lower mobility rates. In contrast, their departure may lead to more frequent job changes and higher workforce mobility. Migration and its likelihood decrease with age (Li & Shen, 2024), supporting the findings regarding a negative relationship with mobility.

Overall, the exit of the Boomer generation presents challenges associated with labour market modernisation, particularly in traditional sectors where their decline may weaken job stability. Altman et al. (2020) found that in the context of the academic labour market, some segments adapt more slowly to the departure of Boomers. At the same time, it creates an opportunity for market adaptation through technological innovations, retraining, and mobility support, which will be essential for ensuring the sustainable development of the labour market in the V4 region.

Table 2. Description of the final model for determining the relationship between Generation X and selected labour market indicators

Dependent/independent variable		const	**Gen X**	GDP	Inflation	Un-employment	Gov. Expenditures	log. Gov. Expenditures	R^2 / adj.R^2
			X2	K1	K2	K3	K6	l_K6	
l_Y11 (Employment in Agriculture)	Coeff.	−0,129641	**−0,129641**	−0,0129746	0,04764	0,08017	-	-	0,83701
	p-value	5,95e-011***	2,25e-013***	0,0052***	3,27e-05***	1,97e-09***	-	-	0,82985
l_Y12(Employ in Industry)	Coeff.	4,88821	**0,01315**	−0,00318643	-	−0,0167114	-	−0,449816	0,77383
	p-value	6,80e-033***	3,72e-010***	5,83e-07***	-	1,14e-014***	-	4,07e-09 ***	0,76389
l_Y13(Empl. in Manufacturing)	Coeff.	28,93280	**0,41114**	−0,0768262	-	−0,504746	−0,231958	-	0,82067
	p-value	2,36e-017***	1,67e-015***	6,72e-08***	-	1,72e-019***	1,12e-08 ***	-	0,81279
l_Y16(Employment in ICT)	Coeff.	−3,30574	**0,04384**	0,03500	-	-	0,02190	-	0,95605
	p-value	2,44e-016***	5,86e-012***	3,81e-059***	-	-	3,11e-05 ***	-	0,95462
l_Y20(Mobility)	Coeff.	49,19210	**−0,479096**	0,28760	-	-	0,20056	-	0,88697
	p-value	1,76e-014***	0,0004***	1,93e-026***	-	-	0,0135 **	-	0,88329
l_Y21(Part-time Employment)	Coeff.	28,71510	**−0,441512**	−0,0772720	−0,151914	-	-	-	0,71675
	p-value	1,07e-021***	1,38e-023***	2,68e-010***	0,0027***	-	-	-	0,70752

Source: own processing

The results of the analysis show that Generation X plays a significant role in the employment structure of V4 countries, with its influence being most pronounced in traditional sectors. The decline of its share in agriculture is associated with a reduction in the workforce in this sector, indicating a decreasing interest among younger generations in physically demanding professions. The decline in Generation X's presence in agriculture

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correlates with lower employment levels, suggesting that younger generations are less interested in physically demanding work (Widiyanti et al., 2023; Ngadi et al., 2023). Similar findings were presented by Lyons et al. (2015), who stated that Generation X in North America still relies on traditional employment, whereas younger cohorts are shifting towards technologically advanced sectors.

Conversely, in the industrial and manufacturing sectors, the impact of Generation X is positive, possibly due to higher technical skill levels and stable work engagement (Bejtkovský, 2016). Additionally, labour market demands for these skills are increasing, altering the preferences of involved stakeholders (Shaji, 2024).

A surprising finding is the positive, albeit weak, relationship between the share of Generation X and employment in the information and communication technology (ICT) sector. This trend may indicate that Generation X is a "transitional cohort" between manual professions and the digital economy. In contrast, a study by Mahmoud et al. (2021) showed that younger generations dominate the ICT sector in Western countries, while Generation X has only partially adapted.

Regarding labour mobility and flexibility, Generation X in V4 countries has a negative relationship with remote work and part-time employment trends. This result aligns with Chawla et al. (2017), who found that in the Indian context, this cohort prefers stable employment and is less adaptable to modern flexible work conditions. In contrast, Bejaković and Mrnjavac (2020) argue that in some European countries, Generation X is gradually adapting to hybrid work models, albeit to a lesser extent than younger generations.

The analysis shows that Generation X in V4 countries remains an essential workforce in traditional sectors, but its adaptation to new trends is limited. This generation is less mobile, more conservative in its work condition preferences, and slower to embrace digitalisation, which may impact its labour market competitiveness in the future.

Table 3. Description of the final model for determining the relationship between Generation Y and selected labour market indicators

Dependent/independent variable		const	**Gen Y**	GDP	Inflation	Unemployment	Gov. Expenditures	R^2 / adj.R^2
			X3	K1	K2	K3	K6	
Y2 (Labor Productivity in Industry)	Coeff.	58,15980	**1,40419**	-	-	−1,61018	-	0,89175
	p-value	8,04e-032 ***	3,09e-034 ***	-	-	2,44e-015 ***	-	0,88942
Y3 (Labor Productivity in Manufacturing)	Coeff.	50,20330	**1,68316**	-	-	−1,99167	-	0,92306
	p-value	3,09e-028 ***	1,72e-041 ***	-	-	7,03e-018 ***	-	0,92141
Y15 (Employment in Trade and Logistics)	Coeff.	20,91160	**−0,0400597**	-	−0,0943260	−0,171725	0,11448	0,90855
	p-value	2,73e-039 ***	3,68e-08 ***	-	2,31e-07 ***	6,65e-016 ***	1,64e-07 ***	0,90204
Y20 (Mobility)	Coeff.	23,09170	**0,38067**	0,19037	-	-	0,37433	0,91480
	p-value	1,03e-07 ***	5,15e-06 ***	2,71e-08 ***	-	-	7,91e-05 ***	0,91202

Source: own processing

The analysis of labour market indicators for Generation Y in V4 countries highlights their high adaptability to technological innovations, which positively influences labour productivity. A statistically significant relationship between this generation and productivity was observed, particularly in the industry and manufacturing sectors, where their technological literacy and flexibility contribute to increased efficiency (Mahmoud et al., 2021). Similar findings were presented by Ghitza et al. (2022), who confirmed that in Western countries, Generation Y adapts better to technological changes compared to older cohorts.

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Conversely, a decline in employment in the trade and logistics sectors was observed for this generation, which may be linked to a preference for innovative and dynamic industries as well as the increasing automation of traditional job positions (Heys, 2024). This trend is further supported by Sum et al. (2020), who argue that digitalisation reshapes the labour market structure, reducing the need for manual labour. A significant factor is also the increased mobility of Generation Y, indicating their willingness to change jobs more frequently and adapt to new conditions. This flexibility supports a more efficient redistribution of labour across regions and sectors, helping to mitigate regional labour market disparities (Yinghui et al., 2020).

Generation Y is currently the dominant workforce in V4 countries and plays a crucial role in the future development of the labour market. As the last sizable generation before the demographic decline, its integration into strategic labour market goals is essential to ensure long-term competitiveness. Employers must better reflect this generation's values and preferences to retain a skilled workforce in an evolving economic environment (Bejtkovský, 2016).

Table 4. Description of the Final Model for Determining the Relationship Between Generation Z and Selected Labor Market Indicators

Dependent/independent variable		Const	**Gen Z**	**Log_ Gen Z**	GDP	log. GDP	Inflation	Un-employment	log. Un-employment	Gov. Expenditures	R^2 / adj.R^2
			x2	**l_x2**	K1	l_K1	K2	K3	l_K3	K6	
l_Y8 (Labor Product. in ICT)	Coeff.	3,5007	-	**0,06436**	0,00641	-	-	0,00859	-	0,0056	0,6802
	p-value	9,23e-037***	-	0,0200**	6,57e-05***	-	-	0,0235**	-	0,0466**	0,6661
Y9 (Labor Product. in Administration)	Coeff.	-117,6	**0,3701**	-	2,35836	-	-	-	-	1,4674	0,6702
	p-value	2,04e-07***	1,18e-012***	-	2,71e-018***	-	-	-	-	0,0020***	0,6595
Y15 (Employment in Trade and Logistics)	Coeff.	-36,31	**-0,233**	-	-	13,0621	-0,077	-	0,5656	0,0823	0,7646
	p-value	6,81e-011***	6,04e-020***	-	-	7,25e-020***	4,20e-05***	-	0,0103**	6,86e-05***	0,7516
l_Y19 (LTU)	Coeff.	5,0656	-	**0,12004**	-0,01068	-	-	-	0,0239	-0,0185	0,6826
	p-value	8,59e-022***	-	0,0483**	0,0030***	-	-	-	0,0090***	0,0066***	0,6687
Y20 (Mobility)	Coeff.	30,835	**0,6076**	-	0,09377	-	-	-	-	0,3989	0,8394
	p-value	2,74e-010***	5,62e-09***	-	0,0413**	-	-	-	-	6,95e-05***	0,8342

Source: own processing

Generation Z significantly impacts labour productivity in the ICT sector; however, its statistically significant effect on employment in this sector was not confirmed. This trend suggests that generational shifts support innovation and digitalisation, but this does not necessarily translate into increased employment for younger cohorts. A similar conclusion is drawn by Oringo et al. (2020), who state that while Generation Z enhances efficiency through technological innovations, automation of work processes may reduce the number of available jobs.

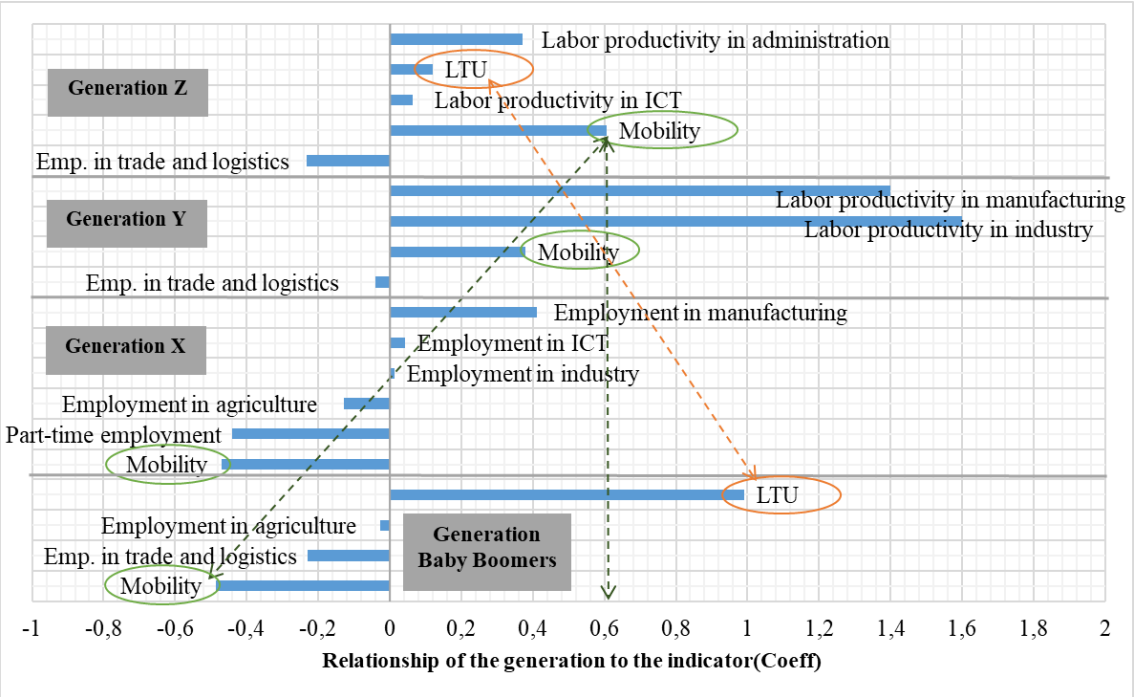
Conversely, the decline in productivity in administration may be related to Generation Z's lower interest in this sector or the increasing automation of administrative processes. Similarly, the decline in employment in trade and logistics can be attributed to the development of smart industries and the decreasing need for manual labour, as confirmed by Bishop et al. (2022), who analysed the declining interest of younger generations in traditional manufacturing and logistics positions.

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A positive relationship between Generation Z and labour mobility indicates that younger employees are more willing to change jobs or relocate, enhancing business competitiveness and posing challenges for employers in retaining talent. This trend is also supported by Mkhize and Mkhize (2024), who argue that Generation Z prefers flexibility and short-term employment commitments, necessitating new approaches to workforce management.

The findings further indicate a potential increase in long-term unemployment among younger generations, which may signal either weak integration of young people into the labour market or insufficient skills to meet current employer demands. Additionally, this relationship may be significant due to the rising NEET (Not in Education, Employment, or Training) trend among young generations, a growing issue at the European level. Fabrizi and Rocca (2024) and Emmanouil et al. (2024) also highlight this negative trend.

Figure 1. Comparison of Intergenerational Impact on Selected Labor Market Indicators (Evaluation of H1 – H4)



Source: own processing

The graph summarises statistically significant variables across generations and labour market indicators, highlighting the differences shaping the current labour environment. The values in the graph represent coefficient values from individual SUR analyses (Tables 2 to 5). The presented results are interpreted in accordance with hypotheses H1 to H4. Based on the hypotheses, it can be stated that statistically significant differences exist between generations and the following labour market indicators: (H1) Employment by sector; (H2) Productivity by sector; (H3) Long-term unemployment; (H4) Labor market mobility. The Boomer generation is gradually exiting the labour market and is strongly associated with traditional sectors, particularly agriculture. Their decline leads to decreased employment in this sector and is linked to rising long-term unemployment and low labour mobility.

Generation X plays a crucial role in industry and manufacturing while exhibiting a weak positive correlation with the ICT sector, making it a transitional cohort between traditional and technological industries. This finding is further supported by Lissitsa and Laor (2021), who describe Generation X as a transitional cohort. Alongside the Boomer generation, Generation X demonstrates reduced mobility, which may be due to established personal and family commitments, resulting in a lower willingness to relocate for work.

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Generation Y has become the dominant labour force and contributes to productivity growth in industry and manufacturing, which is linked to the development of smart industries. While employment in trade and logistics remains stagnant, mobility within this generation has significantly increased, reflecting its openness to career changes.

Generation Z is gradually entering the labour market, particularly in the ICT sector. Conversely, traditional sectors such as administration have experienced a decline in productivity as the share of Generation Z in the labour market increases. Additionally, its higher share correlates with rising long-term unemployment, highlighting challenges such as the NEET phenomenon and the mismatch between skills and labour market demands within the V4 region.

The results highlight the interconnectedness of generational shifts and their impact on the labour market while emphasising the differences among individual cohorts. Key labour market trends include:

1. Sectoral Transformation – A gradual shift from traditional industries to "modern" sectors.
2. Flexibility and Mobility – An increase in labour mobility and flexible work arrangements, which are statistically significant, especially among younger generations.
3. Changes in Sectoral Preferences and Employment Attractiveness – A shift in generational interest in specific sectors.
4. Challenges Related to Workforce Participation – Rising long-term unemployment, initially expected to be most prominent among the Boomer generation due to workforce exhaustion and ageing. However, increasing long-term unemployment is also associated with the youngest generation, representing an underutilised labour force potential.

Changes in the labour market resulting from generational shifts represent a complex issue. These changes occur due to intergenerational disparities in values and attitudes, as well as external factors such as technological advancements, the development of smart industries, and political conditions. Vieira et al. (2024) similarly argue that generational differences are influenced by experiences acquired during early adulthood. The findings from the SUR analyses reveal several insights that may substantially impact labour market behaviour.

The Baby Boomer generation plays a crucial role in traditional sectors such as industry, agriculture, and public services. Their gradual exit from the labour market leads to labour shortages in these industries as younger generations show lower interest in them. This trend is confirmed by Hu and Huang (2023), who highlight the global nature of this issue, particularly in developed countries. The mobility of this generation is low in the European context; however, international research (Hu & Huang, 2023; Jing & Hu, 2022; Szeto et al., 2017) suggests an opposite trend, pointing to regional differences. For example, studies conducted in Sweden and China reached similar conclusions to this study, indicating that Boomers in these countries exhibit lower labour mobility (Zhao & Cao, 2020; Cassel et al., 2013).

Generation X remains a significant workforce in the industrial and manufacturing sectors while also playing a minor role in the ICT industry. Lissitsa and Laor (2021) characterise this cohort as "digital immigrants," distinguishing them from younger cohorts that grew up in a technological era. This generation has low labour mobility and a lower preference for flexible employment forms, which aligns with its preference for stability. Although Generation X remains a critical labour force, its weaker digital skills may limit its competitiveness. Kim and Park (2020) and Cirilli et al. (2019) emphasise the necessity of lifelong learning and retraining, which could help these workers better adapt to evolving labour market demands. The weaker technological skills of these generations (Boomers and X) are mainly linked to the opportunities available to them during their formative years (Chan & Lee, 2023; Lissitsa & Laor, 2021).

Generation Y's increased mobility is just one factor that distinguishes it from previous generations. Cirilli et al. (2019) also discuss the rise in mobility, aligning with this study's findings regarding the connection between this indicator and globalisation. Additionally, this generation is considered more open, contributing to increased mobility. As Bejtkovský (2016) noted, Millennials (Generation Y) are curious, open to new experiences, and focused on the present. These characteristics enable them to better adapt to changes in the work environment and actively engage in career opportunities.

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Their positive relationship with labour productivity is also significant, particularly in the industrial and manufacturing sectors. Several factors may contribute to this trend. On the one hand, the rise of smart industries and technological innovations are naturally aligned with Generation Y (Dania et al., 2023; Kim & Park, 2020). On the other hand, their interest in these sectors may also stem from the significant increase in industrial job opportunities during the period when this generation entered the labour market. This development was particularly evident in Slovakia, where the industrial sector, especially the automotive industry and related businesses, experienced significant growth during their workforce entry period.

Like Generation Y, Generation Z exhibits a positive relationship with labour mobility, which may be attributed to the technological environment in which this generation was raised and its high level of digital skills. According to Dania et al. (2023), Generation Z has been exposed to technology early, contributing to its increased inclination toward technological and digital fields. However, the higher proportion of employment in this sector may result from Generation Z's capabilities and the growing demand for employees in this industry. This relationship is described by Calvo-Porral and Pesqueira-Sanchez (2020) as reciprocal—ICT attracts this generation. Still, their presence in the sector also accelerates technological innovations and increases the demand for additional employees.

Generation Z did not demonstrate interest in the industrial and manufacturing sectors. Although, given the nature of the labour market in Slovakia and its structure, this generation is required to fill these roles, their preferences, as indicated by the research findings, are clear. Johnson (2019) supports these claims, stating that Generation Z is most qualified for digital transformation and ICT-related work. Therefore, despite this generation's lack of interest in specific employment sectors, modifying these sectors and incorporating innovative processes could help employers attract and retain workers from Generation Z. This view is shared by Johnson (2019), who argues that younger employees are eager to embrace cutting-edge technologies, as they perceive them as having a so-called "cool factor."

Conclusions

This study focused on analysing the impact of generational changes on the labour market in V4 countries, with particular attention to sectoral differences in employment, productivity, labour mobility, and long-term unemployment. The results indicate that each generation has distinct characteristics and preferences influencing labour market dynamics and structural transformations.

Findings from the SUR analyses and secondary data highlight statistically significant differences among generations in employment, productivity, long-term unemployment, mobility, and consumer preferences. Older generations, such as Boomers and Generation X, dominate traditional sectors like industry, agriculture, and public services; however, their withdrawal from the labour market poses a risk of labour shortages. Conversely, younger generations Y and Z positively impact productivity in technologically advanced sectors, such as information and communication technologies (ICT) and services. These generational differences emphasise the need for job flexibility, adaptation to technological changes, and support for continuous education.

The Baby Boomer generation remains a key workforce in traditional industries such as agriculture, manufacturing, and public services. Its gradual departure leads to declining employment in these sectors, with younger generations showing insufficient interest in replacing them. A significant finding is the low mobility of this generation, which, when combined with demographic trends, could result in labour shortages in specific industries.

Generation X is characterised by stable employment in the industrial and manufacturing sectors, with a smaller presence in ICT. Despite its limited influence on the digital sector, it is a transitional cohort bridging the traditional and digital economies. However, weaker digital skills and lower labour mobility suggest that lifelong learning and retraining will be essential to maintaining this generation’s competitiveness.

Generation Y emerges as the most mobile and technologically adaptable cohort, allowing it to respond more effectively to labour market changes. It positively impacts productivity in industrial and manufacturing sectors,

particularly due to the expansion of smart industries. This trend confirms employment growth in technological sectors, though it coincides with stagnation in traditional services such as trade and logistics.

Generation Z is most prominently established in the ICT sector, with its labour mobility and digital skills fostering technological innovation and labour market digitalisation. However, it tends to avoid industrial and manufacturing sectors, which could lead to future imbalances in labour supply and demand. Despite its high technological readiness, the findings indicate an increased risk of long-term unemployment, potentially linked to the NEET phenomenon and a mismatch between graduates' skills and labour market requirements.

The research results confirm that generational changes affect labour market stability, sectoral structures, and productivity growth. The main challenges for V4 countries include labour shortages in traditional industries, the need for retraining older generations, and the integration of younger cohorts into the workforce. Furthermore, the findings contribute to identifying sectoral employment interests from a generational perspective. Understanding generational preferences—such as the need for greater flexibility among younger generations or increased motivation for education among older generations—enables the development of targeted work environments and benefits. Ultimately, this could enhance firms' competitiveness in the labour market and reduce employee turnover. The applied SUR methodology has proven to be an effective tool for identifying generational disparities and may serve as a model for further research on similar topics.

The study's limitations are linked to potential extensions of the analysis. Future research should consider incorporating additional control variables, such as integrating smart industry into the analysis. Although data on this aspect have only been available since 2014, their inclusion could more precisely differentiate the impact of technological changes from generational differences. Incorporating this control variable could better account for technological progress and thus refine the analysis of intergenerational disparities.

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INFORMATION TECHNOLOGY / ARTIFICIAL INTELLIGENCE USE AND LABOR PRODUCTIVITY IN FIRMS*

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Abstract. This study aims to develop conceptual frameworks and propose an appropriate research methodology for analyzing the relationship between information technology (IT) and artificial intelligence (AI) use and labor productivity in firms, particularly within the context of Latvian ones. Drawing from a comprehensive literature review, it identifies key theoretical models, including the Technology Acceptance Model, Diffusion of Innovations, Resource-Based View, and Socio-Technical Systems Theory, as foundational for understanding IT/AI use in firms and its effects on productivity. The study also proposes a hybrid research methodology combining quantitative causal inference techniques (such as panel data regressions, difference-in-differences, instrumental variable regressions, and Stochastic Frontier Analysis) with qualitative approaches (including case studies, expert interviews, and content analysis) to capture both the measurable impacts and organizational dynamics of IT/AI use. Furthermore, it outlines how advanced tools like machine learning models and Bayesian networks can model complex interdependencies. The conceptual framework integrates theoretical insights with empirical indicators from Latvian official statistics, illustrating how IT/AI contributes to productivity via automation, augmentation, and labor reallocation. The study concludes by identifying limitations (such as its conceptual focus and country-specific scope) and recommends future empirical studies that apply the proposed framework across sectors and regions using firm-level data to validate and expand upon its findings.

Keywords: information technology (IT); artificial intelligence (AI); enterprises; labor productivity; conceptual framework; correlation vs. causality; research methodology.

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1. Introduction

Currently, information technology (IT) and artificial intelligence (AI) are increasingly recognized as crucial drivers of labor productivity in firms (Mura et al., 2017; Makridakis, 2017; Graetz & Michaels, 2018; Nolan,

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2020; Bonetti et al., 2022; Tugui et al., 2022; Gao & Feng, 2023). Understanding the conceptual frameworks (Ngulube et al., 2015; van der Waldt, 2020; Majeed et al., 2023; Mohammed & Ahmad, 2025) of IT/AI use in firms and their impact on labor productivity (Syverson, 2011; Zirar et al., 2023; Paudel, 2024) (or just simple correlation without any causality (Blalock, 1961; Geels, 2022; Gershman & Ullman, 2023; Little, 2023; Hussain et al., 2024) is essential for both academic research and practical implementation.

The American economist, the author of the theory of the so-called "new economic geography" P. Krugman back in the early 1990s developed the only way by which it is possible to achieve an increase in living standards in a long-term – by increasing productivity (Krugman, 1991a, 1991b, 1997). Productivity is particularly relevant for those countries and regions that are at the so-called efficiency-driven stage of their economic development, since it is at this stage that productivity (and even more efficiency) is the main driver of economic growth (Sala-i-Martín et al., 2016) (in Latvia, such regions are Latgale, Vidzeme and Zemgale (Boronenko, 2009; Zeibote, 2018)). In the modern context of fall of the labor share and the rise of superstar firms (Autor et al., 2020), labor productivity (output per worker) remains crucial for economic growth and rising living standards. However, the way productivity gains translate into wages and labor's share of income has changed. Traditionally, higher labor productivity was expected to drive higher wages, but the rise of superstar firms suggests a decoupling of this relationship, because many of the productivity improvements in superstar firms stem from automation, IT / AI, and other labor-saving technologies. As a result, productivity growth does not necessarily translate into higher demand for labor, weakening the link between labor productivity and wage growth (Autor et al., 2020).

The Superstar Firm Hypothesis (Autor et al., 2020) suggests that aggregate productivity (driven by dominant firms) may increase, even if the average firm's productivity stagnates. This highlights the importance of reallocation effects in productivity measurement. Techniques like work-study, automation, and quality control remain important in conceptual frameworks of productivity (Maheshwari, 2016). However, in industries dominated by superstar firms, productivity improvement is less about efficiency at the firm level and more about market structure (firms gaining market share and exercising pricing power). Some empirical insights into the role of labor productivity in modern firms performance (Yousaf, 2023) challenge the classical view that labor productivity is the most important driver of firms success. In the era of IT / AI, performance is increasingly shaped by market structure, strategic positioning, and quality management – rather than labor productivity alone, in particular, in superstar or high-quality firms (Yousaf, 2023).

Against the backdrop of unanimous acceptance of IT/AI as factors for increasing labor productivity, but ambiguity regarding the role of labor productivity itself in the economic success of firms, contemporary researchers continue to pay close attention to labor productivity along with its efficiency (Korshenkov & Ignatyev, 2020; Ali et al., 2024; Korkmaz & Korkmaz, 2024; Shamim, 2024). In particular, Korshenkov and Ignatyev (2020) distinguish labor productivity from labor efficiency. They define productivity as the ability to create as much output as possible per unit of time, whereas efficiency takes into account the amount of production factors utilized in the process (Korshenkov & Ignatyev, 2020). In turn, other modern studies (for example, Zirar et al., 2023; Korkmaz & Korkmaz, 2024) do not explicitly distinguish between labor productivity and labor efficiency in enterprises but discusses factors influencing productivity, such as human capital, technological change, and economies of scale.

In the international research space, there are suggestions that IT/AI use in firms do not directly influence labor productivity but rather modifies worker routines and interactions in firms (Zirar et al., 2023). There is an uncertainty about the magnitude of IT/AI's impact on workforce productivity, as IT/AI-powered technologies still require human supervision in many cases. Moreover, there is no appropriate and comprehensive research methodology for studying relationship between IT/AI use and labor productivity in firms. This study aims to create conceptual frameworks of IT/AI use and labor productivity in firms, as well as to propose an appropriate research methodology for studying their relationship (correlation or causality). As a result of this study, the following research questions need to be answered: (1) What are the main theoretical backgrounds for understanding IT/AI use and labor productivity in firms? (2) Should labor productivity and labor efficiency in firms be considered distinct concepts, or can they be used interchangeably? (3) What research methodologies are best suited for studying the relationship between IT/AI use and labor productivity in firms? By addressing

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these questions, the study will provide a holistic approach for understanding and analyzing the relationship between IT/AI use and labor productivity in firms, bridging conceptual insights with empirical evidence and methodological innovation.

The subject of this study is IT/AI use in relation to labor productivity in Latvian firms. To create conceptual frameworks of IT/AI use and labor productivity in firms, as well as to propose an appropriate research methodology for studying their relationship (correlation or causality) the following research methods were applied: monographic method reviewing the relevant theories and models, synthesis and logical analysis for conceptualization of IT/AI use in relation to labor productivity in firms. For empirical interpretation of conceptual frameworks of IT/AI use and labor productivity in firms, statistical indicators from the annual survey on IT/AI use in Latvian firms, which [survey] has been conducted by the Central Statistical Bureau of Latvia since 2004, were used (Central Statistical Bureau of Latvia, 2024a).

The structure of the study consists of five main sections. The literature review provides an extensive theoretical background, organized into four parts. The third section presents our original conceptual framework of IT/AI use in relation to labor productivity, integrating theoretical models and empirical indicators from Latvian statistics. The fourth section proposes a research methodology for studying the IT/AI–productivity relationship, suggesting a hybrid approach that combines quantitative causal inference methods with qualitative tools like case studies and interviews. The final section draws conclusions from the study, addresses its limitations, and offers recommendations for future empirical research.

2. Literature review

This literature review aims to explore: conceptual framework of IT/AI use in firms, conceptual framework of labor productivity, studies on impact of IT/AI use on labor productivity in firms, research methodologies used to analyze the relationship between IT/AI use and labor productivity in firms. Accordingly, this literature review is structured into several key sections:

(1) conceptual framework of IT/AI use in firms based on the following models and theories: the Technology Acceptance Model (TAM) that explains how perceived usefulness and ease of use influence technology adoption (Davis, 1986, 1989; Ma & Liu, 2004; Čižo et al., 2024), Diffusion of Innovations (DOI) Theory that examines the adoption curve of new technologies (Acemoglu et al., 2018; Cockburn et al., 2018), the Resource-Based View (RBV) arguing that IT/AI serve as strategic resources enhancing firm capabilities (Przegalinska et al., 2025; Han et al., 2025), Socio-Technical Systems (STS) Theory that highlights the interaction between technology and organizational structures (Appelbaum, 1997; Walker et al., 2008);

(2) conceptual framework of labor productivity including productivity and IT/AI relationship theories: conceptual framework and empirical interpretation of labor productivity (Maheshwari, 2016; Autor et al., 2020; Korshenkov & Ignatyev, 2020; Yousaf, 2023); Solow's Productivity Paradox that questions whether IT/AI investments translate into measurable productivity gains (Brynjolfsson et al., 2018; Capello et al., 2022), Brynjolfsson & McAfee's Second Machine Age arguing that IT/AI drive economic transformation by complementing human labor (Brynjolfsson & McAfee, 2014; Spencer, 2017), Complementarity Theory suggesting that IT/AI enhance productivity when combined with human capital and organizational changes (Biagi & Parisi, 2012; Fitri et al., 2023);

(3) studies on impact of IT/AI use on labor productivity in firms: efficiency gains – how IT/AI optimize workflows, reduce errors, and enhance decision-making (Ali et al., 2024; Shamim, 2024), automation vs. augmentation – the distinction between replacing human labor and augmenting human capabilities (Acemoglu & Restrepo, 2018; Isaza & Cepa, 2024; Paudel, 2024), challenges and risks – potential issues including workforce displacement, upskilling needs, and productivity paradoxes (Zirar et al., 2023);

(4) research methodologies used to analyze the relationship between IT/AI use and labor productivity in firms: quantitative approaches – econometric models (use of Cobb-Douglas production function with IT and AI

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variables), panel data analysis (longitudinal studies examining IT/AI investments and productivity trends),productivity indices (measuring productivity changes through Total Factor Productivity (TFP) and labor productivity metrics); qualitative approaches – case studies (in-depth analysis of specific firms implementing IT / AI-driven solutions), expert interviews and surveys (gathering insights from industry professionals and researchers); hybrid approaches – mixed-methods research (combining qualitative case studies with quantitative statistical models), experimental designs (conducting controlled experiments to measure IT / AI's impact on productivity) (Bartel et al., 2007; Syverson, 2011; Bianchini et al., 2022; Rammer et al., 2022; Necula et al., 2024; Paudel, 2024).

2.1. Literature review on conceptual framework of IT/AI use in firms

The Technology Acceptance Model (TAM) (Davis, 1986, 1989; Ma & Liu, 2004; Čižo et al., 2024) is a widely used framework for understanding and empirical interpretation of IT/AI use in firms. Developed by Davis (1986, 1989), TAM is grounded in social psychology, and has been extensively tested in various organizational settings to predict user acceptance and usage behavior. TAM identifies two key determinants of technology adoption (Davis, 1986, 1989): Perceived Usefulness (PU) – the degree to which a person believes that using a system will enhance job performance, and Perceived Ease of Use (PEOU) – the extent to which a person believes that using a system will be free of effort. Davis (1989) developed validated scales for measuring PU and PEOU, with high reliability (Cronbach's alpha: .98 for PU, .94 for PEOU). Empirical studies show that PU has a stronger correlation with actual usage than PEOU (Davis, 1986, 1989; Ma & Liu, 2004). In other words, users are more likely to adopt a system if they find it useful, even if it is not particularly easy to use. A meta-analysis of 26 empirical studies (Ma & Liu, 2004) on TAM found: (1) strong support for PU's predictive power on IT/AI acceptance, (2) inconsistent effects of PEOU on actual IT/AI use, (3) the need for context-specific modifications (e.g., industry, experience level, cultural factors).

One of the most influential theories in the domain of IT/AI use in firms is the Diffusion of Innovations (DOI) Theory, which explains the adoption curve of new technologies (Acemoglu et al., 2018; Cockburn et al., 2018). IT/AI are often considered General-Purpose Technologies (GPTs) that drive technological advancements across various industries (Acemoglu et al., 2018). These technologies enhance research and development (R&D) efficiency, improve firm survival rates, and contribute to long-term economic growth. Firms differ in their innovative capacity, which determines their ability to use and benefit from IT/AI (Acemoglu et al., 2018). High-type firms with strong innovation capabilities leverage IT/AI for improved efficiency and higher productivity growth. Low-type firms struggle with IT/AI use and may become unproductive over time. Market forces ensure that only productive firms remain active. Taxing incumbent firms can facilitate the exit of low-productivity firms, allowing resources to be reallocated to more innovative, IT / AI-driven firms (Cockburn et al., 2018). The DOI theory examines how IT/AI spread within an industry. Firms use IT/AI at different rates, categorized as innovators, early adopters, majority adopters, or laggards (Acemoglu et al., 2018). To quantify IT/AI use in firms, researchers (Acemoglu et al., 2018) use the following indicators: R&D expenditure measures investment in IT / AI-driven innovation. IT / AI-related patent filings track firm-level technological advancements. The shift of skilled labor to R&D roles examines the effect of IT / AI-driven firm exits on workforce dynamics. IT / AI-induced job creation tracks employment shifts towards AI-based industries. Taxation on incumbents helps reallocate resources to IT / AI-driven firms and enhances productivity. Avoiding excessive R&D subsidies prevents the survival of non-innovative firms, maintaining market efficiency (Cockburn et al., 2018). The above studies highlight the importance of IT/AI as transformative technologies that impact firm productivity, market dynamics, and labor reallocation.

The conceptual framework for understanding and empirical measurement of IT/AI use in firms based on the Resource-Based View (RBV) (Przegalinska et al., 2025; Han et al., 2025) emphasizes that IT/AI adoption and strategic implementation are driven by an organization's internal innovation resources (IIR) and collaborative innovation networks (CIN) (Przegalinska et al., 2025). Firms with proprietary datasets, internally developed algorithms, and specialized IT/AI talent gain a competitive advantage by leveraging these resources for sustained growth. Collaborative networks further enhance IT/AI orientation by fostering knowledge exchange across technology and data domains. However, external factors such as environmental uncertainty negatively moderate this relationship by introducing risks and unpredictability, making AI resource allocation more complex. Conversely, corporate digital culture positively influences IT/AI use in firms by enhancing employees'

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awareness and sensitivity to digital transformation (Han et al., 2025). The empirical measurement of IT/AI use in firms under RBV includes firm-level R&D investments in IT / AI, patent filings, IT / AI-related workforce composition, and the integration of IT / AI-driven decision-making (Przegalinska et al., 2025; Han et al., 2025). The above studies highlight that firms with strong IT/AI capabilities and collaborative innovation networks outperform competitors in terms of efficiency, product innovation, and strategic agility.

The conceptual framework for understanding and empirical measurement of IT/AI use in firms based on Socio-Technical Systems (STS) Theory (Appelbaum, 1997; Walker et al., 2008) emphasizes the integration of both social and technical components within organizations to optimize system performance. STS theory posits that firms using IT/AI in firms must ensure a balance between technological advancements and human processes to achieve sustainable efficiency (Appelbaum, 1997). The joint optimization principle of STS highlights that IT/AI should not only improve productivity but also enhance work quality and employee engagement. Empirical measurement of IT/AI use under STS theory involves assessing organizational technology adoption, employee interaction with IT/AI systems, workflow integration, and system adaptability (Walker et al., 2008). The theory underscores the importance of work design, advocating for decentralized decision-making, multi-skilled teams, and adaptive job roles that allow workers to leverage AI tools effectively (Appelbaum, 1997; Walker et al., 2008). The above studies suggest that firms using IT/AI with an STS approach see improved knowledge sharing, innovation capacity, and collaborative problem-solving, reducing resistance to AI-driven change.

2.2. Literature review on a conceptual framework of labor productivity including productivity and IT / AI relationship theories

Labor productivity is often defined as output per worker or sales per employee, reflecting a firm's efficiency in utilizing labor inputs. Recent studies (Maheshwari, 2016; Autor et al., 2020; Korshenkov & Ignatyev, 2020; Yousaf, 2023) highlight that productivity is influenced by firm-specific resources, industry concentration, and external economic conditions**.** The Resource-Based View (RBV) perspective emphasizes that firms with superior internal capabilities, such as investments in human capital and technology, achieve higher labor productivity (Maheshwari, 2016). The EFQM Excellence Model (Yousaf, 2023) links productivity with quality management, suggesting that firms with quality certifications tend to have different productivity dynamics compared to non-certified firms. Empirical research using firm-level panel data shows that certified firms often have lower labor productivity due to structural constraints, while non-certified firms tend to exhibit stronger performance growth (Yousaf, 2023)**.**

Additionally, the Superstar Firm Hypothesis (Autor et al., 2020) posits that market concentration and technological advancements drive productivity growth among a few dominant firms**,** leading to a decline in the overall labor share of GDP. This phenomenon is observed through industry-wide shifts in sales concentration, where a small number of highly productive firms absorb a disproportionate share of economic output, reducing the relative importance of labor inputs (Autor et al., 2020). Empirical methodologies for measuring labor productivity in these studies include panel data analysis, generalized method of moments (GMM) estimation (Maheshwari, 2016), and correlation tests between firm performance indicators and labor productivity metrics**.** The above studies conclude that productivity is not solely a function of labor efficiency but also depends on firm strategies, technology adoption, and market structure dynamics, reinforcing the need for nuanced measurement approaches to understand labor productivity variations across industries and firm types.

The conceptual framework for understanding and empirical interpretation of labor productivity in firms based on Solow's Productivity Paradox (Brynjolfsson et al., 2018; Capello et al., 2022) focuses on the observed disconnect between technological advancements and their measurable impact on productivity growth. The above studies argue that despite rapid progress in IT/AI and digital automation, aggregate labor productivity growth remains sluggish due to four key explanations: false hopes, mismeasurement, redistribution effects, and implementation lags. The false hopes hypothesis (Brynjolfsson et al., 2018) suggests that technological optimism may be overstated, and IT / AI's real impact on productivity could be lower than anticipated. The mismeasurement explanation (Capello et al., 2022) posits that traditional economic indicators fail to capture the full productivity benefits of IT / AI, especially in industries where IT/AI contributes to quality improvements rather than direct output increases. The redistribution effect hypothesis (Capello et al., 2022) argues that IT / AI's gains are concentrated in a few superstar firms with high market power, leading to rising economic

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inequality and low overall productivity spillovers. Finally, the implementation lags explanation, which is the most widely accepted (Brynjolfsson et al., 2018; Capello et al., 2022), highlights that digital innovations require substantial complementary investments, organizational restructuring, and workforce reskilling before their full productivity benefits materialize. The above studies suggest that while IT / AI-driven firms experience localized productivity gains, sector-wide and economy-wide improvements are delayed due to slow diffusion, skills mismatch, and structural rigidities.

Brynjolfsson & McAfee's Second Machine Age (Brynjolfsson & McAfee, 2014; Spencer, 2017) is centered on the transformative impact of automation, and IT/AI on economic productivity. Their framework explains how digital advancements lead to exponential improvements in labor efficiency, yet paradoxically, these gains are not evenly distributed across the economy (Brynjolfsson & McAfee, 2014). They introduce the concepts of "bounty" and "spread", where the bounty refers to the economic abundance created by digital progress, and the spread highlights the growing inequality caused by automation favoring high-skilled labor while displacing routine jobs. Labor productivity in firms is measured through Total Factor Productivity (TFP), automation adoption rates, IT / AI-enhanced decision-making, and job polarization trends (Brynjolfsson & McAfee, 2014; Spencer, 2017). They emphasize that labor productivity gains from IT/AI and robotics require complementary human skills and institutional adaptations, including education, retraining, and policy interventions. Empirical data shows that leading firms leveraging IT/AI and data analytics experience productivity surges, while others lag behind, leading to a "winner-takes-all" market structure. Measurement approaches focus on IT / **AI**-driven firm efficiency metrics, employment shifts towards knowledge-intensive roles, and industry-wide automation diffusion rates (Spencer, 2017). The Second Machine Age framework suggests that future labor productivity growth depends on firms' ability to integrate IT/AI alongside human intelligence, promoting policies that ensure equitable technology diffusion to prevent workforce displacement and inequality.

The conceptual framework for understanding and empirical interpretation of labor productivity in firms based on Complementarity Theory (Biagi & Parisi, 2012; Fitri et al., 2023) highlights the interdependent role of IT / AI, human capital, and organizational capital in shaping productivity outcomes. The above studies suggest that IT/AI investments alone do not yield significant productivity gains unless complemented by human capital development and organizational change (Biagi & Parisi, 2012; Fitri et al., 2023). Firms that combine digital technologies with skilled labor and adaptive management structures experience higher labor productivity growth **due to** synergistic interactions. Empirical measurement of complementarity in labor productivity relies on Total Factor Productivity (TFP) estimation, firm-level panel data on IT/AI investments, employee skill assessments, and management practice indicators (Biagi & Parisi, 2012; Fitri et al., 2023). Study on Italian manufacturing firms indicate that organizational change and human capital investment significantly enhance the impact of IT/AI on productivity, with firms that undergo structural transformation achieving higher efficiency levels than those that merely adopt new technologies (Biagi & Parisi, 2012). The evidence also supports that IT / AI-enabled decentralization of decision-making, skill-intensive job design, and flexible work arrangements further strengthen the complementarities among technology, workforce, and management (Biagi & Parisi, 2012). The above studies conclude that labor productivity growth depends not just on technological inputs but on firms' ability to integrate complementary assets, reinforcing the idea that IT / AI's productivity effects materialize only when accompanied by appropriate human and organizational capital investments.

2.3. Studies on impact of IT/AI use on labor productivity in firms

The impact of IT/AI use on labor productivity in firms is reflected in efficiency gains through multiple dimensions, including automation, decision optimization, and innovation enhancement (Ali et al., 2024; Shamim, 2024). IT/AI use improves operational efficiency (Shamim, 2024) by automating repetitive tasks, reducing human errors, and optimizing resource allocation, leading to faster workflows and reduced costs. The above studies show that firms integrating IT/AI in human resource management, production processes, and customer service achieve higher labor efficiency by reallocating human workers to more complex, value-added tasks. Empirical measurement of IT / AI-driven labor productivity includes output per worker, total factor productivity (TFP), and process efficiency improvements, with findings indicating that firms with IT / AI-enabled decision support systems exhibit greater adaptability and innovation (Ali et al., 2024). While efficiency gains are evident, the above studies also highlight challenges such as skills mismatches, resistance to

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technological change, and capital investment barriers, which can delay the realization of AI-driven productivity benefits. Overall, the findings suggest that IT/AI use in firms is a key driver of labor productivity growth, provided there is complementary investment in workforce training, digital infrastructure, and strategic implementation frameworks (Ali et al., 2024; Shamim, 2024).

The impact of IT/AI use on labor productivity in firms is reflected also in studies through a complex interplay between automation, augmentation, and reallocation of labor (Acemoglu & Restrepo, 2018; Isaza & Cepa, 2024; Paudel, 2024). Automation enhances productivity by substituting human labor with IT/AI for routine and repetitive tasks, reducing costs and increasing efficiency (Acemoglu & Restrepo, 2018). However, it also introduces displacement effects, where workers previously performing automated tasks face job losses or role modifications. Augmentation, on the other hand, complements human labor by integrating IT/AI that assist rather than replace, leading to an increase in workers' capabilities, efficiency, and task complexity (Acemoglu & Restrepo, 2018; Paudel, 2024). The above studies highlight that automation can initially increase workloads as employees adapt to new technologies, reconfigure their tasks, and develop new skills. This process can cause temporary inefficiencies and even demotivation. However, once IT/AI systems and automation technologies are well-integrated, firms experience long-term productivity gains due to improved operational efficiency, error reduction, and enhanced decision-making capabilities. Augmentation, particularly in knowledge-based jobs, enables employees to leverage IT/AI for data analysis, decision support, and predictive modeling, leading to higher output per worker (Acemoglu & Restrepo, 2018; Isaza & Cepa, 2024). In general, the above studies show that IT/AI use in firms drive productivity growth by automating repetitive tasks, augmenting human decision-making, and reallocating labor towards high-value activities. However, to achieve sustainable productivity gains, firms and policymakers must carefully balance automation and augmentation while facilitating labor force transitions through training and reallocation strategies.

The impact of IT/AI use on labor productivity in firms, as reflected in the study on AI coexistence workplace (Zirar et al., 2023), is primarily viewed through the lens of worker-AI coexistence and the evolving nature of workplace interactions. AI integration in firms contributes to operational efficiency, faster decision-making, and innovation, yet the impact on labor productivity is complex and contingent on worker adaptability (Zirar et al., 2023). The above study identifies a dual effect of AI on labor: while automation reduces worker involvement in repetitive tasks, it also demands continuous upskilling and adaptation to maintain a productive human-AI relationship. AI is not merely a substitute for human labor but acts as an augmenting force, enabling workers to focus on higher-value cognitive and creative tasks. However, labor productivity gains are not uniform across all firms and industries; firms that invest in technical, human, and conceptual skill development for their employees tend to experience more sustainable productivity improvements. A key challenge to productivity growth with AI adoption is the distrust and fear of job displacement among workers (Zirar et al., 2023). The above study highlights that AI's impact on labor varies depending on skill levels: low-skilled workers face higher risks of job displacement, while high-skilled workers benefit from AI augmentation. The above study proposes that AI-driven workplaces should foster a symbiotic relationship where workers leverage AI for efficiency rather than being replaced by it. However, firms that neglect workforce training and adaptation strategies may struggle with AI implementation, leading to reduced productivity and workforce resistance.

2.4. Research methodologies used to analyze the relationship between IT/AI use and labor productivity in firms

Some reviewed studies (Bartel et al., 2007; Syverson, 2011; Bianchini et al., 2022; Rammer et al., 2022; Necula et al., 2024; Paudel, 2024) suggest several quantitative and qualitative approaches for analyzing the relationship between IT/AI use and labor productivity in firms. Quantitative approaches include econometric modeling such as panel data regressions, which incorporate firm-level data on IT/AI investments, and productivity indicators such as output per worker, innovation outputs (e.g., patents, R&D spending), and efficiency gains (Bartel et al., 2007; Bianchini et al., 2022; Necula et al., 2024). The Cobb-Douglas production function augmented with IT/AI variables is commonly used to estimate their contribution to firm productivity (Syverson, 2011; Bianchini et al., 2022). Another statistical method is difference-in-differences (DiD) estimation (Bartel et al., 2007; Necula et al., 2024), which compares firms using IT/AI with those that do not, controlling for external economic trends and firm-specific factors. This approach helps identify the causal impact (Gershman & Ullman, 2023; Little, 2023; Hussain et al., 2024) of IT/AI on labor productivity. Instrumental variable (IV) regressions are used to

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address endogeneity issues, leveraging exogenous factors such as historical IT/AI infrastructure levels or government incentives for IT/AI use as instruments (Necula et al., 2024). Some studies (Syverson, 2011; Bianchini et al., 2022; Paudel, 2024) employ Stochastic Frontier Analysis (SFA) to distinguish productivity gains due to IT/AI from those arising from conventional efficiency improvements. Machine learning techniques, including random forests, support vector machines, and gradient boosting methods, are used to predict labor productivity changes and capture complex non-linear relationships between IT/AI use, workforce skills, and firm performance (Bianchini et al., 2022; Rammer et al., 2022; Necula et al., 2024). Bayesian network analysis provides insights into probabilistic dependencies between IT/AI usage, innovation, and firm-specific factors (Paudel, 2024).

Among qualitative approaches**,** case studies and firm-level surveys are commonly used to understand the impact of IT/AI on workplace productivity (Bartel et al., 2007; Syverson, 2011; Bianchini et al., 2022; Rammer et al., 2022; Necula et al., 2024). Researchers conduct interviews and observational studies to capture employee perceptions of IT/AI-driven changes in workflow efficiency and task augmentation (Bartel et al., 2007; Bianchini et al., 2022; Rammer et al., 2022). Content analysis of corporate reports, job postings, and policy documents helps assess how firms integrate IT/AI into their business strategies (Rammer et al., 2022). Thematic analysis of employee feedback provides insights into challenges associated with IT/AI adoption, such as skill mismatches, resistance to change, and ethical concerns (Syverson, 2011; Bianchini et al., 2022). Event studies combined with propensity score matching (PSM) are used to compare firms before and after IT/AI adoption while ensuring that firms with similar characteristics are compared to minimize selection bias (Rammer et al., 2022; Necula et al., 2024). By integrating quantitative econometric models with qualitative insights from case studies and surveys, researchers obtain a comprehensive understanding of how IT/AI use impact labor productivity in firms, identifying both measurable productivity effects and broader organizational transformations.

Summarizing, we identified the following challenges and gaps in existing research: (1) lack of a complex conceptual framework of IT/AI use if firms in relation to labor productivity, (2) measurement issues, which mean difficulties in quantifying IT / AI-driven productivity gains, (3) causal vs. correlational relationships establishing causality between IT/AI use and productivity in firms. Overall, this literature review highlights the significant role of IT/AI in shaping labor productivity while emphasizing the need for rigorous research methodologies in order to study the relationship between IT/AI use and labor productivity in firms. We hope to fill this gap by developing conceptual frameworks of IT/AI use and labor productivity in firms and the methodology for studying the relationship between them.

3. Conceptual frameworks of IT/AI use in relation to labor productivity in firms

The main ideas and guidelines for conceptual frameworks of IT/AI use in relation to labor productivity in firms, drawn from the above literature review, emphasize the theoretical foundations, methodological approaches, and empirical findings shaping this relationship. IT/AI are widely acknowledged as critical drivers of productivity, yet their effects are complex and dependent on firm-specific, industry-wide, and macroeconomic factors. The Technology Acceptance Model (TAM) explains IT/AI use based on perceived usefulness and ease of use, highlighting that productivity gains depend on how effectively firms integrate and utilize these technologies (Davis, 1986, 1989; Ma & Liu, 2004; Čižo et al., 2024). The Diffusion of Innovations (DOI) Theory underscores the adoption curve of IT / AI, identifying firms as innovators, early adopters, majority adopters, or laggards, suggesting that productivity benefits are distributed unevenly based on adoption speed and scope (Acemoglu et al., 2018; Cockburn et al., 2018). The Resource-Based View (RBV) conceptualizes IT/AI as strategic assets, meaning that firms with strong internal capabilities, such as proprietary data, specialized algorithms, and skilled labor, derive higher productivity benefits (Przegalinska et al., 2025; Han et al., 2025). The Socio-Technical Systems (STS) Theory posits that IT/AI productivity effects depend on the interplay between technology, organizational structures, and worker adaptation, advocating for human-IT/AI collaboration rather than pure automation (Appelbaum, 1997; Walker et al., 2008).

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We suppose that conceptually the difference between the availability of IT/AI and its real use is important. It is stressed by van Dijk's Theory of Digital Divide (van Dijk, 2006, 2017) and the Resource-Based View (RBV) (Przegalinska et al., 2025; Han et al., 2025) rooted in Bourdieu's Theory of Social Fields Bourdieu, 2005). Van Dijk (2006, 2017) emphasizes that mere access to IT/AI (material access) does not automatically lead to its effective use. He identifies four types of IT/AI access: (1) motivational access, which refers to interest and willingness to use IT/AI, (2) material access, which is the physical availability of devices and the Internet, (3) access skills, which encompass the necessary skills for effective IT/AI use, (4) and access use, which refers to the actual usage and application of IT/AI. This framework highlights that a lack of skills or motivation can prevent individuals from effectively using IT/AI, even if they have access to technology. The resource approach developed from Bourdieu's theory explains that individuals and firms have different "resource portfolios" and its activation/capitalization capacity, which determine how effectively they can capitalize on available technology (Komarova et al., 2022). This means that some firms may have IT/AI access but struggle to translate it into real benefits due to differences in education, social capital, and skills. Both van Dijk's Theory of Digital Divide and the Resource-Based View (RBV) stress that equal access to IT/AI does not mean equal outcomes. While infrastructure and devices may be available, their actual use (the subject of this study) depends on socioeconomic status, digital skills, and motivation of employees, as well as organizational efficiency in the field of IT/AI use. Table 1 summarizes the above theoretical background for the conceptual framework of IT/AI use in relation to labor productivity in firms providing also the empirical interpretation of the concept of IT/AI use in relation to labor productivity in firms and the empirical indicators from the official statistics of Latvia.

Table 1. Theoretical backgrounds and empirical interpretations for the conceptual framework of IT/AI use in relation to labor productivity in firms

Theoretical background for the conceptual framework	Empirical interpretation of the concept of IT/AI use in relation to labor productivity in firms	Empirical indicators from the official statistics of Latvia
Technology Acceptance Model (TAM)	IT/AI use based on perceived usefulness and ease of use; productivity gains depend on how effectively firms integrate and utilize these technologies	Firms which provide training to develop IT/AI skills of the employees Firms which employ/recruit IT specialists Firms whose employees have remote access to the firm's e-mail system, documents, applications or software Presence of own personnel for IT functions performance in firms Firms paying for advertising on the Internet Internet connection downloading speed in firms Employees using any type of device with Internet connection in their job regularly Use of Internet and websites in firms Use of website function in firms Use of business software Use of social media in firms Cloud computing services purchased by firms Firms using cloud computing services Internet use in firms for interaction with public authorities IT/AI-related environmental protection measures in firms Firms that provide employees with information on IT/AI security requirements Use of Internet of Things in firms Firms that analyzed big data
Diffusion of Innovations (DOI) Theory	Firms are identified as innovators, early adopters, majority adopters, or laggards, suggesting that productivity benefits are distributed unevenly based on adoption speed and scope	
Resource-Based View (RBV)	Firms with strong internal capabilities, such as proprietary data, specialized algorithms, and skilled labor, derive higher productivity benefits	
Socio-Technical Systems (STS) Theory	IT/AI productivity effects depend on the interplay between technology, organizational structures, and worker adaptation, advocating for human-IT/AI collaboratin rather than pure automation	

Source: own elaborated based on Davis, 1986, 1989; Ma & Liu, 2004; Čižo et al., 2024; Acemoglu et al., 2018; Cockburn et al., 2018; Przegalinska et al., 2025; Han et al., 2025; Appelbaum, 1997; Walker et al., 2008; Central Statistical Bureau of Latvia, 2024b–2024t.

Table 1 presents theoretical backgrounds also empirical interpretations for the conceptual framework for understanding IT/AI use in relation to labor productivity in firms, integrating multiple theoretical perspectives with empirical interpretations and measurable indicators from official Latvian statistics. For example, the empirical indicators reflecting TAM, DOI, RBV and STS Theory include firms providing IT/AI skills training, employing IT/AI specialists, ensuring remote access to firm systems, investing in online advertising, and having

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high-speed internet connections. Additionally, firms' regular use of internet-connected devices, websites, business software, social media, cloud computing services, and big data analytics further exemplify this framework. Theoretical backgrounds also empirical interpretations for the conceptual framework for understanding IT/AI use in relation to labor productivity in firms suggest that labor productivity in firms depends not only on technology adoption but also on organizational readiness, employee training, resource availability, and the balance between human and technological capabilities. The official statistics of Latvia provide empirical validation through indicators that measure IT integration in firms, workforce preparedness, IT-enabled interactions with public authorities, security measures, and environmental initiatives. By synthesizing these theories, the framework establishes that IT/AI's impact on labor productivity is multidimensional, requiring firms to align technological investments with human capital development, infrastructure, and strategic adaptation to maximize efficiency and competitive advantage.

The reviewed literature on the conceptual understanding of labor productivity in firms corresponds with the above methodological premises examining productivity measurement challenges based on the Solow Productivity Paradox, which questions why IT/AI investments do not always translate into measurable productivity gains (Brynjolfsson et al., 2018; Capello et al., 2022). Brynjolfsson & McAfee's Second Machine Age framework highlights exponential productivity growth driven by IT/AI but warns of increasing inequality and job polarization (Brynjolfsson & McAfee, 2014; Spencer, 2017). Complementarity Theory suggests that IT/AI productivity gains are maximized when combined with human capital development and organizational change, supporting evidence that firms integrating IT/AI with skilled labor and adaptive management structures outperform those relying on technology alone (Biagi & Parisi, 2012; Fitri et al., 2023). The studies reviewed emphasize that IT/AI improves labor productivity primarily through automation, augmentation, and reallocation of labor. IT/AI-driven productivity (which is often studied together with organizational efficiency in the reviewed literature) can be empirically interpreted using e-commerce indicators from official Latvian statistics:

- countries of origin of clients, from which enterprises received orders, using Internet (Central Statistical Bureau of Latvia, 2024u);
- Internet sales of goods and services (Central Statistical Bureau of Latvia, 2024v, 2024w);
- firms which have sold goods or services via Internet or other computer networks (Central Statistical Bureau of Latvia, 2024x);
- firms that issued/sent electronic or paper invoices (Central Statistical Bureau of Latvia, 2024y).

And common labor productivity (not only IT/AI-driven, but influenced by other factors) can be empirically interpreted using the indicator of total Gross Domestic Product (GDP) per person employed (Central Statistical Bureau of Latvia, 2024z).

Based on the theoretical backgrounds also empirical interpretations obtained from the reviewed literature and summarized in Table 1, we propose our own conceptual framework of IT/AI use in relation to labor productivity in firms.

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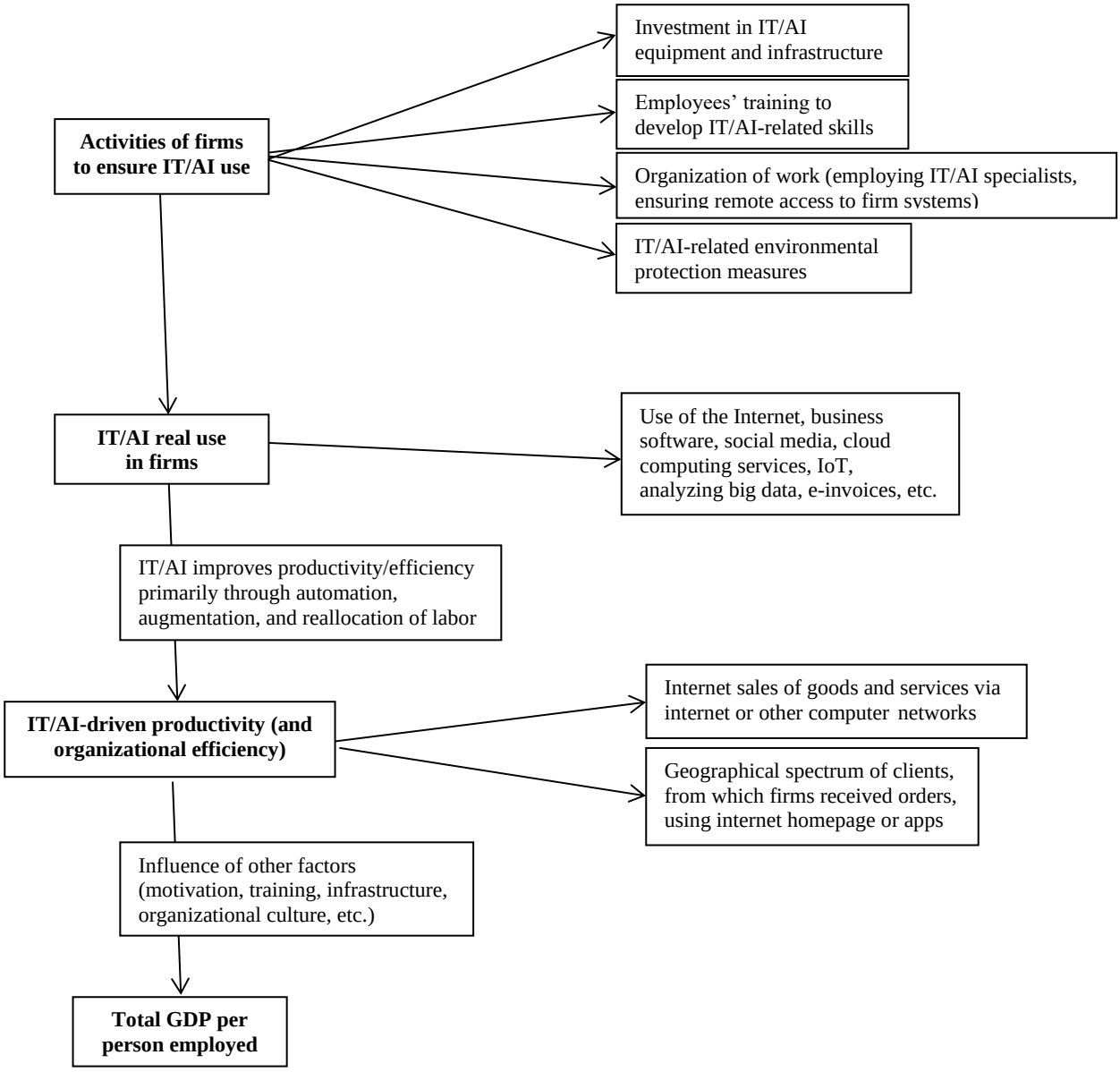


Figure 1. Conceptual framework of IT/AI use in relation to labor productivity in firms
Source: own elaborated based on the reviewed literature, Table 1 and empirical indicators provided by Latvian official statistics.

Figure 1 presents a comprehensive conceptual framework illustrating the relationship between IT/AI use and labor productivity in firms, integrating multiple theoretical models, empirical findings, and indicators from Latvian statistics. The framework is structured as a flow-like visual narrative beginning with investments in IT/AI infrastructure and employee training, highlighting the foundational role of internal firm activities. It emphasizes that real use of IT/AI technologies—including business software, social media, cloud services, IoT, and big data analytics—is central to improving productivity. The model stresses that the productivity gains from IT/AI stem from three interrelated mechanisms: automation, augmentation, and labor reallocation. Automation refers to substituting human labor in routine tasks, augmentation means enhancing human capabilities through IT/AI, and reallocation involves shifting labor toward more complex, value-added roles. The model also links IT/AI use to firms' digital business operations such as internet-based sales, issuance of electronic invoices, and international digital reach through web platforms, portraying these as outcomes of digital maturity and contributors to productivity. All these elements together feed into IT/AI-driven productivity and organizational efficiency, which in turn contribute to broader labor productivity measured through indicators like GDP per

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person employed. The framework further acknowledges the influence of many other external factors on productivity, stressing that IT/AI is not a sole determinant. Conceptually, it also highlights "synergy effects" at each stage—suggesting that productivity outcomes are not just additive but result from interconnected improvements across technology, human capital, and organizational processes. In essence, Figure 1 encapsulates a systemic view where IT/AI adoption is a multi-layered process involving technological, human, and structural dimensions, all of which interact to shape firm-level productivity in a digital economy.

4. The methodology for studying relationship between IT/AI use and labor productivity in firms

Methodologically, the literature highlights quantitative and qualitative approaches for studying IT/AI and labor productivity. Econometric models, particularly panel data regressions, difference-in-differences (DiD), and instrumental variable (IV) regressions, help isolate causal effects of IT/AI use (Bartel et al., 2007; Bianchini et al., 2022; Necula et al., 2024). Stochastic Frontier Analysis (SFA) decomposes productivity into efficiency gains from IT/AI versus other factors (Syverson, 2011; Bianchini et al., 2022; Paudel, 2024). Machine learning techniques, including random forests, support vector machines, and Bayesian networks, predict labor productivity trends and uncover complex interactions (Bianchini et al., 2022; Rammer et al., 2022; Necula et al., 2024; Paudel, 2024). Qualitative methods, such as case studies, expert interviews, and content analysis, provide insights into organizational adaptation and worker experiences (Bartel et al., 2007; Syverson, 2011; Bianchini et al., 2022; Rammer et al., 2022; Necula et al., 2024). We believe that hybrid approaches, such as mixed-methods research and experimental designs, integrate statistical modeling with firm-level observations to capture both quantitative impacts and qualitative transformations.

Table 2. Research methodology for studying IT/AI use and labor productivity relationship (correlation or causality) in Latvian firms

Approaches	Methods	Data and analysis	Benefits
Quantitative (causal inference-focused) approach (to isolate **causal effects**, not just correlations)	Panel data regression models	Longitudinal data from the Central Statistical Bureau of Latvia (2004–present) on IT/AI use and labor productivity indicators Control for firm characteristics (size, industry, region) and macroeconomic conditions	Captures time-based trends and effects
	Difference-in-differences (DiD) estimation	Comparing productivity changes in firms **before and after** significant IT/AI use against firms that didn't use	Helps establish causality by removing time-related and firm-specific biases
	Instrumental variable (IV) regression	Using instruments like prior regional IT/AI infrastructure, EU funding eligibility, or national digitalization policies to account for endogeneity	Strengthens causal claims when IT/AI use may be influenced by unobserved productivity-related factors
	Stochastic Frontier Analysis (SFA)	Decomposing total productivity into "technical efficiency" and "technological innovation" components	Useful to identify how much of productivity is driven specifically by IT/AI efficiency gains
Qualitative component (complementary)	Case studies	Deep diving into specific firms that are innovators, early adopters, majority adopters, or laggards (based on DOI theory) classified using cluster analysis	Highlight internal processes, organizational change, employee experience, and managerial practices
	Expert interviews & surveys	Sociological data from firms executives, IT managers, and employees	Assesses subjective perception of IT/AI influence on day-to-day productivity in firms
	Content & thematic analysis	Analyzing corporate reports, digitalization strategies, or internal communications	Assesses how firms perceive and manage IT/AI-related transformation
Advanced predictive/exploratory tools (optional but insightful)	Machine learning models (random forests, SVMs, gradient boosting)	A well-structured dataset containing **firm-level data** with both **input** features (predictors) and a **clear** target variable (output)	Can identify complex, non-linear interactions between IT/AI use and productivity outcomes
	Bayesian networks	Firm-level data structured to capture not only direct cause-effect relationships but also probabilistic dependencies between variables	Explore probabilistic dependencies among factors like training, infrastructure, remote access, and productivity

Source: own elaborated based on the reviewed literature and Figure 1.

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Thus, for studying the relationship between IT/AI use and labor productivity in firms (especially to distinguish **correlation** from **causality**) the most effective approach would be a hybrid methodology that combines rigorous quantitative analysis with rich qualitative insights. For further empirical study of IT/AI use in relation to labor productivity in Latvian firms, we will use such a hybrid approach combining DiD and panel regression models (for causality), supported by firm-level case studies and interviews (for depth and context). This combination not only strengthens the empirical validity of our results but also allows us to explore the multidimensional factors (like motivation, training, infrastructure, organizational culture) that the conceptual framework in Figure 1 emphasizes.

5. Conclusions

The study set out to develop conceptual frameworks and propose an appropriate research methodology to study the relationship between IT/AI use and labor productivity in firms, particularly within the context of Latvian ones. Addressing the three core research questions, the study has yielded several key insights:
(1) the main theoretical foundations (such as the Technology Acceptance Model (TAM), Diffusion of Innovations (DOI), Resource-Based View (RBV), and Socio-Technical Systems (STS) Theory) collectively provide a multidimensional understanding of IT/AI use in firms. These theories show that technology adoption is not solely about infrastructure or access, but deeply tied to organizational capabilities, human resources, and sociotechnical dynamics;
(2) the study distinguishes between labor productivity and labor efficiency, arguing they are related but conceptually distinct. Labor productivity typically refers to output per worker, while efficiency considers the broader use of all production factors. However, among the key terms of this study are labor productivity and organizational efficiency, which [organizational efficiency] refers to the organization of work in firms and efficiency of business processes;
(3) a hybrid research methodology was proposed to capture both the correlational and causal aspects of the IT/AI–productivity relationship. This includes panel data regressions, difference-in-differences estimation, instrumental variable models, and Stochastic Frontier Analysis for causal inference, complemented by qualitative methods such as case studies and expert interviews. Advanced tools like machine learning and Bayesian networks are also recommended for modeling complex relationships and probabilistic dependencies.

The conceptual framework presented in Figure 1 captures how IT/AI investments, skills development, and digital business practices interact to drive labor productivity through automation, augmentation, and labor reallocation. The framework reflects empirical realities by incorporating measurable indicators from official Latvian statistics and emphasizing synergy effects between technological, human, and organizational elements. Overall, the study provides a robust conceptual and methodological foundation for exploring the IT/AI–labor productivity nexus. Its proposed hybrid approach offers a roadmap for future research to generate both theoretically grounded and empirically validated insights in the rapidly evolving digital economy.

The study has the following limitations:

- while the study proposes comprehensive frameworks and methodologies, it remains conceptual and methodological in nature. Empirical validation of the proposed models using real-world Latvian firm data is yet to be conducted;
- the framework is rooted in data and policy conditions specific to Latvia. As such, the generalizability to other countries (especially those with different digital maturity levels) may be limited;
- the study relies on indicators from national statistics, which, although rich, may not fully capture nuanced organizational practices, employee attitudes, or informal uses of IT/AI.

For future empirical research, we are planning to c**o**nduct hybrid empirical study using panel datasets from Latvian firms, applying the proposed causal inference methods (e.g., DiD, IV models) supplementing official statistics with firm-level surveys and interviews that capture employee experiences, managerial strategies, and barriers to IT/AI use. Furthermore, we would like to apply the developed framework within specific industries (e.g., manufacturing, logistics, services) to identify and compare sectoral patterns in IT/AI use and productivity dynamics.

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TOURISM GROWTH, ECONOMIC DEVELOPMENT, AND ENVIRONMENTAL SUSTAINABILITY IN SAUDI ARABIA

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Abstract. This study investigates tourism development's economic and environmental impacts focusing on sustainability and long-term , growth, among other economic indicators, in Saudi Arabia. It evaluates the Tourism-Induced Environmental Kuznets Curve (T-EKC) hypothesis, which suggests that while initial tourism growth may harm the environment, pollution levels typically decline as economies mature and adopt sustainable practices. Using Fully Modified Ordinary Least Squares (FMOLS) regression, this study analyzes the relationship between the ecological footprint and key variables—GDP per capita, squared GDP per capita, tourism expenditure per capita, energy production per capita, and trade openness—from 2002 to 2020. The results indicate that GDP and energy production per capita increase environmental pressure, while tourism expenditure also adds to the ecological footprint. Conversely, trade openness may reduce environmental impact through cleaner production practices. These findings support the T-EKC hypothesis and highlight tourism's dual economic and environmental challenges. They underscore the necessity for policy-driven strategies that effectively balance economic growth and sustainability, which aligns with Saudi Arabia's Vision 2030.

Keywords: tourism development; economic development; environmental Kuznets Curve; environmental sustainability

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1. Introduction

Tourism has long been recognized as a critical driver of economic growth, contributing significantly to GDP, employment, and foreign exchange earnings. Empirical studies illustrate a strong correlation between tourism indicators, such as expenditure, revenue, international tourist arrivals, and overall economic development (Ageli, 2013; Ali & Salameh, 2021; Emam & Ali-Dinar, 2024; Bayramli & Karimli, 2024, Awanet al., 2025).

In Saudi Arabia, tourism is a key component of Vision 2030, a strategic initiative designed to reduce oil dependence and encourage new economic sector growth (Vision 2030, 2024). However, the rapid expansion of the tourism sector also brings environmental challenges, necessitating policies that harmonize economic advantages with ecological sustainability. Notable concerns include carbon emissions from transportation, excessive water usage in the hospitality industry, and waste management challenges. Furthermore, the substantial influx of visitors to Mecca and Medina for religious tourism exacerbates these pressures, underscoring the urgency of effective sustainable management strategies. Tourism can boost economic growth, but proper management is required to avoid harming the environment (Holden, 2016; Kilinc-Ata & Barut, 2024; Segarra et al., 2024).

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Saudi Arabia has introduced ambitious sustainability initiatives to address environmental challenges, including the Saudi Green Initiative (SGI) and Sustainable Tourism Global Center (STGC). These initiatives are aligned with the nation's objective of achieving net zero emissions by 2060, as outlined in Vision 2030 (Vision 2030, 2024). The country is making significant investments in renewable energy, promoting green transportation, and implementing stricter environmental regulations to minimize the ecological footprint of tourism. The private sector is also crucial in developing eco-friendly accommodations and sustainable transportation options. Notable projects, such as the Red Sea Project, which operates solely on renewable energy, and Trojena in NEOM, which integrates cutting-edge clean energy solutions, exemplify Saudi Arabia's commitment to leading the way in sustainable tourism (Vision 2030, 2024).

This study utilizes Fully Modified Ordinary Least Squares (FMOLS) regression to investigate the validity of the Tourism-Induced Environmental Kuznets Curve (T-EKC) hypothesis in Saudi Arabia, spanning 2002 to 2020. This research focuses on the ecological footprint as the dependent variable, with tourism expenditure per capita as the primary independent variable. Additional variables considered included GDP per capita, the square of GDP per capita, energy production per capita, and Trade openness. The T-EKC hypothesis expands on the broader Environmental Kuznets Curve (EKC) hypothesis by emphasizing the influence of tourism on environmental change. While the EKC examines the impact of industrialization and energy usage on environmental quality, the T-EKC suggests that initial increases in tourism may negatively impact the environment. Pollution levels decline as economies mature and adopt sustainable practices (Akadiri et al., 2021). This research adopts ecological footprint as a more holistic indicator of environmental impact rather than focusing exclusively on CO_2 emissions, thereby contributing to the growing body of literature on sustainable tourism economics.

The primary goal of this study is to analyze the relationship between tourism growth and environmental quality in Saudi Arabia, evaluate the validity of the T-EKC hypothesis within the country's economic context, and assess the effectiveness of sustainable tourism policies in mitigating environmental degradation. The study indicates that higher GDP and energy production per capita increase environmental pressure, while tourism expenditure also contributes to ecological footprint expansion. In contrast, greater trade openness can reduce environmental impact through technology transfer and cleaner production methods. The relevance of the GDP squared per capita supports the T-EKC hypothesis, suggesting that economic growth can eventually enhance environmental quality. The findings offer valuable insights for policymakers as they develop tourism strategies that align with Vision 2030. Enhancing sustainable tourism policies through investment in green infrastructure and implementing eco-friendly initiatives is essential. Expanding the adoption of renewable energy is crucial to reduce tourism emissions. Stricter regulations for pilgrimage tourism, such as mandatory carbon offsets, promotion of sustainable transportation methods, and improved waste management, can significantly mitigate its environmental impact. Moreover, encouraging eco-tourism and cultural tourism can help distribute environmental pressure evenly across regions. Investing in and trading green technologies can bolster Saudi Arabia's sustainability efforts. This study comprises four primary sections: theoretical background, research objectives and methodology, results and discussion, and conclusions.

2. Theoretical Background

The relationship between tourism and environmental degradation has been examined thoroughly using various datasets and methodological approaches. Existing literature can be categorized into three primary groups: panel studies, country-level studies, and studies focused explicitly on Saudi Arabia. This organized framework underscores the key findings and emphasizes the distinctive contributions of this research on the T-EKC in Saudi Arabia from 2002 to 2020.

Panel studies provide valuable insights into the T-EKC hypothesis by examining various countries over extended periods. Nosheen et al. (2021) focused on Asian economies using Dynamic Ordinary Least Squares (DOLS) and cointegration tests. Their findings confirm that while economic growth initially deteriorates environmental quality, it ultimately leads to improvement. They noted that tourism and energy consumption contributed significantly to increased CO_2 emissions. Similarly, Rahman et al. (2022) analyzed the top ten tourist destinations worldwide using Cointegration and Structural Autoregressive Distributed Lag (CS-ARDL) and

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Average Mean Group (AMG) estimators. Their study revealed that tourism and fossil fuel consumption further exacerbated CO_2 emissions, whereas renewable energy played a crucial role in alleviating environmental degradation. Işık et al. (2020) examined G7 countries and found that the T-EKC hypothesis related to tourism was applied only to France, whereas tourism had a detrimental impact on CO_2 emissions in Italy. Azam et al. (2018) explored the T-EKC hypothesis in Malaysia, Singapore, and Thailand, uncovering contrasting results. Tourism in Malaysia was associated with increased CO_2 emissions, while in Singapore and Thailand, it was correlated with improved environmental quality due to advanced environmental regulations and green policies. Ahmad et al. (2018) analyzed the provinces involved in China's One Belt One Road (OBOR) initiative using FMOLS and cointegration tests. Their findings indicate that tourism reduces CO_2 emissions in most provinces but increases pollution in high-tourism areas.

The second category focuses on individual countries, allowing for a more in-depth examination of the relationship between tourism and the environment within specific economic and policy contexts. De Vita et al. (2015) expanded the traditional EKC model in Turkey, showing that while tourism contributes to higher emissions during the early stages of development, it later supports environmental improvements as the economy grows and cleaner technologies are adopted. Bamidele et al. (2022) examined the relationship among tourism development, energy consumption, and CO_2 emissions in Nigeria from 1995 to 2016. Researchers found that while tourism contributes to economic growth, it does not harm environmental quality. Fossil fuel-based energy consumption increases CO_2 emissions, whereas renewable energy use helps to reduce them. Their findings confirm the T-EKC hypothesis.

The third category includes studies that focus on Saudi Arabia, highlighting the environmental effects of tourism in the context of its rapidly expanding economy. As Saudi Arabia has undergone swift economic expansion and a burgeoning tourism sector, numerous investigations have explored its environmental repercussions. Li et al. (2024) examined the country's carbon emissions from 1990 to 2022 through the lens of the T-EKC framework and utilized Granger causality analysis. They identified a U-shaped correlation between economic growth and ecological decline, suggesting that, although international tourism leads to higher carbon emissions, using renewable energy helps reduce environmental damage. Tabash et al. (2023) analyzed the environmental impacts of religious tourism from 1986 to 2020 by employing the FMOLS and DOLS models. Their findings indicate that pilgrimage-related activities significantly exacerbated environmental degradation, contradicting the EKC hypothesis and supporting the Pollution Halo Hypothesis. By contrast, Emam and Ali-Dinar (2024) conducted Granger causality tests. They discovered that while tourist arrivals fostered GDP growth, they did not directly contribute to CO_2 accumulation, possibly because of practical government sustainability efforts. Ozturk et al. (2022) further reinforced that pilgrimage tourism substantially increases CO_2 emissions, revealing bidirectional causality between GDP and pollution. Finally, Faisal et al. (2024) concentrated on Saudi Arabia's sustainability initiatives from 2002 to 2020. They concluded that, while tourism expenditure did not significantly influence CO_2 emissions, energy consumption remained a critical driver of environmental degradation, with a direct relationship between GDP growth and emissions.

This study examines the connection between tourism development, economic growth, and environmental sustainability in Saudi Arabia from 2002 to 2020. It employs the ecological footprint as the dependent variable, with tourism expenditure, trade openness, GDP, GDP squared, and energy production as independent variables. Unlike earlier studies that primarily focused on CO_2 emissions, this investigation utilized the ecological footprint as a more comprehensive environmental indicator, encompassing land use, resource depletion, and carbon footprint. While previous research specific to Saudi Arabia has primarily centered on pilgrimage tourism, this study considers total tourism expenditure, offering a more comprehensive view of tourism's environmental impact. These findings align with the T-EKC hypothesis, showing that higher tourism expenditure leads to the deterioration of the ecological footprint. This finding contrasts with the results of Faisal et al. (2024), who found no significant correlation between tourism expenditure and CO_2 emissions. Furthermore, this study highlights the role of trade openness in reducing the ecological footprint, drawing attention to a factor that has often been overlooked in prior Saudi-focused EKC research.

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3. Research Objectives and Methodology

3.1. Model Specification

This study explores the long-term link between environmental degradation, measured by the ecological footprint (EF), and several key economic and tourism-related factors in Saudi Arabia. These factors included GDP per capita (GDP), squared GDP per capita (GDP^2), tourism expenditure per capita (Tourism), energy production per capita (EP), and trade openness (Trade). Additionally, this study examined the validity of the T-EKC hypothesis.

$EF = f(Tourism, GDP, GDP^2, EP, Trade)$.

The analysis employs the FMOLS estimation technique and utilizes time series data from Saudi Arabia from 2002 to 2020.
The model is specified as follows:

$$EF = \beta_0 + \beta_1 Tourism_t + \beta 2\ GDP_t + \beta 3\ GDP^2_t + \beta 4\ EP_t + \beta 5\ Trade_t + \epsilon$$

Where ϵ: error term

The framework for this analysis is based on the T-EKC hypothesis. While the traditional EKC hypothesis investigates the relationship between economic growth and environmental quality, the T-EKC hypothesis addresses how tourism development affects environmental degradation. By integrating tourism expenditures with conventional economic indicators, this study seeks to provide deeper insight into the interplay between tourism development, economic growth, and environmental sustainability in Saudi Arabia.

The initial estimation employed Ordinary Least Squares (OLS) to analyze the relationship between the ecological footprint and its key determinants. As shown in Table 1, GDP and Tourism have a significant positive impact on the ecological footprint, while Trade has a significant negative effect. Additionally, GDP^2 indicated a marginally significant negative effect, and energy production per capita was not statistically significant. The goodness-of-fit test for the OLS model presented in Table 2 demonstrated a high level of explanatory power, with an R-squared value of 0.9089 and an adjusted R-squared of 0.8739, suggesting that the model accounted for a substantial portion of the variation in the ecological footprint. However, the Durbin-Watson statistic of 1.38 pointed indicates potential autocorrelation. Coupled with concerns regarding endogeneity and serial correlation, this indicates that OLS may not be suitable for accurately estimating long-term relationships in time series data.

This study uses the FMOLS technique, initially developed by Phillips and Hansen in 1990 (Ucal & Bilgin, 2009), to estimate cointegrating relationships. FMOLS corrects for serial correlation and endogeneity while adjusting for autocorrelation and heteroscedasticity, which results in unbiased and efficient parameter estimates. The FMOLS method is particularly valued for its ability to provide reliable estimates, even with small sample sizes, making it an important robustness check (Bashier & Siam, 2014). This method is particularly effective for examining the long-term relationship between the ecological footprint and its determinants, as it minimizes the potential distortions found in standard OLS regressions.

Before applying FMOLS, we verify that all variables are integrated of order one (I(1)) and that cointegration is essential. As shown in Table 3, the unit root tests reveal that the variables are non-stationary at their levels but achieve stationarity after the first differencing, thereby satisfying the I(1) condition. Furthermore, the Johansen Cointegration Rank Test presented in Table 4 confirms the presence of long-run equilibrium relationships among the variables. This evidence suggests a shared long-term movement among the variables, justifying the use of FMOLS to estimate the long-term relationship between the ecological footprint, economic growth, and tourism development in Saudi Arabia.

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Table1. Ordinary Least Squares (OLS) Regression Estimates

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	-0.070036	1.211218	-0.057823	0.9548
EF	1899904.	1254695.	1.514236	0.1539
GDP	0.000297	8.59E-05	3.456403	0.0043
GDP^2	-5.27E-09	2.53E-09	-2.081961	0.0577
Trade	-3.319251	0.772151	-4.298707	0.0009
Tourism	4.842604	1.906012	2.540700	0.0246
R-squared	0.908893	F-statistic	25.93796	
Adjusted R-squared	0.873852	Prob(F-statistic)	0.000002	

Table 2. Goodness-of-fit for the OLS model

Goodness-of-fit tests	
Durbin-Watson test	DW = 1.378150
	p-value = 0.01395
Jarque-Bera normality test	Jarque-Bera statistic=1.891660
	p-value = 0.388357
Homoscedasticity Test:Breusch-Pagan-Godfrey	F-statistic=1.0115 p = 0.4495
Breusch-Godfrey Serial Correlation LM Test	F-statistic = 0.6903 p-value = 0.5219

Table 3. Unit Root Test Results Using the Elliott, Rothenberg, and Stock DF-GLS

Variable		**At Level**	**At first Difference**	
		Constant	Constant	constant and trend
EF	test statistic	-1.029	-3.538	-4.099
	Test critical values:			
	1% level	2.699	-2.708	-3.770
	5% level	1.961	-1.963	-3.190
	10% level	-1.606	-1.606	-2.890
EP	test statistic	-1.082	-3.867	-4.433
	Test critical values:			
	1% level	-2.699	-2.708	-3.770
	5% level	-1.961	-1.963	-3.190
	10% level	-1.607	-1.606	-2.890
GDP	test statistic	-1.489	-3.488	-4.049
	Test critical values:			
	1% level	-2.699	-2.708	-3.770
	5% level	-1.961	-1.963	-3.190
	10% level	-1.607	-1.606	-2.890
GDP^2	test statistic	-1.446	-3.296	-3.644
	Test critical values:			
	1% level	-2.699	-2.708	-3.770
	5% level	-1.961	-1.963	-3.190
	10% level	-1.607	-1.606	-2.890
Trade	test statistic	-0.855	-2.058	-3.669
	Test critical values:			
	1% level	-2.708	-2.708	-3.770
	5% level	-1.963	-1.963	-3.190
	10% level	-1.606	-1.606	-2.890
Tourism	test statistic	-2.689	-4.527	-3.952
	Test critical values:			
	1% level	-3.770	-2.708	-3.770
	5% level	3.190	-1.963	-3.190
	10% level	-2.890	-1.606	-2.890

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Table 4. Johansen Cointegration Rank Test

Null hypothesis (r)	Test Statistic	Critical Value (5%)	Decision
r ≤ 5	9.7	9.24	Reject r ≤ 5
r ≤ 4	26.9	19.96	Reject r ≤ 4
r ≤ 3	48.78	34.91	Reject r ≤ 3
r ≤ 2	89.87	53.12	Reject r ≤ 2
r ≤ 1	641.93	76.07	Reject r ≤ 1
r = 0	NaN	102.14	Not Computed

3.2. Data

Ecological footprint (EF) data were obtained from the Global Footprint Network (Global Footprint Network, n.d.). Data on tourism expenditure per capita (Tourism), GDP per capita (GDP), GDP squared per capita (GDP^2), and trade openness (Trade) for 2002–2020 were sourced from the World Bank. The energy production (EP) data were retrieved from the Energy Information Administration (EIA).

EF measures human demand on Earth's ecosystems and is expressed in hectares. EF is preferred over CO_2 emissions as a primary environmental indicator because it provides a more comprehensive environmental impact assessment (Al-Malki et al., 2024). While CO_2 emissions only account for greenhouse gases from fossil fuel use, ecological footprint measures the total biologically productive area required for human activities. This broader indicator captures the cumulative effects of land use, resource extraction, and waste production, making it essential for assessing sustainability and guiding policy decisions. Tourism is the primary independent variable that measures tourism development by calculating international tourism expenditure (in current US dollars) per capita in that year. Nosheen et al. (2021) state that tourism contributes to air, water, and noise pollution. Air pollution primarily results from transportation and energy-intensive development of tourism infrastructure, such as hotels and resorts. Following these studies (Ozturk et al., 2022; Nosheen et al., 2021; Zhang et al., 2020; Adebayo et al., 2022; Saenz-de-Miera & Rosselló, 2014), this study assumes a positive correlation between tourism expenditure and ecological footprint. GDP is the total gross domestic product in current US dollars divided by population for a given year. The relationship between economic growth and environmental impacts varies across studies. Ozturk et al. (2022) suggest that GDP negatively affects CO2 emissions, whereas other studies (Li et al., 2024; Tabash et al., 2023; Nosheen et al., 2021; Adebayo et al., 2022) indicate that GDP growth is linked to increased CO2 emissions. This study assumes that economic growth positively affects the ecological footprint.

GDP^2 reflects a nonlinear and inverted U-shaped association between economic growth and environmental degradation, suggesting that a higher GDP^2 contributes to reducing the ecological footprint (Nosheen et al., 2021). EP was assumed to drive the ecological footprint. Ghaderi et al. Ozturk et al. (2023), Ozturk et al. (2022), and Adebayo et al. (2022) showed that energy utilization contributes to pollution. Trade measures a country's engagement in international Trade and is calculated as the sum of exports and imports relative to the GDP. This study suggests that Trade negatively affects the ecological footprint. Managi et al. (2008) contend that trade openness enhances environmental quality.

4. Results and Discussion

4.1. Descriptive and Summary Statistics

Table 5 presents the summary statistics for the EF and key independent variables. The EF showed moderate variability (mean = 3.26, std. dev.: 0.63) and a relatively normal distribution (skewness: -0.11, kurtosis: 1.84). Among the independent variables, the EP (mean = 8.83E-07, std. dev.: 8.08E-08) and GDP (mean: 18,329.24, std. dev.: 5,154.89) display slightly positive and negative skews, respectively, while GDP^2 (mean: 3.61E+08) suggests potential nonlinear relationships. Tourism (mean: 0.127, skew: 0.53) shows a moderately positive skew, and Trade (mean: 0.75, skew: -0.21) indicates a moderate variation in trade openness. Normality tests (Jarque-Bera) revealed no significant deviations from normality across the variables. This dataset offers

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valuable opportunities to explore the drivers of ecological footprint, including the roles of energy production, GDP, tourism expenditure, and trade openness.

Table 5. Descriptive statistics of the variables.

	EF	**EP**	**GDP**	**GDP²**	**Tourism**	**Trade**
Mean	3.262105	8.83E-07	18329.24	3.61E+08	0.127289	0.753716
Median	3.320000	8.69E-07	19930.41	3.97E+08	0.117988	0.795617
Maximum	4.280000	1.04E-06	24175.58	5.84E+08	0.212221	0.961026
Minimum	2.330000	7.40E-07	8380.959	70240479	0.055566	0.497135
Std. Dev.	0.632083	8.08E-08	5154.889	1.76E+08	0.046393	0.130943
Skewness	-0.107546	0.353022	-0.563866	-0.225347	0.533138	-0.205168
Kurtosis	1.840191	2.364049	2.114210	1.745295	2.331383	2.045817
Jarque-Bera	1.101543	0.714820	1.627985	1.407117	1.253993	0.854083
Probability	0.576505	0.699486	0.443086	0.494821	0.534194	0.652437
Sum	61.98000	1.68E-05	348255.5	6.86E+09	2.418488	14.32061
Sum Sq. Dev.	7.191516	1.18E-13	4.78E+08	5.57E+17	0.038742	0.308627
Observations	19	19	19	19	19	19

4.2. Model Estimation

The FMOLS estimation results in Table 6 indicate significant long-run relationships between independent variables and EF. EP and GDP positively impact EF, showing that economic growth and increased energy production lead to greater environmental pressure (Li et al., 2024; Tabash et al., 2023; Nosheen et al., 2021; Adebayo et al., 2022; Ghaderi et al., 2023; Ozturk et al., 2022). Tourism also has a strong positive effect, emphasizing its environmental costs (Ozturk et al., 2022; Nosheen et al., 2021; Zhang et al., 2020; Adebayo et al., 2022; Saenz-de-Miera & Rosselló, 2014). By contrast, Trade negatively impacts EF (Managi et al., 2008), suggesting that it may lead to cleaner technologies and efficient resource use. The marginal significance of GDP^2 supports the T-EKC hypothesis (Nosheen et al., 2021), suggesting that environmental decline may first increase with economic growth but then decrease after surpassing a certain threshold. The model shows strong explanatory power, with R-squared values of 0.8887 and 0.8545, confirming the robustness of long-run relationships.

Table 7 presents the goodness-of-fit tests and diagnostic checks used to assess the reliability of the FMOLS estimation. The Breusch-Godfrey serial correlation LM test confirms no serial correlation in the residuals, as the test fails to reject the null hypothesis of no autocorrelation. Additionally, the Breusch-Pagan-Godfrey Heteroskedasticity test indicates that heteroskedasticity is not present, as the null hypothesis of homoscedasticity is not rejected. These diagnostic results suggest that the FMOLS model was correctly specified and provided reliable estimates. It is a suitable method for analyzing the long-term connections among economic activity, tourism, and ecological footprint in Saudi Arabia.

Table 6. FMOLS estimation.

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
EP	2064358.	623915.1	3.308717	0.0057
GDP	0.000252	5.98E-05	4.217932	0.0010
GDP^2	-4.02E-09	1.89E-09	-2.124414	0.0534
Trade	-3.271224	0.564711	-5.792744	0.0001
Tourism	5.782995	1.534811	3.767887	0.0023
R-squared	0.888713	Mean dependent var	3.313333	
Adjusted R-squared	0.854471	S.D. dependent var	0.608470	
S.E. of regression	0.232121	Sum squared resid	0.700441	
Long-run variance	0.029416			

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Table 7. Goodness-of-fit for the FMOLS model

Goodness-of-fit test	***FMOLS model***
Breusch- Serial Correlation LM Test:	p-value=0.5219
Heteroskedasticity Test: Breusch-Pagan-Godfrey	p-value=0.4495

Conclusions

This study validates the Tourism-induced Environmental Kuznets Curve (T-EKC) theory in the context of Saudi Arabia, demonstrating that tourism expenditure and economic growth initially increase ecological degradation but later contribute to environmental improvements as sustainable policies and technologies advance. The findings also highlight that energy production significantly impacts the ecological footprint, emphasizing the need for cleaner energy sources during the country's economic transition. Furthermore, trade openness reduced the ecological footprint, suggesting that greater economic integration and sustainable trade policies can support environmental sustainability in Saudi Arabia.

The key benefit of this study lies in its country-specific approach, which provides insights tailored to Saudi Arabia's unique economic and environmental landscape. Given the ambitious Vision 2030 goals, there is an urgent need for more studies that specifically utilize Saudi data, rather than applying generalized findings from other countries. Every nation has distinct economic structures, environmental policies, and tourism dynamics, making it essential to generate localized empirical evidence that aligns with the national strategies for sustainable development. However, this study has certain limitations. Data availability over a relatively short period (2002–2020) restricted the scope of the models that could be applied. Additionally, this period does not fully capture the impact of major economic disruptions, such as the COVID-19 pandemic, which has significantly affected global tourism, transportation, and economic activity. The absence of such economic shocks in the dataset may have influenced the results, warranting further research.

Another significant limitation of this study is its focus on the tourism sector. While this focus enables a comprehensive analysis of tourism's contribution to economic development and its role in Saudi Arabia's sustainable development goals, it is essential to recognize that other non-oil industries may also make substantial contributions to economic growth and environmental outcomes. Consequently, the relationship between tourism development, economic expansion, and environmental sustainability may not be unique to this sector; similar patterns could emerge in other areas of the economy. To gain a deeper understanding of the broader economic and environmental implications, future research should conduct cross-sectoral comparisons to ascertain whether tourism exhibits distinct economic-environmental dynamics or reflects more general trends associated with national development.

Future research should extend the data set to include a longer period and incorporate major economic shifts to enhance the robustness of the analysis. Moreover, advanced econometric models such as the Nonlinear Autoregressive Distributed Lag (NARDL) model can offer a more in-depth analysis of the asymmetric impacts of economic expansion and environmental changes. Additionally, incorporating renewable energy production as a key variable would offer more comprehensive policy insights and help shape sustainable tourism strategies aligned with Saudi Arabia's long-term economic and environmental goals.

By addressing these gaps, future research can provide more precise and actionable recommendations for policymakers to ensure that Saudi Arabia's tourism sector contributes to economic prosperity and environmental sustainability.

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STUDY OF THE EFFECTS OF BUSINESS INFORMATION SYSTEMS ON THE PREVENTION OF CORRUPTION IN THE PUBLIC ADMINISTRATION IN BULGARIAN CONDITIONS*

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Abstract. Modern business management entirely relies on the use of information technologies, covering all important aspects of business life. At the same time, introducing new ICT solutions in public administration remains in the shadow of business organizations – insufficiently studied from one side and from the other – with various and complex limitations such as financial, expert, lack of sufficient strategic planning, etc. In all cases, however, the use of information systems can improve the overall transparency of the administration, including by reducing the possibilities for subjective judgment on the part of the relevant employee. The main goal of this article is to study the effect that the use of business information systems will have in the fight against corruption in the public sector in the Bulgarian context. For this purpose, we conducted study, covering 73 public organizations (public enterprises and public administration) operating at the national and local level in Bulgaria. The survey was conducted in the period May-September 2024. The idea is to assess how employees in public organizations perceive the effects of using information systems in terms of the transparency of work processes, responsibilities, control over activities, the curbing of corruption and unfair practices, and the intention to use the system. Our findings based on the correlation analysis of the opinion of employees, indicate that the implementation and use of information systems in public organizations, on the one hand, increase the transparency of work processes, the distribution of responsibilities and the control of activities, and on the other hand limits the corruption and unfair practices. All this affects the intention of employees to use information systems in their work.

Keywords: business information systems; corruption; public sector; administration; transparency and accountability

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JEL Classifications: H7, M15, O38

1. Introduction

Modern management is completely based on the use of information technologies – for better strategic and operational planning, for managing the stock availability in warehouses, contract management, logistics, Human Resource Management, specific project management, etc. There are numerous technological solutions when it

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comes to business organizations and the possibility of improving their overall performance through new technologies. At the same time, the introduction of new technical solutions in public administration remains in the shadow of business organizations, and in most cases, when implementing new technologies, their full capacity is not used in practice, and very often different systems are purchased, which, however, cannot work together. As a result, introducing various technical solutions may even hinder rather than improve the efficiency of the administration.

On the other hand, the development of new technologies and achievements related to effective solutions, proven in the practice of business organizations, undoubtedly have their application in the conditions of public administration. The desire of all citizens to receive improved public services can ultimately be satisfied precisely through new technologies, as long as they are introduced as part of an overall strategic policy of the administration.

In all cases, however, the use of information systems can improve the overall transparency of the administration, including by reducing the possibilities for subjective judgment on the part of the relevant employee. In this sense, the main goal of this article is to study the effect that the use of business information systems will have in the fight against corruption in the Bulgarian context.

2. Theoretical background

Corruption and, respectively, the fight against corruption, unfortunately, are not a new phenomenon in the practice of public administration. Corruption and all its manifestations corrode the rule of law, undermine the public's faith in the justice of all public entities and have an extremely harmful effect on the structure and moral of the entire society. Therefore, the fight against corruption is one of the major priorities for any public authority (Vyas-Doorgapersad, 2024). New technologies could contribute significantly to this fight, giving the needed tools for securing transparency and lack of subjectivity of critical procedures.

The scientific literature is not so rich in researchers exploring different possibilities for new technologies to strengthen the fight against corruption.

Bhattacherjee and Shrivastava (2018) find that ICT use impacts corruption by enhancing both the likelihood and speed of punishment for corrupt activities. Additionally, ICT-specific legislation moderates this effect, indicating that ICT investments alone may have a limited impact on reducing corruption unless reinforced by suitable ICT regulatory frameworks. In this regard, Lee, Choi, Kim and Jung (2018) define the factors affecting the decrease in corruption using ICT development and e-government service. They confirm that ICT and e-government development play a mediating role in reducing government corruption, suggesting that expanded ICT use and technological monitoring of government activities will be key factors in corruption prevention within government institutions. Ali and Gasmi (2017), after a comprehensive analysis, also conclude that ICT diffusion serves as an effective mechanism for controlling corruption. Additionally, as countries achieve greater economic development, their corruption levels tend to decline. The results indicate that higher per capita GDP, along with trade openness and strong institutional frameworks, correlates with reduced corruption levels.

Adam and Fazekas (2021) examine different digital public services, crowdsourcing platforms, whistleblowing mechanisms, transparency portals, distributed ledger technology, and artificial intelligence. Analyzing the shared features of these technologies, scholars observe that ICT can enhance anti-corruption efforts by strengthening public oversight in multiple dimensions: it enables corruption reporting, fosters transparency and accountability, and supports citizen engagement as well as interactions between governments and citizens. However, the authors warn that ICT also introduces potential avenues for corruption through mechanisms such as the dark web, cryptocurrencies, and the potential misuse of centralized databases (ibid). In this regard comes the research of

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Schopf (2019), who argues that although ICTs generally help reduce corruption, ICT aid from leading providers in Korea was found to increase corruption levels in recipient countries. After profound research on the different factors for this situation, the scholar advises that e-government initiatives should be aligned with complementary anti-corruption administrative reform programs, including measures such as the anti-corruption integrity index, the ombudsman system, integrity pledge contract systems, whistleblower protection, results-oriented management, and budget transparency (ibid). This conclusion is complementary to the findings, made earlier by Sassi and Ali (2017), who empirically prove that African economies experience the anti-corruption benefits of ICT adoption only after achieving a certain threshold of rule of law. Ndoya, Okere, Belomo and Atangana (2023) scrutinize the relationship between ICT and the informal economy in Africa. Their findings indicate that ICT use reduces the prevalence of the informal economy. According to the authors, this relationship remains consistent across various robustness checks.

Additionally, mediation analysis reveals that the impact of ICTs on the informal economy is mediated by factors such as financial development, human capital, and corruption control (ibid). Wang, Luo and Jurkat (2022) explore data from 133 countries and conclude that ICT infrastructure enhances the positive effect of e-participation on corruption control. Their results highlight key relationships among e-participation, voice and accountability, ICT infrastructure, and corruption control.

Thommandru, Maratovich and Saparovna (2024) explore the possibility of strengthening the fight against corruption in Uzbekistan by using a good example of India, especially in the field of tech-driven strategies. Scholars admit that, although technology alone cannot resolve all corruption issues, the strategic integration of ICT into Uzbekistan's anti-corruption efforts—drawing on lessons from India's experience—can be a powerful instrument to enhance governance, reduce corruption and promote social justice for citizens. Khan, Ullah and Nobanee (2024) also confirm that technology has a spill-over effect on innovation, overall transparency, and institutional quality and could secure the sustainability of authorities.

Wu, Yan and Vyas (2020) scrutinize the attitude of civil servants in China and India in the fight against corruption. Based on the research, they conclude that civil servants in both countries generally hold positive views on the potential of transparency and technology to reduce corruption. At the same time, the authors discover that the effectiveness of these innovations depends on factors such as political commitment, levels of income inequality, and the readiness of infrastructure. According to their findings, Chinese respondents expressed greater optimism about the role of transparency, while Indian respondents were more favorable toward the impact of technology. This difference, argue scholars, may reflect the distinct drivers of corruption and the unique challenges faced by anti-corruption efforts in China and India (ibid).

Adam (2020) examines the development of e-government and its impact on the corruption level. The results indicate a strong relationship between e-government development and ICT development, institutional quality, and between ICT development and corruption. These relationships collectively affirm the impact of ICT development on reducing corruption. However, according to the author, the research found no significant direct effect of e-government on corruption reduction (ibid). The same opinion is reached by Sabani, Farah, and Dewi (2019), who studied the possibility of a corruption fight in Indonesia based on new technologies. They define several important barriers (such as budget limitation, available Infrastructure, Unprepared staff, Low awareness and participation, etc.) but also pay attention to the drivers of this effort (such as government support, motivation, policy enforcement, transparency and trust). The potential of e-government in fighting against corruption is also comprehensively studied by Silal, Jha and Saha (2023). Khan, Krishnan and Dhir (2021) argue that policymakers should prioritize building ICT-related knowledge, expertise, and infrastructure to enhance their capacity for designing effective e-government platforms and services. According to the authors, strategies should be developed to raise public awareness and improve technical skills, such as through targeted training programs. Addressing the digital divide is also crucial, ensuring broad access to the internet and other ICT resources. They

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are convinced that without widespread citizen access to e-government, its potential impact on reducing corruption cannot be accurately evaluated (ibid).

Ibrahim, Norta and Normak (2024) reveal the potential of blockchain-based governance models that secure transparency and fight against corruption. Valle-Cruz, Sandoval-Almazan and Gil-Garcia (2016) explore the relationship between citizens and local authorities mediated by information technologies. Their study finds that technology-supported interactions between citizens and municipal governments significantly influence citizens' perceptions of transparency, efficiency, and corruption. Among the technologies examined, websites, social media, and mobile technologies were identified as having the greatest impact. At the same time, scholars reported that employment status emerged as the only demographic factor significantly affecting these perceptions (ibid). At the same time, Senator, Senyo and Addo (2021) explore the role of digital payment in reducing the corruption level. Using a fixed-effects analysis, their results indicate that digital transactions effectively reduce corruption. These findings are robust even when authors used instrumental variable analysis to address potential endogeneity issues, highlighting important implications for reducing corruption in developing countries (ibid).

Fan, Kuper, Choi and Choi (2021) reveal the impact that ICT have on the level of corruption pressure on the business. ICT development has the potential to significantly reduce the incidence of illicit payments made by firms to regulatory officials. Additionally, according to the scholars, the influence of ICT on perceived corruption pressure is shaped by elements of the institutional and competitive contexts: its effectiveness is enhanced in environments with strong institutional quality—characterized by robust checks and balances and secure private property rights—while it is diminished in competitive settings where firms face challenges such as the liability of foreignness and informal competition (ibid). This conclusion goes with the ideas of Jeong, Shenoy and Zimmermann (2023) who admit that corruption endures due to a disparity between formal (de jure) transparency laws and their actual (de facto) implementation.

Jiménez, Hanoteau and Barkemeyer (2022) explore the impact of e-procurement on the corruption. They conclude after a comprehensive data analysis that the adoption of an e-procurement system appears to reduce firm-level corruption, although this effect becomes evident only when the quality of national governance institutions is considered, which also strengthens the relationship. Additionally, they find that an e-procurement system effectively curtails firm corruption primarily when it receives support from supranational bodies (ibid).

Zhou et al. (2022) provide an interesting experiment on the impact of anti-corruption measures on the level of innovation in the environment. Their findings confirm that firm-level environmental innovation rises significantly in response to the anti-corruption campaign. Romero-Martínez and García-Muiña (2021) study the location choice of tourists in the hotel industry. Based on data from the Spanish hotel industry, their results confirm that corrupt or weak institutions significantly influence country selection. Conversely, a high level of digitalization reduces the likelihood of corrupt practices. Sahoo, Sethi, and Padilla (2023) focus on the ICT control of corruption in the field of green economies. Their findings indicate that green energy and innovation play a significant role in reducing carbon emissions. Additionally, according to their research, the interplay between corruption control, innovation, and ICT contributes to enhanced environmental quality over the long term.

Interesting aspects of the nexus between the fight against corruption and ICT development and digitalization, are also developed by Larsson and Teigland (2019), Angelova (2020), Adams et al. (2024), Park and Xiao (2021), Roomen and Jonge (2024), Susanto et al. (2024); Nazarova et al. (2020); Prodanchuk et al. (2023). In this regard, Bulgaria, as a regular member state of the EU, has big challenges in overcoming corruption practices. Studies of authors on the development of information and communication technologies in the Bulgarian state show a low level of implementation of modern technologies, especially in municipalities (Tsonkov, Petrov & Berberova-Valcheva, 2022).

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Based on the profound research, Matheus, Janssen and Janowski (2021) conclude that government organizations should establish strong technological and institutional foundations to attain digital transparency. These foundations should then be utilized to structure and prepare the organization to operate transparently before developing and deploying digital solutions.

3. Research goal and methodology

The present study is based on the results of a survey conducted to investigate the opinion of employees in public organizations concerning the effects of the use of information systems in the project "Effective Models for the Implementation of Business Information Systems in the Public Sector". This project examines business information systems in public administration from different perspectives. In this article, we present the results related to the prevention of corruption through business information systems in Bulgarian public administration and enterprises with state and municipal participation (Methodological model is presented in Figure 1 below).

The survey includes 73 public organizations (public enterprises and public administration) operating at the national and local level in Bulgaria, conducted in the period May-September 2024. The study focuses on organizations that have recently implemented and are using an information system. The aim is to evaluate the effects of the use of the system and the factors influencing its implementation, by evaluating the opinion of the employees (users of the information system). The selection of public organizations is random, but the survey does not claim to be representative of the sample.

The questionnaire is designed to identify the factors influencing the implementation and use of information systems and the effects on employees in public organizations. The survey questions cover 5 main groups of questions that aim to identify:

- The structure and characteristics of the respondents - age, level of education, position held in the organization and others.
- Technological factors – factors related to the information system.
- Organizational factors – the conditions that the organization has regarding the implementation and use of the information system.
- Environmental factors – external factors affecting the functioning of the organization and the possibilities for implementing and using information systems.
- Human perceptions – factors that the information system has on the employee's perceptions of its use.

The present study focuses on employee perceptions of information system use. The aim is to assess how employees in public organizations perceive the effects of using information systems in terms of the transparency of work processes, responsibilities, control over activities, the curbing of corruption and unfair practices, and the intention to use the system. In this regard, the following two research hypotheses are defined:

H1: The use of information systems in public organizations increases the transparency of work processes and the responsibilities of employees, which affects the prevention of corruption and unfair practices.

H2: Increasing the transparency of work processes and the distribution of responsibilities affects the intention to use information systems by employees.

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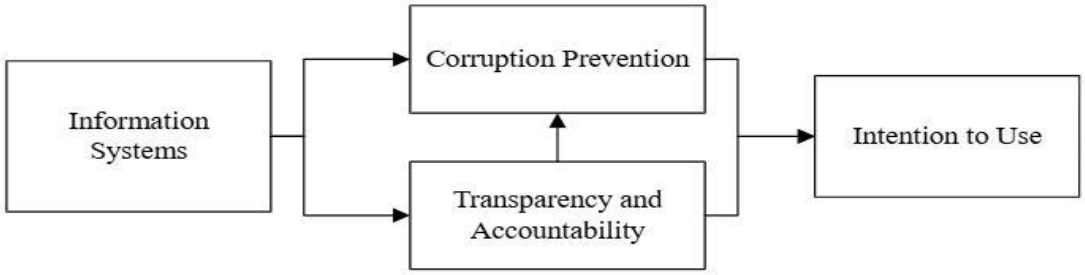


Figure 1. Methodological model of interaction.

The questions included in the present study refer to statements related to the effects of the use of an information system, for the surveyed employees to evaluate.

The possible values of each measure are located on a standardized Likert scale from 1 to 5 (from "strongly disagree" through to "strongly agree"). The aim is to evaluate the effects on employees of using an information system. First, to what extent has the information system contributed to increasing the transparency of work processes, the distribution of responsibilities, and the control of activities? Next, does the increase in transparency of work processes and employee responsibilities, as a result of the use of the information system, lead to the prevention of corruption and unfair practices in the public sector? Finally, do all these effects affect employees' intention to use information systems?

The model includes the opinion of employees regarding the statements:

- Has the information system increased transparency of work processes, distribution of responsibilities and control over activities? - the variable "Transparency and Accountability";
- Does the use of information systems in public organizations curb corruption and unfair practices? – the variable "Corruption Prevention";
- How do you rate your intention to use information systems in your work? – the variable "Intention to Use".

To determine the dependence between employee ratings, we use a statistical method of dependence analysis. Since employee ratings range from 1 to 5 (from "strongly disagree" to "strongly agree"), the data in the model is placed on an ordinal (ranking) scale. For the needs of the analysis is used non-parametric criteria for testing hypotheses - Spearman rank-order correlation. The Spearman rank-order correlation coefficient (Spearman's ρ) was used to prove the defined research hypotheses. In this study, rank (ordinal) data are used, and sometimes in the process of statistical analysis, it is necessary to transform primary interval or proportional data into rank data. In these cases, and when the assumption of a normal distribution of the Pearson coefficient is not fulfilled, it is appropriate to use the Spearman correlation coefficient. The Spearman rank-order correlation coefficient measures the strength of the increase or decrease in the relationship between two variables by not using the original data, but by ranking it and analyzing the ranked data. Spearman's ρ takes values from - 1.00 to + 1.00 and are interpreted similarly. A ρ of +1 indicates a perfect association of ranks, a ρ of zero indicates no association between ranks and a ρ of -1 indicates a perfect negative association of ranks. The closer ρ is to zero, the weaker the association between the ranks (Laerd Statistics, 2018).

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The prerequisites for calculating Spearman's rank correlation coefficient are the same as for any nonparametric test:

- Random sampling. The selection of respondents must be random.
- The data for the variables must be independent. Each respondent completed only one survey and was not influenced by the opinions of other respondents.
- There is a monotonic relationship between the two variables. A monotonic relationship exists when the value of the variables increases together, or when the value of one variable increases, the value of the other variable decreases.

The statistical hypotheses that are tested are the following:

H_0: There is no monotonic relationship between the two variables.
H_1: There is a monotonic relationship between the two variables.

The processing of the received data is based on a set of statistical methods implemented through the software product IBM SPSS Statistics. The statistical methods of analysis were chosen according to two main aspects: the nature of the empirical data provided through the above-described methodology, the goals and objectives of the statistical analysis of the data. The methods for analyzing the variables are: descriptive analysis and statistical testing of hypotheses - research of dependencies by Spearman rank-order correlation.

4. Analysis of survey results

The research includes the answers of 73 respondents - employees in public organizations. The territorial level of public administration in Bulgaria includes two levels - national and local (municipal). Public organizations such as public enterprises and public administration are also divided into national (state) and local (municipal). The distribution of employees by territorial level is 39 working in organizations at the local level and 34 in organizations at the national level. The number of respondents working in public enterprises is 23 (31.5%), of which 12 are in national companies and 11 in municipal enterprises. The number of employees included in the survey working in the public administration is 50 (68.5%), of which 22 work in the state administration and 28 in the local administration (see Figure 2 below).

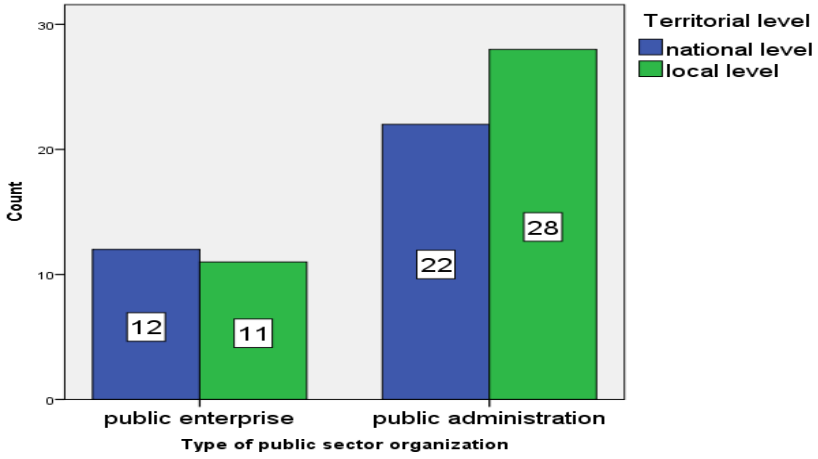


Figure 2. Distribution of respondents by type of organization and territorial level.

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The territorial structure of the respondents is essential for the detection of imbalances in the manifestation of factors at different territorial levels. Territorial structure may influence the research model regarding employee perceptions of the effects of information system use and its benefits.

Figure 3 shows the distribution of respondents according to their assessment of the level of digitization in the organization they work for and the corresponding type of organization. The general opinion of the respondents (39 of the employees) is that the level of digitization of the organization in which they work is average. 20% of employees believe that the level of digitalization is high and very high, and 26% believe that the level of digitalization is low.

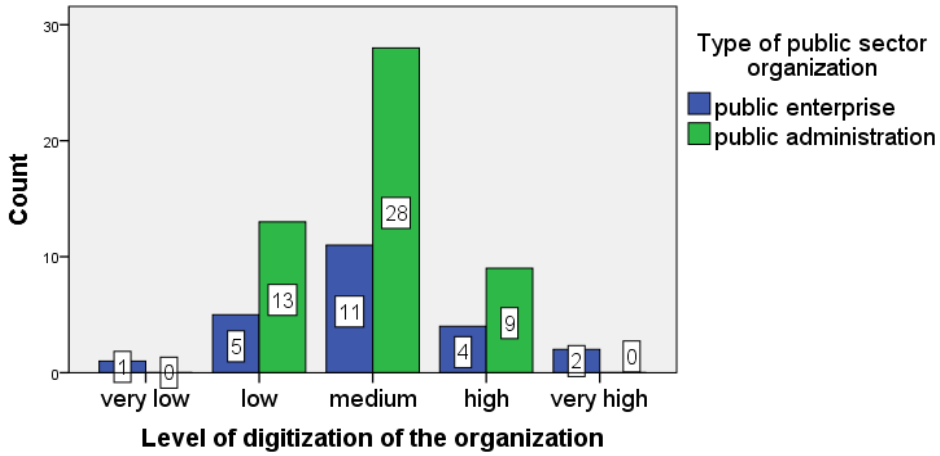


Figure 3. Distribution of respondents by type of organization and level of digitalization.

Comparing the respondents' assessments of the level of digitalization by type of public organization, it can be concluded that public enterprises have a greater level of digitalization compared to public administration. According to employee evaluations, 26% of the respondents believe that the level of digitalization of public enterprises is high and very high, while 18% of public administration employees believe that the level of digitalization is high.

The structure of the respondents by hierarchical level in the organization is important in the evaluations of the factors. Figure 4 presents the distribution of employees according to their position in the organization. The distribution of employees occupying and not occupying managerial positions in the organization is approximately equal, which gives representativeness of their opinion. About 50% of the surveyed employees hold management positions in public organizations. Their distribution is: about 15% operational management level, about 16.5% middle management level and about 19% senior management. The rest of the respondents (nearly 50%) are employees/experts in the organization.

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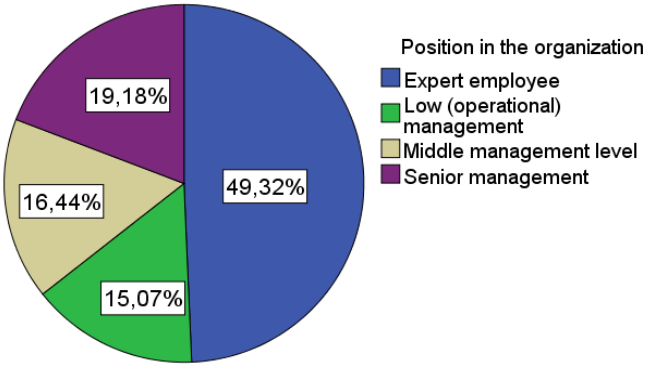


Figure 4. Position of the employees in the organizations

The participation of such a large proportion of employees in managerial positions is reflected in the estimates of the research model. Employees in management positions have a more objective assessment of the effects of the use of the information system, as regards the transparency of work processes, the distribution of responsibilities, the control of activities and management decisions. On the other hand, the large share of employees in non-managerial positions gives insight into the effects of using the information system in terms of control over their work and the perceived usefulness of using the system in daily work.

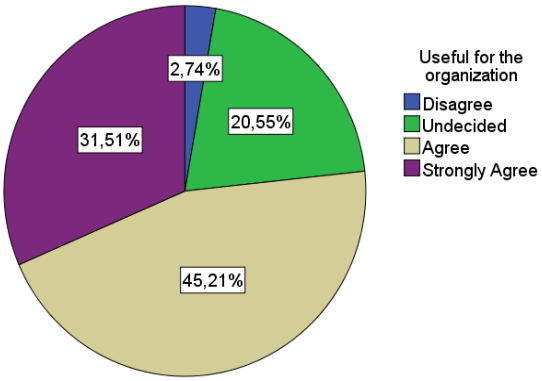


Figure 5. Evaluation of usefulness.

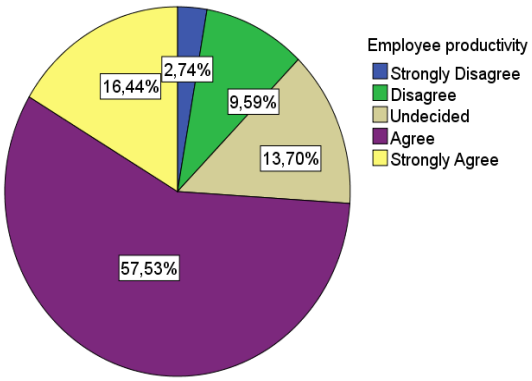


Figure 6. Evaluation of employee productivity.

The evaluation of the effects of the use of the information system depends on the opinion of the employees regarding the perceived usefulness for them and for the organization. Figure 5 presents the distribution of the ratings of the surveyed employees regarding the information system and its perceived usefulness to the organization. Nearly 77% of the employees surveyed believe that the information system is useful for the organization, about 20% cannot judge and only two indicated that the system is not useful.

The effectiveness of information systems depends on the perceived usefulness of employees and the effects it has on them. Figure 6 presents the distribution of employees' ratings of the survey question, "Did the information system make your work easier and increase your productivity?". The general opinion is that the use of the information system has made work easier and increased the productivity of employees (74% of respondents). About 12% of employees believe that the information system has not increased their productivity, and 13.7% cannot judge.

Summarizing the responses of the respondents, it can be said that the use of information systems in public organizations facilitates the work of employees and increases their productivity, which affects the utility of the organization.

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To prove the research hypotheses, a relationship is sought between the variables in the model "Transparency and Accountability", "Corruption Prevention", "Intention to Use". This includes the respondents' assessments of the effects of the use of the information system in terms of increasing the transparency of work processes, the distribution of responsibilities and the control of activities; curbing corruption and unfair practices; employees' intention to use information systems in their work. The table presents the respondents' evaluations of the relevant statements.

The general opinion of the employees is that the information system increases the transparency of work processes, the distribution of responsibilities and the control of activities, with 85% of respondents indicating "Agree" and "Strongly Agree". 13.7% could not decide and one indicated "Disagree". No respondent indicated "Strongly Disagree". The average rating is 4.27, average rank 4 - "Agree" (Table 1).

Table 1. Evaluation of factors by employees.

Factors	Rating	Frequency	Percent %	Mean	Median	Mode
Transparency and Accountability	Strongly Disagree	0	0	4,27	4	5
	Disagree	1	1,4			
	Undecided	10	13,7			
	Agree	30	41,1			
	Strongly Agree	32	43,8			
Corruption Prevention	Strongly Disagree	0	0	4,05	4	4
	Disagree	4	5,5			
	Undecided	14	19,2			
	Agree	29	39,7			
	Strongly Agree	26	35,6			
Intention to Use	Strongly Disagree	1	1,4	4,18	4	5
	Disagree	3	4,1			
	Undecided	13	17,8			
	Agree	21	28,8			
	Strongly Agree	35	47,9			

Regarding "Corruption Prevention", about 75% of the respondents believed the use of information systems curbs corruption and unfair practices. 19.2% indicated "Undecided" and 5.5% indicated "Disagree". No respondents indicated "Strongly Disagree". The average rating is 4.05, with an average rank of 4 - "Agree".

The general opinion of the surveyed employees is that they would use an information system in their work, with nearly 77% indicating "Agree" and "Strongly Agree". Four of the employees have no intention of using an information system. The average score according to the "Intention to Use" criterion is 4.18, with an average rank of 4 - "Agree".

From the rank evaluations of employees, it can be concluded that information systems contribute to increasing transparency, accountability and control in public organizations and limit unfair practices. The intention to use information systems by employees in public organizations is high.

5. Testing the research hypotheses

In the dependence assessment model, the rank assessments of the employees on the variables "Transparency and Accountability", "Corruption Prevention", "Intention to Use" are included. The results of the implemented Spearman rank-order correlation in SPSS are (Table 2):

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Table 2. Spearman rank-order correlation

Correlations

			Corruption Prevention	Transparency and Accountability	Intention to Use
Spearman's rho	Corruption Prevention	Correlation Coefficient	1,000	,666**	,385**
		Sig. (1-tailed)	.	,000	,000
		N	73	73	73
	Transparency and Accountability	Correlation Coefficient	,666**	1,000	,314*
		Sig. (1-tailed)	,000	.	,015
		N	73	73	73
	Intention to Use	Correlation Coefficient	,385**	,314*	1,000
		Sig. (1-tailed)	,000	,015	.
		N	73	73	73

**. Correlation is significant at the 0.01 level (1-tailed).
*. Correlation is significant at the 0.05 level (1-tailed).

Concerning research hypothesis ***H1***: The use of information systems in public organizations increases the transparency of work processes and the responsibilities of employees, which affects the limitation of corruption and unfair practices; the sought relationship is between the variables "Transparency and Accountability" and "Corruption Prevention". Spearman's rho value is 0.666 and is statistically significant (Sig. (1-tailed) = 0.001) at a one-sided critical region and error risk α = 0,01. There is a monotonic relationship between the two variables. This gives reason to reject the null hypothesis in favor of the alternative, i.e. there is a dependence between the respondents' assessments of the two factors - "Transparency and Accountability" and "Corruption Prevention". The relationship can be rated as moderately strong to strong. The value of Spearman's rho is positive, which means that the information system, increasing the transparency of work processes and responsibilities, has a positive effect on preventing corruption and unfair practices in public organizations. Research hypothesis *H1* is confirmed.

To research hypothesis ***H2***: Increasing the transparency of work processes and the distribution of responsibilities affects the intention to use information systems by employees, the sought relationship is between the variables "Transparency and Accountability" and "Intention to Use". Spearman's rho value is 0.314 and is statistically significant (Sig. (1-tailed) = 0.015) at a one-sided critical region and error risk α = 0,05. There is a monotonic relationship between the two variables. This gives reason to reject the null hypothesis in favor of the alternative, i.e. there is a dependence between the respondents' assessments of the two factors. The relationship can be rated as moderately strong. The value of Spearman's rho is positive, which means that the increase in the transparency of work processes and the distribution of responsibilities as a result of the use of the information system affects the intention of employees to use information systems. Research hypothesis *H2* is confirmed.

According to the present correlation model, it is observed that the curbing of corruption and unfair practices is also dependent on the intention of employees to use information systems. Spearman's rho value is 0.385 and is statistically significant (Sig. (1-tailed) = 0.001) at a one-sided critical region and error risk α = 0,01. There is a dependence between the respondents' assessments of the two factors "Corruption Prevention", and "Intention to Use".

From the correlation analysis made, based on the opinion of employees, it can be concluded that the implementation and use of information systems in public organizations, on the one hand, increase the transparency of work processes, the distribution of responsibilities and the control of activities, and on the other

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hand prevent corruption and unfair practices. All this affects the intention of employees to use information systems in their work.

6. Comment on the results of open questions to identify missing influential factors

The answers to the open questions provide some interesting directions for searching for the influence of various factors. In essence, they do not differ from the established regularities by proving the two research hypotheses, but they specify some complementary understandings of the influence of information systems on the prevention of corruption and transparency in the public sector. The respondents' answers confirm the main conclusions made in the monograph "Information and communication technologies, as a strategy for the prevention of corruption" (Anguelov, K., 2008) related to the main functions that information and communication technologies have in terms of the sustainability of work processes, among which are retrospection of the actions taken, the possibility of publicity and public control, integration of information and the impossibility of individual employees to make decisions in an unregulated manner (anti-discretion).

From the respondents' answers, it can be concluded that implementing and using information and communication technologies in the public sector affects the transparency of work processes, control and limitation of corruption and unfair practices. However, the delayed implementation of information systems and the low level of digitalization of the public sector in Bulgaria are dictated by some significant factors.

First, according to the respondents, there is a lack of sufficient financial resources and technical conditions in public organizations.

Next, the respondents point to the low level of qualification of employees, low computer literacy and skills for working with information systems. This is the main reason for employees' resistance to using information systems. This negative factor can be greatly limited as a result of familiarizing employees with the effects of information systems even before their implementation, as well as conducting appropriate training.

The most significant factor indicated by the surveyed employees is the low desire by senior management to use information systems and political will. This may be due to the skills and competencies of senior management to work with such systems and outdated legislation. On the other hand, this is a significant obstacle to achieving digitalization and curbing corruption in the public sector.

Conclusions

The main purpose of this article was to investigate the effect that the use of business information systems will have in the fight against corruption in the Bulgarian context. The present study demonstrates the fundamental role of a group of factors influencing public sector employees' perceptions of their intention to use information systems. The two research hypotheses have been proven – there is a relationship between the employees' perceptions regarding corruption prevention and the increase in the transparency of work processes and the distribution of responsibilities, as a result of the use of information systems. Next, it can be concluded that information systems, increasing transparency, responsibilities and control affect employees' intention to use. Naturally, the employees' perceptions of the effects of the implementation of information systems in public organizations are influenced by other factors, which gives rise to the need for additional research on the issue.

According to the opinion of employees in public organizations, the main challenges to the effective digitalization of the public sector in Bulgaria are financial constraints, the skills of civil servants and the intention to use information systems, both by employees and management bodies. The implementation and use of information systems in public organizations would affect the improvement of the transparency of work processes, as well as

the control and limitation of corruption and unfair practices. All this affects employees' intention to use information systems.

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INCLUSIVE LABOUR MARKET: CHALLENGES AND SOLUTIONS FROM EMPLOYERS' PERSPECTIVE*

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Abstract. This article is devoted to the employment problem of socially vulnerable groups, but the issue is disclosed from employers' point of view. As it is known, the labour market is represented by two sides: demand for the labour force and labour supply. In the inclusive labour market, labour supply is represented by persons from social categories of the population. In Kazakhstan, they include persons with disabilities, orphans, former convicts, alcohol and drug addicts, mothers with many children, and women raising children alone, who, due to various life situations, do not have the opportunity to work full-time and/or without special conditions of employment. These categories of people are vulnerable and need support in finding work and jobs. The other side of an inclusive labour market is employers willing to hire social group representatives. At the same time, there is a considerable gap between these two sides of the labour market. While the first side does not have the opportunity (does not know how) to find a decent job, employers willing to offer employment are understaffed and elementary do not know the peculiarities of working with persons with disabilities. Others are afraid of the difficulties in adapting workplaces to the needs of people with disabilities. In addition, there is stereotypical thinking, due to which many people believe that employees with disabilities or mothers with small children will work worse than other employees. Nevertheless, there is a trend of increasing social awareness in Kazakhstan, with employers seeking to contribute to developing a social society. In this research article, the authors confirm some of the hypotheses based on expert semi-structured interviews, while others are rejected. The research is conducted within the framework of the state order for scientific research in social sciences from the Committee of Science under the Ministry of Science and Higher Education of the Republic of Kazakhstan. In this study, we will see the difference between working with people with mental disabilities and physical disabilities and how the process of adapting workplaces for employees with these or those disabilities differs. In addition, we will show the differences between the employment of persons with disabilities and other social groups and how employers think these or those groups adapt to the work process.

Keywords: social groups; socially vulnerable segments of the population; persons with disabilities; inclusive labour market; inclusive employment; social entrepreneurship

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1. Introduction

In earlier works, we studied the state of the inclusive labour market in Kazakhstan, but the focus was on the situation through the eyes of job seekers. Persons with disabilities and other categories in the interviews assessed the problem with job search issues and further employment. The reasons for the low percentage of employment of persons with disabilities were identified, among which are: 1) lack of accessible environment, 2) lack of education and work experience of job seekers, 3) dependent attitudes because many persons with disabilities have been receiving benefits from the state since birth and are accustomed to special treatment of their status. At the same time, it was noticed that among employed people with disabilities, more people were injured in adulthood, who have an understanding of "normal" life, experience and education, as well as a desire to return to their previous standard of living. Such groups have a sustained desire to find work and realize their potential. Also, many respondents with disabilities cited the desire to provide for their families as one of the reasons for wanting to work. A proactive attitude to life characterizes them: despite the hardships of life with a disability, they open a business, start a new business, and, in addition, help other people in difficult life situations.

At the same time, the low percentage of employed persons with disabilities and other social groups indicates the problem of the availability of jobs and the creation of conditions for employment. In this research paper, we will consider the issues from the employers' side. Earlier in the literature, more attention was paid to social groups; there is a perception that this site is vulnerable. However, there is another side to the inclusive labour market: specific barriers exist to employing people from these social groups. In this study, we will try to identify the difficulties faced by employers who employ people with disabilities, mothers of many children, ex-prisoners and other categories. In addition, interviews with entrepreneurs in Kazakhstan will allow us to identify the peculiarities of working with social categories and the unique experience of each respondent, enabling us to identify patterns of an inclusive labour market.

2. Literature Review

The employment of socially vulnerable groups is a multifaceted issue encompassing various dimensions, including economic, social, and educational factors. Vulnerable populations often face significant barriers to employment, which systemic inequalities and lack of access to resources can exacerbate. This response synthesizes recent literature to explore the challenges and strategies for improving employment outcomes for these groups. One of the primary challenges faced by socially vulnerable groups is the existence of structural barriers that hinder their access to employment opportunities. Research indicates that employment rates vary significantly among different demographic groups, influenced by age, gender, ethnicity, and disability status (Acar & Findikli, 2020).

For instance, individuals with disabilities, ex-convicts, and immigrants are frequently categorized as disadvantaged, facing unique obstacles in the labour market (Çetin, 2024). Additionally, the role of active labour market programs (ALMPs) has been scrutinized, with findings suggesting that these programs may inadvertently prioritize the most job-ready candidates, leaving those further from the labour market without adequate support (Ingold & Valizade, 2017). This "creaming" effect can perpetuate existing inequalities, making it imperative for policymakers to design inclusive strategies that genuinely cater to the needs of all vulnerable groups (Ingold & Valizade, 2017).

Moreover, the intersectionality of vulnerabilities complicates the employment landscape. For example, individuals from minority ethnic backgrounds often experience compounded disadvantages due to both racial and socio-economic factors (Masha & Fihla, 2025). This intersectionality highlights the necessity for targeted interventions that address the specific needs of diverse groups within the workforce. The literature suggests that fostering a diverse workforce improves access to employment for underrepresented populations and enhances

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service delivery in sectors such as healthcare, where minority health professionals are more likely to serve minority patients (Salsberg et al., 2021).

Thus, increasing diversity within the workforce is not merely a matter of equity; it also has practical implications for improving outcomes in various fields. Educational attainment is another critical factor influencing employment opportunities for disadvantaged groups. Studies have shown that higher education levels correlate with better employment prospects, yet marginalized groups often have lower access to quality education (Sharma, 2016). This disparity necessitates reevaluating educational policies and practices to ensure that they are inclusive and supportive of vulnerable populations. For instance, initiatives aimed at enhancing educational access for women and ethnic minorities can significantly improve their employment outcomes (Sharma, 2016; Çetin, 2024). Furthermore, integrating vocational training and support services can help bridge the gap between education and employment, equipping disadvantaged individuals with the skills necessary to thrive in the labour market (Acar & Findikli, 2020; Çetin, 2024).

In addition to structural and educational barriers, the psychological aspects of employment for vulnerable groups cannot be overlooked. The stigma associated with particular identities or conditions, such as HIV, can significantly impact job effectiveness and overall employment experiences (Ocampo et al., 2023). Addressing these psychological barriers through supportive workplace environments and anti-stigma campaigns is essential for fostering an inclusive workforce. Furthermore, social support systems within organizations can alleviate stress and enhance job performance among vulnerable employees (Powell et al., 2017).

In conclusion, the employment of socially vulnerable groups requires a comprehensive approach that addresses structural barriers, promotes educational equity, and fosters inclusive workplace environments. By implementing targeted policies and practices that consider the unique challenges faced by these populations, stakeholders can contribute to a more equitable labour market that benefits both individuals and society as a whole.

The employment challenges faced by individuals from marginalized social categories are multifaceted and deeply rooted in societal structures. Discrimination based on race, gender, disability, and social class significantly impacts labour market outcomes for these groups. Research indicates systemic biases and social norms contribute to market segmentation, further exacerbating employment opportunity inequalities.

One of the primary issues is racial discrimination in hiring practices. A comprehensive analysis by Quillian et al. (2019) highlights that discrimination varies across countries, with evidence from 97 field experiments demonstrating that minority groups often face significant barriers in securing employment due to biases held by employers. This is echoed by Bertrand and Mullainathan (2018), who found that applicants with traditionally African American names received fewer callbacks compared to those with more common Anglo names, underscoring the persistent nature of racial discrimination in hiring processes. Such biases affect immediate hiring outcomes and perpetuate broader social inequalities.

Gender discrimination also plays a critical role in employment disparities. Research by Benard et al. (2018) reveals that mothers experience a "motherhood penalty," where their parental status negatively impacts their hiring prospects and wage potential compared to equally qualified candidates without children.

Furthermore, Yavorsky's (2019) study indicates that discrimination against female applicants is particularly pronounced in male-dominated industries, suggesting that occupational gender norms further complicate the employment landscape for women. This intersection of gender and occupational segregation illustrates how social norms and institutional practices can disadvantage women in the labour market. Moreover, individuals with disabilities face unique challenges in employment.

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Hemphill and Kulik (2015) emphasize the importance of mainstream employment for the social and economic inclusion of disabled individuals. Yet, they identify significant barriers, including employer stigma and uncertainties regarding the abilities of disabled applicants. Similarly, Dillahunt et al. (2021) discuss the inadequacies of existing employment support tools for marginalized job seekers, highlighting the need for more effective strategies to assist these individuals in navigating the job market.

Employers often desire to hire individuals with disabilities but are hindered by systemic issues within the hiring process and a lack of support from public employment services (Henry et al., 2014). Social class also significantly influences employment opportunities. Rivera and Tilcsik's (2017) research indicates that social class signals can affect hiring decisions in elite labour markets, where applicants from lower social classes may face discrimination despite having similar qualifications to their higher-class counterparts. This aligns with Ridgeway's (2013) assertion that status beliefs about group superiority contribute to material advantages for higher-status groups, further entrenching social inequalities in employment.

The employment problems faced by individuals from marginalized social categories are deeply intertwined with systemic discrimination, social norms, and institutional practices (Malatji, 2024). Addressing these challenges requires comprehensive policy interventions and a commitment to fostering inclusive hiring practices that recognize and mitigate biases against these groups.

Employment issues for individuals with disabilities are multifaceted, encompassing a range of barriers that hinder their access to meaningful job opportunities. These barriers can be broadly categorized into attitudinal, structural, and policy-related challenges. Attitudinal barriers are significant impediments to employment for people with disabilities. Stigma and negative perceptions about the capabilities of individuals with disabilities often lead to discrimination in hiring practices.

Research indicates that employers frequently harbour misconceptions about the productivity and reliability of disabled workers, which can result in a reluctance to hire them (Tarawneh, 2016; Khayatzadeh-Mahani et al., 2019; Goodman, 2024). For instance, studies have shown that employers may prefer candidates without visible disabilities due to fears of reduced productivity or the costs associated with workplace accommodations (Paušić et al., 2021).

Furthermore, the lack of exposure to individuals with disabilities can foster discomfort among employers, perpetuating stereotypes that further marginalize this group in the labour market (Kaye et al., 2011; Gupta et al., 2021). Structural barriers also play a critical role in limiting employment opportunities for individuals with disabilities.

Physical accessibility remains a significant concern, as many workplaces are not equipped to accommodate the needs of disabled employees (Chikwe, 2024; Tessier, 2024). This lack of accessibility can deter individuals from pursuing job opportunities or lead to high turnover rates among those who secure employment. Additionally, inadequate transportation options can further isolate individuals with disabilities, making it challenging for them to attend interviews or maintain consistent employment (Bezyak et al., 2017).

The interplay of these structural barriers often exacerbates the difficulties faced by disabled individuals in securing and retaining jobs. Policy-related challenges are equally important in understanding employment issues for people with disabilities. Although various laws and initiatives aim to promote the employment of disabled individuals, such as the Employment First initiative, the effectiveness of these policies is often undermined by insufficient enforcement and a lack of awareness among employers (Edeiken_Cooperman, 2017). Moreover, the absence of comprehensive human resource policies that cater specifically to the needs of disabled workers can lead to environments that are not conducive to their success (Anuaruddin et al., 2018). Employers may also lack

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knowledge regarding the legal obligations to provide reasonable accommodations, further complicating the employment landscape for individuals with disabilities (Goodman, 2024).

In conclusion, addressing the employment issues faced by individuals with disabilities requires a multifaceted approach that tackles attitudinal, structural, and policy-related barriers. Educating employers, enhancing workplace accessibility, and enforcing existing laws are crucial steps toward creating a more inclusive workforce that values the contributions of all individuals, regardless of their abilities.

Inclusive employment is an essential socio-economic topic that requires a comprehensive analysis of the factors affecting the employment of people with disabilities and the study of barriers that may limit their opportunities. The scientific literature presents many approaches to the study of this issue.

One aspect is investigating the protective factors that enable qualified young people with visual impairments to participate in the labour market. According to Chhabra (2021), such factors play a key role in overcoming barriers and adapting to employment.

Disability inclusion practices, programs, and social and professional networking opportunities vary significantly across countries. As Ghosh, Liu and Mishra (2022) point out, successful disability inclusion initiatives must consider national employee career paths and cultural differences.

Janssens and Zanoni (2021) emphasize the need to go beyond empirical and ideological constraints within companies to achieve equality and social justice. This approach promotes a more inclusive corporate culture.

Knowledge of the type of disability becomes essential, as does matching job characteristics and adaptations to specific needs. A study by Suresh and Dyaram (2022) shows that the accessibility of physical infrastructure, external pressures and the representation of people with different types of disabilities in the workplace can facilitate and hinder their employment.

Understanding the economic benefits of an accessible and inclusive society, according to Tompa et al. (2021), is beneficial not only for governments but also for disability advocates and industry leaders. This aspect allows for the formation of informed and long-term inclusion strategies.

However, there are significant barriers to inclusive employment. Bialik and Mhiri (2022) identify denial of access to education, security concerns, forced self-employment and discrimination among them. These challenges require a comprehensive approach to addressing them. Positive factors also contribute to the employment of people with disabilities. Taubner, Magnus and Carin (2022) identify five factors: the opportunity to try different types of work, the desire to work, the balance between expectations and adaptation, mutual participation and flexibility, and wage subsidies. These elements provide the basis for successfully integrating people with disabilities into the labour market.

Thus, inclusive employment requires a multidisciplinary approach integrating social policy, economics, and management research. Further research on this topic will help to develop effective mechanisms to overcome existing barriers and create a more equitable society.

3. Research Methodology

The research is based on qualitative methods aimed at in-depth study of employers' perception of employment problems of socially vulnerable groups. The primary data collection method was semi-structured, in-depth interviews conducted with key business representatives actively working with social categories of the population.

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The choice of the interviewing method is conditioned by the need to obtain detailed and multifaceted data, allowing us to study both objective and subjective aspects of the perception of this problem. Thematic analysis was used to analyze the received data, which helped to systematize and identify key themes and patterns in the respondents' answers. Respondents were selected using a purposive sampling method, which allowed us to focus on those employers who have experience interacting with social groups experiencing difficulties in employment. This approach provided a comprehensive understanding of actual practices and existing stereotypes in the labour market and allowed us to test the hypotheses put forward earlier.

Informed consent was obtained from study participants by providing detailed information about the aims of the research study and the expected risks and benefits of participation. All interviews were recorded with the consent of the participants and then transcribed for subsequent analysis. The data were analyzed using a thematic analysis approach that identified key themes and patterns related to barriers and ways to overcome them in the inclusive employment process. This approach allowed the collection of comprehensive data reflecting multiple dimensions of the problem and the development of recommendations based on practical experience and the real needs of employers and people with disabilities. All recorded semi-structured interviews were transcribed verbatim in local languages: Kazakh or Russian, depending on the language the research participants spoke. The qualitative interview data was processed inductively according to the main themes.

4. Results and Discussion

During the research commissioned by the Committee of Science of the Republic of Kazakhstan, interviews were conducted with employers hiring representatives of socially vulnerable groups to identify their motivations, barriers and practical aspects of interaction with such employees. This allowed a deeper analysis of the difficulties and prospects of an inclusive labour market and an assessment of the adaptation of jobs and working conditions depending on the specific socio-demographic characteristics of employees.

48 employers from different cities of Kazakhstan were selected for the study. They were men and women between 32 and 47 years old, the average age being 43 years. The surveyed entrepreneurs own existing businesses in which they started to integrate social categories of employees, and they were also social entrepreneurs who started their activities with the primary goal of employing people from social groups. Some of the interviewed entrepreneurs (59%) are formal social entrepreneurs, but other respondents have no formal status.

To conduct interviews, the research team prepared questions on the difficulties and peculiarities of working with social categories of people. The questions contained the following information (Table 1).

Table 1. Structure of questions for employers

Theme	Questions
Introductory	Your full name, age, gender, place of residence
Professional	1. Scope of activities 2. Experience in the field
Employment experience of persons with disabilities	3. Which socially vulnerable categories are most represented in your organization? 4. What are the main challenges you can point out when working with social groups?

The first set of questions was aimed at finding out the existing experience of employers in the employment of persons with disabilities. The interviewees were asked whether they had previous experience working with this category of employees and what difficulties and successes they had noted in integrating persons with disabilities into work teams.

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These businesses' diverse activities include carpentry and sewing workshops, a massage parlour and social café at the university, furniture production, educational centres, centres to support children with autism and others. It is worth noting that today, some respondents have stopped hiring people with disabilities, and some have already closed their enterprises due to moving to another city for permanent residence. At the same time, other employers, on the contrary, open social café branches in different cities and regions. Entrepreneurs are expanding their cooperation with colonies to provide work for convicts. These examples offer a unique opportunity to explore the practical implementation of inclusiveness in the labour market.

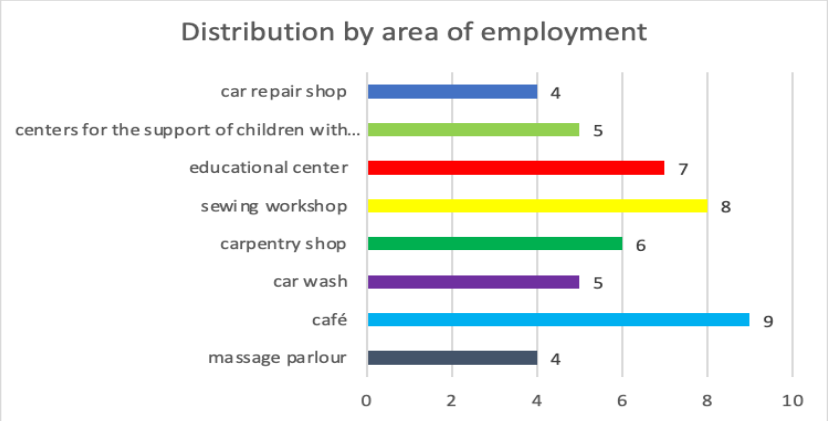


Figure 1. Distribution of employers by field of activity

Figure 1 shows a significant diversification of entrepreneurial activity with the predominance of services related to cafés and sewing. Persons with disabilities are often employed in catering, car washes, sewing and carpentry shops due to the possibility of adapting work processes. These industries allow for physically demanding jobs with minimal education and experience requirements, making them more accessible to people with special needs.

The average age of respondents was 43 years, indicating that entrepreneurial activity is highest among middle-aged people (see Figure 2).

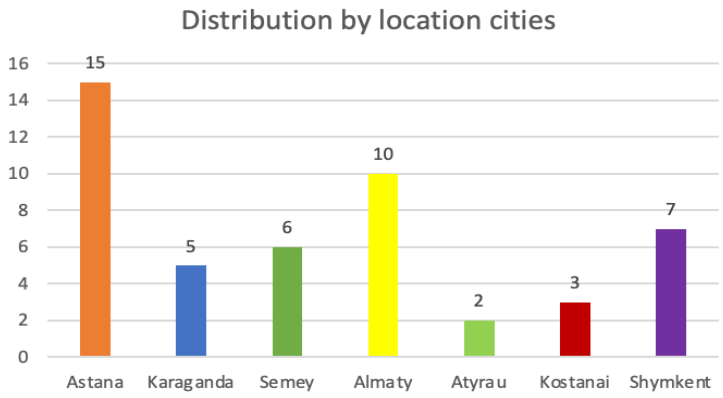


Figure 2. Distribution of social entrepreneurs by rayons of Kazakhstan

As for the geographical distribution of enterprises, the majority are concentrated in the capital of the country - Astana (15), in large cities of Kazakhstan - Almaty (10), Shymkent (7) and other cities of the country. Thus, there

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is some concentration of entrepreneurial activity in major economic centres of Kazakhstan, such as Astana, Almaty, Shymkent, and Semey, which corresponds to expectations, as these cities are significant business and financial hubs of the country.

As mentioned above, previous studies have highlighted the problem of employment of social categories of people from the perspective of these people, where it was noted that employers are not interested in hiring people with disabilities. Several reasons were given, including reluctance to employ due to fear and lack of knowledge of how to work with people with disabilities. In addition, the business requires full-time employment with a continuous production process, which does not allow for employment of, for example, women raising children alone, who prefer part-time employment. Also, job seekers noted prejudice against them due to their disability.

The problem of employment of persons with disabilities from the perspective of employers is a relevant and significant area of research. In this regard, the research team developed and proposed special questions that allow for a deeper analysis of situations when hiring persons with disabilities and representatives of other social categories (Table 2).

Table 2. Special questions for employers to identify the specifics of working with people from social categories

Directing questions	Question box
Psychological issues	1. How do employees and the team react to new colleagues from socially vulnerable categories? 2. Are there training or support programs for people from social categories? 3. What challenges have you experienced when working with social categories?
Adaptation issues	1. How does your company adapt workplaces and working conditions for employees with disabilities? 2. What are the main challenges in hiring people with disabilities and/or from other categories?
Assistance and support from the state	1. Have you used any government programs or received subsidies to employ people with disabilities?

The first block of questions was more psychological and was created to understand better entrepreneurs' motivation to hire people from social categories. To the question "How do employees and the team react to new colleagues from socially vulnerable categories?" all respondents answered in the same way - in absolutely every company, neurotypical people accepted people with disabilities well. This indicates that the understanding of inclusion in Kazakhstan is increasing; people are ready to work and help people with disabilities. Thus, we observe that the hypothesis about the biased attitude of employers or the collective is not confirmed. According to all surveyed employers, the team and the entrepreneurs were very loyal to people with disabilities.

For the survey, it was essential to understand whether there are training or support programs for people from social categories in employment. For example, Yerkezhan, 41 years old, an entrepreneur from Semey city, answered that she paid for massage training for visually impaired people. Thus, before starting work, they were trained in this business, received a certificate and only then began working with clients. It should be noted that the quality of their work was not inferior to that of normotypic people.

Another entrepreneur from Karaganda, Indira, 37, when employing people with mental disabilities, first gave tasks to each person in specific work areas. Then, observing them, she identified which jobs he was best at. And she trained them in at least three types of jobs. For example, several girls with mental disabilities were not good at washing dishes. But when a boy with mental disabilities came in, he did very well at this particular activity. Thus, an individualized approach is needed for people with cognitive disabilities.

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Social entrepreneur Emin, 41, from Astana, notes that before hiring a person with a disability, he must undergo an internship. This is done to understand whether the employee is suitable, whether you are suitable for him, and how he behaves in the team.

Entrepreneurs from Almaty, Astana and Shymkent (Akhmet, 38 years old; Irina, years old 40; Sharif, years old 35) believe that mentoring, whereby an experienced employee with a similar status is assigned to a new employee with a disability, is an effective practice. This approach helps to strengthen motivation: the new employee strives to justify the mentor's trust, and the mentor, feeling his importance to the company, learns to take responsibility for the support and professional development of the mentee. This helps increase the commitment level and the quality of work performed. Organizing team-building and other joint activities is recommended to strengthen collective cohesion and integration of employees with disabilities into the working environment. All surveyed employers practise this.

This block of questions allowed us to conclude that when working with people with mental disabilities, it is necessary to be patient and to explain the assigned tasks several times until the person memorizes and brings them to automaticity. According to employers' opinion, neurotypical people from social categories, as well as people with physical disabilities, should be kept strict and disciplined and treated equally.

In addition to psychological aspects, the research team was interested in practical issues and difficulties in working with persons with disabilities. For this purpose, questions of an adaptation nature were voiced: "How does your company adapt workplaces and working conditions for employees with disabilities?" and "What are the main difficulties encountered when hiring people with disabilities and/or from other categories?". The answers are presented below.

Indira, 37 years old, Karaganda: "Not all people with disabilities require workplace adaptation. For example, deaf people do not need special conditions. It is only necessary to learn a few gestures and write everything down on paper so they can read it. As a recommendation from one of the employers, deaf people should be hired in pairs to communicate and fit in more easily.

Aliya, 40 years old, Atyrau, believes that "for people with Group 3 disabilities who have diseases such as oncology or others that do not require significant physical limitations, often no major adaptation of the workplace is needed. It is essential to create comfortable working conditions, such as a flexible schedule, the possibility of working from home or the availability of breaks for recuperation. Employers note that such employees tend to demonstrate high responsibility and motivation, contributing to their successful integration into the team. The focus should be on supporting their morale and providing opportunities for equal participation in the workplace.

Victor, 43 years old, Astana: "We simply removed all sharp and breakable objects for an employee with visual impairment for dishwashing work and put utensils in a way that was convenient for him. In other words, the visually impaired employee knew where he had what he needed for his work and coped with his job perfectly.

Yerkezhan, 41 years old, Semey city: "We put couches and sinks for hand washing for blind people to work in the massage parlour so that they could find them quickly, put everything next to each other for the convenience of work of blind people, which allowed them to get used to the workplace and do their work well".

It is worth noting that absolutely all employers pointed out that the quality of work of people with physical disabilities does not differ from the quality of work of neurotypical people. For example, the cases of businesswomen from Semey and Astana cities, Yerkezhan and Aigerim, about the work of visually impaired people in a massage parlour prove that they do their job well. Also, there are the cases of Victor and Yergali (Astana) about the work of people with hearing impairment at a car wash, when they even received tips for a well-

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done job from customers. Wages of people with disabilities do not differ from normotypical people; even if entrepreneurs do not receive state support, they pay from "their own pockets".

Thus, this study refutes the hypothesis that people with disabilities cannot find employment due to the lack of an accessible environment and that it is challenging to create such an environment. The answers of the respondents proved the opposite. If desired, every employer can create an accessible environment, at least in those types of jobs that do not require special equipment, such as car wash (employees of deaf people and deaf-mute), massage parlour (employees of blind people), dishwasher (blind), etc. The survey also shows that it is possible to create an accessible environment for people with disabilities.

The peculiarity of working with social categories is that many of them, for personal reasons, may not go to work. Due to such peculiarities, which were proved in the conducted interviews, it is more effective in working with people with disabilities, as well as with other social categories, that all of them are interchangeable. This is to prevent downtime in production when, for example, people with mental disabilities have crises and miss work. In general, people with cognitive disabilities are complicated to understand, meaning that you have to be prepared for their peculiarities. For example, one of the employers (Victor, 43 years old, Astana) cited a case when an employee with a mental disability did not come to work only because in a situation when the car wash was very noisy, the managing director raised his voice at another employee. This made a big impression on the employee with a mental disability, and he stopped going to work for a few days. So, these situations need to be prepared so that if one employee is absent from work, another employee can replace him. Since this is primarily a business, social entrepreneurs, just like traditional businesses, must fulfil orders to stay afloat. While working with people from social categories, there is a risk of not fulfilling orders on time. It can also be noted that mothers raising small children may not be able to work because the child is sick.

Almost all respondents noted no notable difficulties in employing social categories but neurotypical people. The only inconvenience is when, for example, mothers bringing up small children in case of a child's illness do not go to work. Also, many do not hire former convicts in organizations where teenagers and women work. At the same time, one businesswoman from Karaganda organizes courses for convicts to start their businesses directly in the colonies themselves and also provides them with jobs in the colonies themselves.

A separate social category can be distinguished for people from orphanages, cooperation with whom differs from other categories. According to one employer (Emin, Aliya, Aigerim, Astana), people from orphanages are not so attached to their workplace because they are looking for an easier job, as they are used to receiving a lot of things for free from the state and charity funds. Being in orphanages until the age of 18, they get used to getting many things without effort. This is because Kazakhstan has developed a charity for orphanages. Growing up and leaving orphanages, it is difficult for young people to keep a job where wages are low, and they must work hard. Therefore, there are also difficulties in hiring people from this category.

Another category of people who find it challenging to find a job is those who are addicted to alcohol and drugs. Many employers believe that there is no such thing as an ex-alcoholic or drug addict. The case of one employer shows that such people are prone to breakdowns and go on a bender for weeks, and the production process cannot wait. Therefore, it is challenging to work with such people, and the percentage of such categories is very low.

Another social category that deserves our attention is young mothers raising children alone. But this problem could be solved by an entrepreneur from Karaganda, Indira, who is 37 years old and remotely provides jobs for young mothers raising small children. The women come to the office once a week, receive an order and the materials needed to produce the product, and do the work from home at a time that suits them. That is, the employer has adapted the working hours for the applicant as comfortably as possible. At the same time, such

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employees receive wages on a par with those employees who are directly at the place of work. In this way, the employment problem of one of the social categories - young mothers raising children alone - is also solved.

Dismissal of employees with disabilities occurs for various reasons; most often, they leave after gaining experience and skills, looking for a better-paid job or with a more convenient schedule for them (Victor, Astana). However, there are cases where they are dismissed because of parental interference (Indira, Karaganda). Also, dismissal occurs not because a person has a disability but because of some human behaviour (e.g., stealing, unfriendliness in the team, etc.) (Erkezhan, Semey City, Indira, Karaganda City). There was a case in which an employee with a hearing disability won a grant and went to work in Russia (Victor, Astana). At the same time, in some teams (Emin, Sergey), employees do not quit for years; on the contrary, they even create families among themselves.

The need for state support for entrepreneurs who are taking the difficult path of employing people with disabilities and people from social categories is undoubtedly essential. However, in our study, not all respondents are social entrepreneurs; accordingly, not all can use state support assistance, i.e., they cannot participate in state grants for social entrepreneurs. Entrepreneurs registered as social entrepreneurs enjoy active state support. For example, state programs, unique jobs, and youth practice exist. Under the "Special Workplaces" program, the state allocates funds to compensate the wages of employers who hire social categories (Erkezhan, Emin, Maulen).

Thus, the study allowed us to look at the problem of employment of socially vulnerable groups from the point of view of employers rather than from the side of vulnerable groups. As we see, this problem can be considered from two sides, and it is necessary to consider both sides' interests: both from the side of labour demand and supply.

Conclusions

The research conducted has led to the following conclusions. Some of the interviewed respondents have experience in employing both social categories and people with disabilities, while other entrepreneurs employ only people with disabilities. As the research has shown, there are differences in the approach to the employment of people from social categories, such as mothers with many children, mothers raising small children, former and current convicts, etc., and persons with disabilities. There are also differences in the employment of people with disabilities based on the nature of their impairments, specifically between people with physical disabilities and those with mental disabilities. Furthermore, within the group of people with physical disabilities, there are differences between individuals with acquired disabilities and those with congenital disabilities. Generally, people with congenital disabilities differ from those with acquired disabilities in that they are less adapted to life circumstances, and they often lack basic work-related knowledge and skills. As a result, their employment is more challenging. Many employers note a low level of interest in work among people with congenital disabilities, particularly those with hearing and visual impairments.

Additionally, there is often a dependency attitude, with individuals believing that those around them should treat them specially, offering preferential treatment in their work while expecting higher wages. From a business perspective, this is seen as a deterrent for employers, as entrepreneurs rely on a high production volume, which requires qualities such as responsibility and efficiency—traits that people with congenital disabilities may lack. Consequently, this leads to a pattern of low employment rates for individuals with congenital disabilities. A significant issue in the employment of people with congenital disabilities is the way they are raised. Their parents often instil a dependent mindset from childhood, treating them with pity and fostering a belief that society, employers, and others owe them something. Growing up, these individuals tend to believe they deserve special treatment, forgetting that they cannot perform work at the same level as neurotypical people. Parents can sometimes exacerbate this problem by psychologically pressuring both the employer and the child (Emin, Indira, Victor).

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In contrast, the situation is different for people with acquired disabilities. Many employers note that such individuals remember their lives before the injury and strive to return to the same standard of living they had before the disability. They also tend to have education and work experience, which allows them to adapt more quickly to new work environments. These individuals strongly desire to find a job and earn a good salary to provide for their families. They do not feel sorry for themselves and seek to be treated as equals to neurotypical individuals, avoiding any condescending attitudes. Expert interviews with employers in Kazakhstan who have unique experience in hiring people with disabilities and other social categories reveal that specific difficulties exist, especially when working with people with mental disabilities. These individuals require a unique approach, and patience is needed.

However, the research has also shown that stereotypical attitudes about the barriers to employment for people with disabilities and the reasons for their low employment due to the lack of accessible work environments are being dismantled. The experience of entrepreneurs in Kazakhstan from cities such as Semey, Karaganda, Almaty, and Astana indicates that, when desired, employers can create adaptive conditions to accommodate blind and deaf-blind individuals in the workplace. Therefore, the hypothesis that the low employment rate of people with disabilities is due to the lack of accessible environments has been disproven. Of course, this conclusion does not apply to individuals with disabilities who use wheelchairs, as none of the respondents employed individuals with locomotor disabilities. Creating special adaptive conditions for this group is necessary but remains a separate challenge.

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DIGITAL TWINS AND INNOVATION IN SUSTAINABILITY MANAGEMENT: A BIBLIOMETRIC ANALYSIS, CHALLENGES AND FUTURE DIRECTIONS

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Abstract. This paper systematically explores the current research status and application potential of digital twin technologies (DTs) in sustainable development management, using bibliometric and segmented regression analyses to reveal the field's dynamic trends and research hotspots. Based on the analysis of 421 papers extracted from the Scopus database, this paper summarises the vital role of DTs in smart cities, circular economy, and Industry 4.0. It identifies the key challenges to their implementation, including the digital divide, high cost, data privacy protection, and technical complexity. The paper further suggests future research directions through case studies and theory: exploring the integration of DTs with AI, enhancing interdisciplinary collaboration, and developing low-cost implementations. The contribution of this paper is to provide comprehensive academic support and practical suggestions for the application and development of DTs.

Keywords: Digital twin; bibliometric analysis; management; SDGs

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JEL Classifications: O32, O36, Q01

1. Introduction

Sustainable development is a core concept currently widely used in many fields. Its goal is to improve human well-being while protecting the natural systems that support life on Earth. The idea of sustainable development can be traced back to ancient times and forestry practices in 18th-century Europe (Carlowitz, 1713; Grober, 2010), but the modern definition originated from the report "Our Common Future" published by the World Commission on Environment and Development in 1987 (World Commission on Environment and Development, 1987), which defined sustainable development as "meeting the needs of the present without compromising the ability of future generations to meet their own needs". In 1992, the United Nations Conference on Environment and Development (Rio Summit) officially endorsed this concept and emphasised the vital role of academic institutions in addressing environmental and development issues. Today, sustainable innovation has become a leading principle of global development, and its application extends far beyond traditional areas such as energy and transportation to all aspects of society (De Oliveira et al., 2021).

In this context, Digital Twins (DTs) have emerged as a key tool to support sustainable development management due to their unique advantages in precise modelling, real-time monitoring and optimal management. In 2003, Professor Grieve first proposed the concept of DTs, defining them as a comprehensive

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digital engineering view from product design to production planning, production engineering, manufacturing and related services, i.e. product lifecycle management (Semeraro et al., 2021). With the rapid development of technology, the application of DTs has expanded to transportation and logistics, smart cities, manufacturing, industrial product lifecycle management, and hybrid energy systems (Lu et al., 2020; Wang et al., 2024).

The core advantage of digital twin technology is that through an extensive sensor network, real-time processing of massive amounts of data, and efficient computing power, complex systems embedded in physical entities can be accurately modelled to predict system behaviour under different conditions and constraints (Tao & Qi, 2019; Niederer et al., 2021). Therefore, DTs are regarded as a significant breakthrough in digitalisation and represent the future trend of simulation technology. In an environment where enterprises innovate rapidly, digital twins can be used as both a technical tool and an innovative concept in stakeholder collaboration, business model optimisation, disruptive technology development, and customer interaction (Riascos et al., 2023).

Digital twins have demonstrated their potential in applications ranging from microscopic molecular modelling (Cannoodt et al., 2021) to macroscopic landscape management (Bauer, Dueben, Hoefler et al., 2021), from epidemic prevention and control in public health (Laubenbacher, Sluka, & Glazier, 2021) to planetary science and climate prediction (Bauer, Stevens, & Hazeleger, 2021; Voosen, 2020). In recent years, digital twins have begun to support social mitigation and adaptation measures to address climate change, such as flood prediction and monitoring, disaster-resilient community building, and supporting the achievement of the Sustainable Development Goals (SDGs) (Deren, Wenbo, & Zhenfeng, 2021). In the energy sector, efficient grid construction (Francisco, Mohammadi, & Taylor, 2020) and epidemic prevention and control modelling in public health (Deren, Wenbo, & Zhenfeng, 2021) are examples of their wide application across multiple fields. However, despite the breakthroughs that digital twins have achieved in many fields, they have not yet received sufficient attention in the global sustainable development agenda (Tzachor et al., 2022). Future research and policy need to explore further how to fully realise the potential of DTs in achieving the SDGs.

2. Theoretical background

Digital twin technology was first proposed by Grieve (2003), which refers to the synchronisation and simulation of physical entities through virtual modelling to achieve data-driven complete life cycle management (Grieves, 2003). The core of this technology is to use real-time data and virtual models to achieve complete life cycle management of physical entities (Grieves, 2014), and in practical applications, it has three distinct technical features: real-time data collection and transmission of physical systems through the Internet of Things (IoT) and sensors (Shehadeh et al., 2024); dynamic simulation using virtual models to predict the behaviour of systems under different conditions (Allam et al., 2021); and system integration to support cross-domain resource optimisation and management (He & Bai, 2020). In recent years, with the rapid development of the Internet of Things (IoT), artificial intelligence (AI), and big data technologies, this technology has been widely used in many fields, such as manufacturing, aerospace, urban planning, healthcare, and agriculture. It has demonstrated unique advantages in resource optimisation, energy efficiency improvement, and system prediction (Liu et al., 2021; Shehadeh et al., 2024). Digital twins are a vital tool for driving innovation in sustainable development management.

In sustainability, DTs support the optimisation and collaborative management of resources in complex systems through real-time monitoring and simulation (Zahedi et al., 2024). Digital twin technologies enhance spatial planning and management of urban and rural sustainability initiatives. Miszczak, Krivins, and Kaze (2024) emphasise that sustainable spatial development depends significantly on integrating economic, ecological, and social dimensions through advanced spatial planning and stakeholder engagement. Digital twins provide a robust technological framework to facilitate these integrations, offering data-driven simulations that align economic growth with environmental preservation. As a core innovative technology of Industry 4.0, DTs can optimise production processes, reduce resource waste, and achieve green manufacturing. (Liu et al., 2021). For example, in water-energy-food-environment (WEFE) management, digital twin technology supports the efficient use of resources and decision-making optimisation by integrating multi-source data (Jurgelane-Kaldava et al., 2024) and building dynamic models (Shehadeh et al.,

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2024). In addition, the rise of urban digital twin (UDT) technology has further expanded the application of this field. In smart city planning, UDT can support low-carbon transportation and intelligent energy management through dynamic monitoring (Allam et al., 2022). Supporting the smart city planning and low-carbon infrastructure construction can help achieve sustainable development goals at the city level (Miehe et al., 2021). Similarly, in the field of circular economy, DTs can support waste reuse and closed-loop resource management (Verdouw et al., 2021).

Effective sustainability management through digital twins relies on technical capability but must also account for organisational capacities and humans - their values and behaviours that influence technology acceptance and application.

In this context, workforce characteristics profoundly influence organisational innovation and sustainability management through digital twins. Recent studies highlight that workforce diversity significantly enhances organisational performance through improved creativity, innovative solutions, and better responsiveness to environmental and operational challenges (Etalong et al., 2025). Such diversity can also enrich the implementation and use of digital twin technologies by incorporating varied perspectives and expertise into sustainability practices.

Earlier research demonstrated that aligning sustainability initiatives with regionally relevant human values enhances adoption and economic viability (Kaže et al., 2011). Additionally, recently adopted innovative image-based methodologies for measuring personal values significantly improve understanding of individual motivations (Kaže et al., 2022), thus being critical for designing targeted digital sustainability interventions. Similarly, consumer values directly influence economic behaviours, including willingness to participate in formal economic processes, which is crucial when planning digital interventions to mitigate grey economy practices (Kaže & Bolinskis, 2011).

The aforementioned suggests a significant area not limited to values and motivation only but also human factors such as digital literacy, resistance to change, sociocultural readiness, and even philosophical worldviews underlying these perceptions of experts in the field (Elsehrawy et al., 2023). For instance, successful implementation of DTs depends on alignment with human values and significantly on societal acceptance, digital literacy, and organisational cultures. Resistance to change, lack of technical knowledge, and sociocultural attitudes towards technology significantly influence adoption rates and effectiveness (Rasheed et al., 2020).

It might raise additional ethical questions, for instance, from a privacy perspective. While offering significant benefits, DT technologies also bring critical ethical and privacy challenges. Their dependence on extensive data collection, including sensitive and personally identifiable information, concerns about data security, user privacy, and surveillance have emerged. Organisations employing digital twins must navigate complex issues of informed consent, data ownership, transparency in data handling, and compliance with privacy regulations such as the General Data Protection Regulation (GDPR) in the European Union. Addressing these ethical implications requires robust governance frameworks and clear ethical guidelines to prevent data misuse and build public trust in digital twin deployments (De Kerckhove et al., 2022; Helbing & Sánchez-Vaquerizo, 2023; Naikwadi & Shrivastav, 2025).

Despite the great potential of digital twins in sustainable development, their implementation still faces many challenges, including environmental impact: high energy consumption and carbon footprint issues limit the long-term sustainability of DTs (He & Bai, 2020); insufficient data standardisation: the integration of multi-source heterogeneous data is complex and the level of standardisation is low (Zahedi et al., 2024); infrastructure constraints: developing countries lack the necessary technology and infrastructure (Allam & Jones, 2021; Muhamud et al., 2024). In addition, there may be risks of corruption, especially in developing countries (Krivins, 2014; Krivins et al., 2023). These challenges indicate that multifaceted technological, policy and societal efforts are still needed to achieve the large-scale application of technology and sustainable development goals.

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Deploying digital twins can significantly aid regions heavily reliant on a single resource, such as oil, in achieving broader economic diversification. Okueweze et al. (2025) argue that diversifying away from oil dependency is essential for sustainable economic growth, reducing vulnerability to price volatility, and fostering resilience by expanding innovative sectors and value-added manufacturing. Digital twin technology could play a pivotal role in simulating and planning this transition, thus reinforcing sustainable economic development strategies for transforming economies towards more sustainable models. In the past, it has been particularly relevant to digital transformation and adopting new technologies and business practices. Such a transformation of economic sectors through digital technologies, as exemplified by digital banking, underscores the necessity of aligning technological innovations with customer needs and expectations. Kaže, Baumane, Šumilo, and Škapars (2007) highlight that successfully integrating digital technologies within traditional sectors such as banking demands comprehensive adaptation strategies, considering both technological readiness and consumer behavioural shifts towards knowledge-intensive interactions. Digital twins, similarly, require businesses and industries to realign strategies towards more interactive and knowledge-intensive sustainability practices. Digital twins exemplify broader trends in digitalisation and e-environment tools crucial for sustainable business practices. For instance, an effective use of digital environments significantly accelerates sustainable business development, though many organisations remain at the preliminary stages of digital adoption. Effective digital twin implementation requires overcoming these initial barriers by enhancing digital literacy, aligning business models with digital innovation, and capitalising fully on available digital tools for sustainability.

Beyond these aspects, scholars emphasise several critical perspectives of digital twins, particularly concerning the practical adoption perspective. From an economic and financial perspective, despite clear benefits, digital twins' financial and economic feasibility remains challenging. High initial investment, complex integration processes, and uncertainty about return on investment can act as barriers, particularly for small and medium-sized enterprises, thus requiring careful financial planning and targeted policy support (Qi & Tao, 2018; Jones et al., 2020). From a regulatory and governance framework perspective, widespread adoption of digital twins is contingent upon supportive regulatory environments and robust governance frameworks. Clear standards and interoperability regulations are essential to facilitate integration across diverse systems and industries, particularly within cross-border contexts and international collaborations (Melesse et al., 2020; Mureddu et al., 2025). Scalability and interoperability perspectives pose additional technical challenges for DT implementation. Ensuring seamless communication and integration among heterogeneous systems, especially when scaling digital twin solutions across industries or geographical regions, requires standardised protocols and data formats (Cimino et al., 2019; Lu et al., 2020), which might be a challenge from the practical adoption perspective to many enterprises. Another perspective is lifecycle management, including end-of-life considerations for digital twins, which remains underexplored but critical for sustainability. As DTs involve significant technological resources, strategies for responsible disposal, recycling, or repurposing of digital assets and hardware infrastructure are essential components of comprehensive sustainability management (Parrott & Warshaw, 2017). One of the most topical perspectives is integrating artificial intelligence and machine learning algorithms, which significantly enhances digital twins' predictive power and adaptive capabilities. Advanced AI-driven analytics enable more accurate simulations, predictive maintenance, anomaly detection, and adaptive responses, thus increasing efficiency and reliability in complex systems management (Shao & Kibira, 2018; Fuller et al., 2020).

These perspectives show that digital twin technologies offer a multifaceted approach to sustainability management, integrating advanced technical capabilities with significant consideration of human, organisational, ethical, economic, regulatory, and technological challenges. As highlighted, successful deployment of DTs requires addressing these complex factors collectively rather than in isolation. Given these theoretical insights, it is essential to systematically examine how these aspects are currently discussed in practical contexts. The subsequent chapter employs a bibliometric analysis to map existing research trends, knowledge gaps, and future directions, providing empirical evidence to support strategic development and informed policymaking for the broader implementation of digital twins in sustainability management.

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3. Methods

This study selected bibliometric analysis as the core research method, which is highly respected and widely used in academic research (Zupic & Cater, 2015). This method provides an objective and solid framework for systematically reviewing the literature. Its essence lies in a comprehensive, multidimensional, in-depth analysis of the conceptual framework and scope covered by digital twins and innovation in sustainable development management (Ramos-Rodríguez & Ruíz-Navarro, 2004). Bibliometric analysis can accurately analyse the complex paradigms of specific scientific topics in the key dimensions of quality and quantity using scientific statistical methods (De Bakker, Groenewegen, & Den Hond, 2005; Niu et al., 2016). In this review of the literature, the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) standard process was strictly followed to ensure the scientific nature, reliability and standardisation of the research (Moher, Liberati, Tetzlaff, & Altman, 2009). The use of bibliometric analysis tools can accurately extract high-frequency keywords, keenly capture the dynamics of research hotspots, and carefully sort out the distribution of core academic journals in this research field, thus laying a solid foundation and providing key support for in-depth exploration of the theme of digital twins and sustainable development management innovation (Bornmann & Mutz, 2014).

This study also used a more advanced method called segmented regression analysis, which is used in the regression analysis of the data. Segmented Regression Analysis can better identify nonlinear changes and periodic characteristics in time series data. This method can effectively reveal turning points in trends and growth patterns in each period by dividing the data into multiple intervals and modelling each interval separately (Bornmann & Mutz, 2014).

Mathematically, the basic form of a segmented regression model is as follows:

$$y(t) = \begin{cases} b_0 + b_1 \cdot t + \epsilon, & if\ t \le a_1 \\ b_0 + b_1 \cdot a_1 + b_2 \cdot (t - a_1) + \epsilon, & if\ a_1 < t \le a_2 \\ b_0 + b_1 \cdot a_1 + b_2 \cdot (a_2 - a_1) + b_3 \cdot (t - a_2) + \epsilon, & if\ t > a_2 \end{cases}$$

Among them, a_1, a_2 are turning points, b_1, b_2, b_3 are the growth rates of each stage, respectively, representing the error term. The model parameters are estimated by least squares, which can identify key turning points and their corresponding growth patterns (van Raan, 2000).

Segmented regression analysis has demonstrated critical value in studying scientific growth and technology diffusion. As Bornmann and Mutz (2014) discovered when investigating the growth of scientific literature, the trajectory of global scientific activity since the Industrial Revolution has been characterised by multiple stages, from slow growth to exponential growth. This finding provides conclusive evidence of the central role of segmented regression analysis in accurately revealing the process of long-term trend changes. Moreover, van Raan's (2000) research results clearly show that factors such as policy orientation, war conflicts, and technological changes significantly impact scientific development, which is characterised by significant differences in stages. In digital twin research, segmented regression analysis also plays a key role. It is widely used to explore the dynamic evolution model of technology diffusion and its internal influencing factors in detail. For example, by systematically analysing the growth of digital twin technology in different professional fields, researchers can accurately identify key nodes in the technology promotion process and deeply reveal the core mechanisms driving its development (Zahedi et al., 2024).

At present, the profound impact of digital twin technology in driving the innovation dimension of sustainable development management has aroused the interest and attention of scholars, policymakers, and industry experts. This situation urgently calls for a comprehensive bibliometric, in-depth exploration of the intersection of these fields. It is of great importance to comprehensively review the existing literature, gain insight into emerging research topics, accurately define the framework of the role of digital twins in sustainable innovation practices, and prospectively identify potential trends for future research.

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Given this, this study innovatively uses bibliometric analysis to explore the research hotspots of digital twin technology (DTs) in sustainable development management. It organically integrates segmented regression analysis to discuss the dynamic evolution model of its technology diffusion intensely. Furthermore, through a comprehensive quantitative analysis and a case study paradigm, this study reveals research trends and practical challenges from multiple perspectives by profoundly analysing the following core issues to construct a systematic reference framework for academic research communities and practitioners:

RQ1. What is the growth of scientific publications concerning digital twins and sustainability management innovation? Does it have research potential?
RQ2. By segmenting and analysing the number of citations and high-frequency keywords in the literature, this study examines the hotspots in different time frames to explore the innovation vitality of this research field. What is the future development direction?
RQ3. In which journals do researchers mainly publish articles?
RQ4. Who are the top institutions involved in digital twins and sustainability management innovation?
RQ5. How is the literature geographically distributed? Is there a digital divide?
RQ6. Which authors have been the most prolific regarding digital twins and innovation in sustainability management? What challenges do DTs face from the perspective of innovation in sustainability management?

3. Data sources and search strategy

The data used in this study were obtained from the Scopus database, currently the largest abstract and citation database of peer-reviewed literature (Baas et al., 2020). Scopus indexes various elements of scientific publications obtained from external publishers, such as publication titles, abstracts, keywords, author names, linked affiliations, references, and drug terms (Berkvens, 2012). The data were obtained by executing a general search query. The database search was limited to one day, November 4, 2024, to prevent bias that could result from frequent routine updates. The research focused on literature related to digital twins and innovation management for sustainable development indexed in the Scopus database between 2014 and 2024 for review in bibliometric analysis (see Figure 1).



Figure 1. Outline of the data retrieval process

Search term: ('Digital twin'OR 'Digital twins' OR 'DT'OR 'DTs') AND ('Innovate' OR 'Innovation' OR 'Innovative' OR 'Innovativeness' OR 'Create' OR 'Creation' OR 'Creative' OR 'Creativity' OR 'Creativeness') AND ('manage' OR 'management') AND ('sustainable development' OR 'sustainability')

To combine many subtopics in a search query, we used Boolean operators OR and AND to accomplish this task and include all relevant information. Table 1 below illustrates the Boolean operators (OR, AND) search method in the Scopus database. Researchers obtained a sample document in *CSV format from Scopus to analyse key information. This information includes the year of publication, title, author name and affiliation, abstract, keywords, journal name, document type, and references. In addition, the search criteria were refined to include only Articles and exclude Reviews, Book chapters, Conference papers and Conference reviews. Finally, a dataset of 421 documents was obtained.

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Table 1. The search strings

Database Search criteria	Search string strategy Boolean operators	No. Documents
Search string keyword	('Digital twin'OR 'Digital twins' OR 'DT'OR 'DTs') AND ('Innovate' OR 'Innovation' OR 'Innovative' OR 'Innovativeness' OR 'Create' OR 'Creation' OR 'Creative' OR 'Creativity' OR 'Creativeness') AND ('manage' OR 'management') AND ('sustainable development' OR 'sustainability')	20,298
Documents Types	Articles only	11,164
Year Published	2017-2023	-
Language	English	-
Scopus Database	Total databases	421

After identifying the documents, the data is verified and cleaned manually. All entries in the columns are checked to ensure no important data is missed and to ensure standardisation. After sorting, the data is saved for analysis, and the author, title, ID, year, source, volume, issue, citation time, link, abstract, keywords and publisher information of the study are finalised. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart is as follows (see Figure 2). Publication trends ae

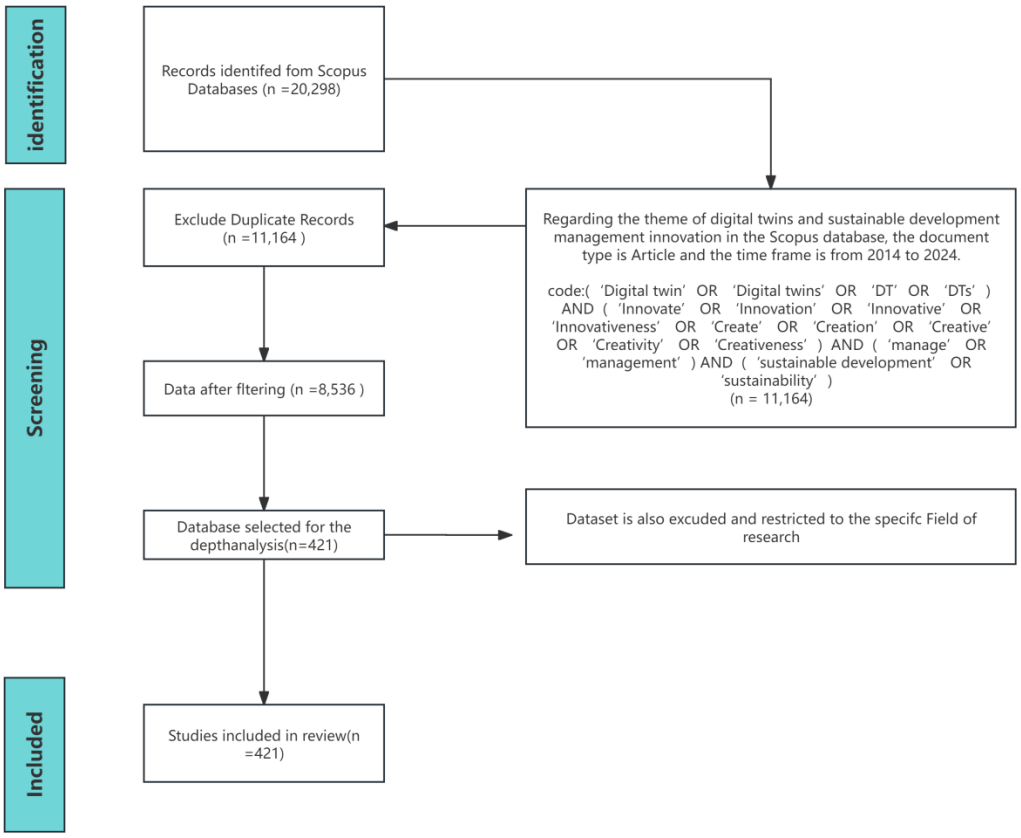


Figure 2. PRISMA Model

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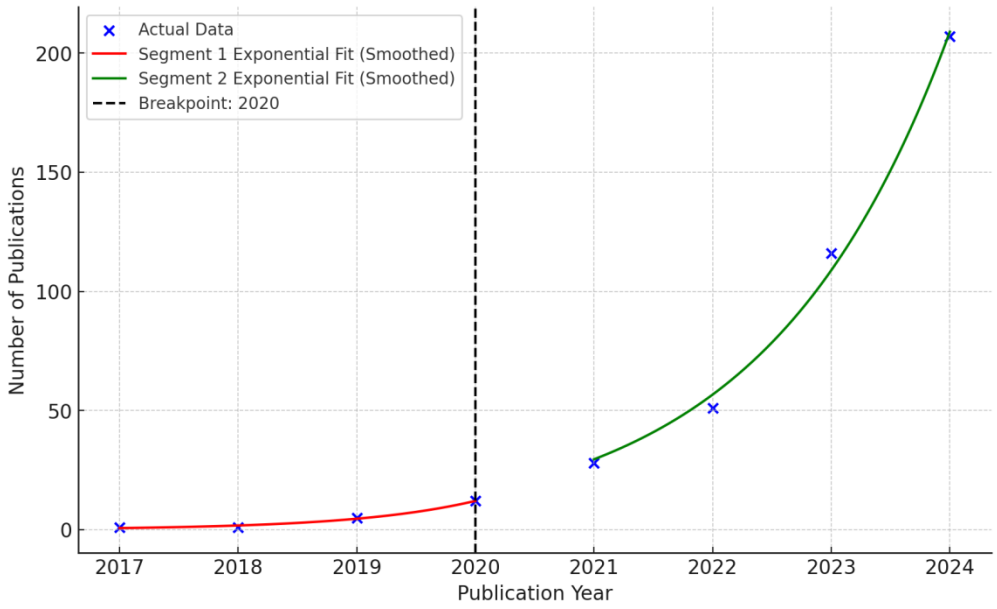


Figure 3. Publication Trend
Source: Scopus Database

3. Analysis and discussion

RQ1. What is the growth of scientific publications concerning digital twins and sustainability management innovation? Does it have research potential?

In this study, the intersection of digital twins and sustainable development is an emerging direction that is still in the early stages of discipline development. The time frame is significant, and we have used an advanced statistical technique, segmented regression analysis, to analyse and describe the relationship between the year of publication and the number of papers published in the field (Bornmann & Mutz, 2015).

We selected 2020 as the breakpoint and performed segmented exponential regression analysis on the relationship between the year of publication and the number of publications, which yielded the following results:

An exponential regression model was used for each segment:

$y=a\cdot e^{b.x}$

y: Number of publications.

x: Publication year.

a: the number of publications in the base year, indicating the initial baseline level of academic output

b: the exponential growth rate of publications per year, indicating the rate at which the number of publications increases over time

Before 2020: For years $x\leq 2020$, $y=0.6612\cdot e^{0.9682.(x-2017)}$

After 2020: For years $x>2020$, $y=29.5232\cdot e^{0.6523.(x-2020)}$

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The analysis shows that before 2020, the number of publications started small but grew relatively quickly, almost doubling yearly. After 2020, the number of publications grew even more, but the growth rate slowed down. However, it still maintained an extremely high rate, showing the huge research potential in this field.

In addition, our model has a high degree of fit: Segment 1: R2=0.9896, Segment 2: R2=0.9953, Overall: R2=0.9976. This statistical result shows that about 99.76% of the observed changes in the number of published papers can be attributed to changes in the year of publication. This substantial R-squared value emphasises the importance of the temporal trend, indicating that the year of publication is a strong predictor of the number of papers in our field of study. It is a strong testament to the evolving nature of the field and the key role that the passage of time plays in influencing research output. Overall, our analysis highlights the significant influence of the temporal factor on publication patterns and reveals essential trends in our field of study.

RQ2. By segmenting and analysing the number of citations and high-frequency keywords in the literature, this study examines the hotspots in different time frames to explore the innovation vitality of this research field. What is the future development direction?

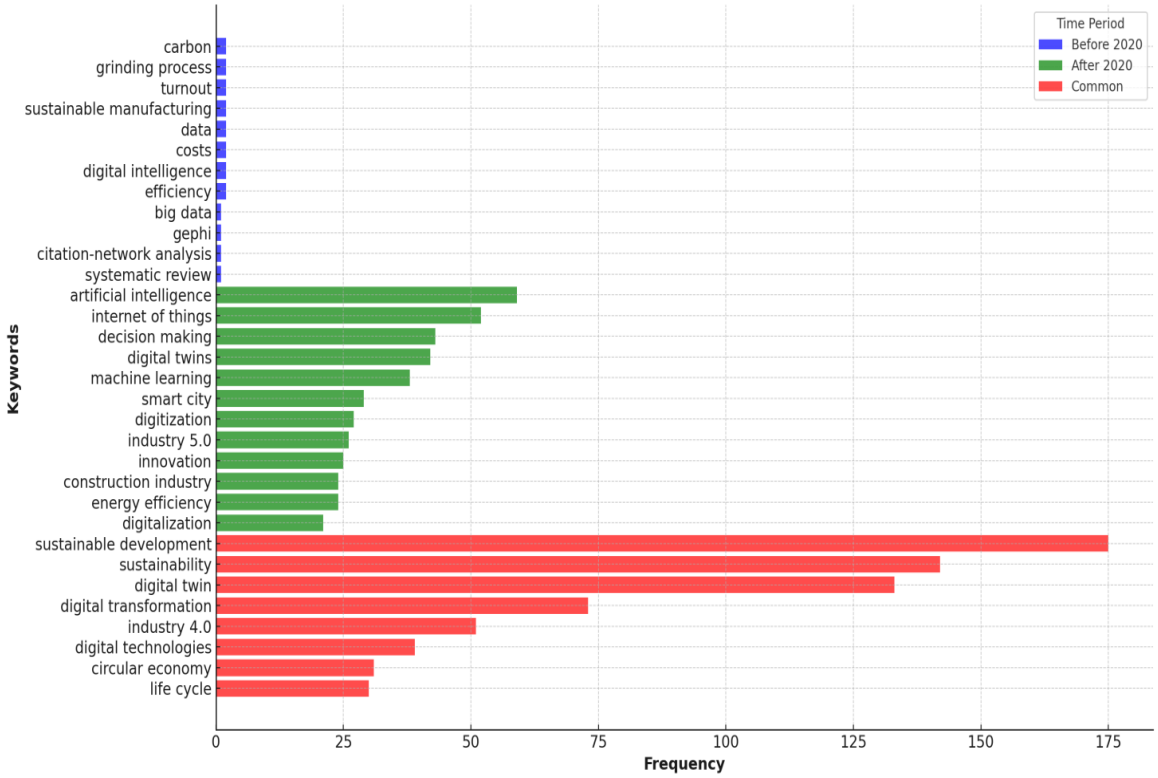


Figure 4. Quotation trends
Source: Scopus Database

This study analyses citation trends for datasets in our research field. The datasets reveal a dynamic pattern of academic recognition over time (see Figure 4 above). In the opening year of 2017, research articles were cited 13 times, indicating that the field has reached a benchmark level of academic recognition. Subsequently, citations increased significantly, peaking at 832 in 2020 and 2048 in 2021.

This significant spike highlights the increased influence and recognition within the research field. However, the number of citations in 2022 fell back to 1916, indicating a stabilisation in the recognition of research articles.

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These fluctuations in the number of citations are evidence of the evolving nature of research influence, with 2020 again identified as a key turning point, reflecting the impact of the COVID-19 pandemic on DTs research promotion (Allam et al., 2021). We then used 2020 as a cut-off point to conduct a segmented analysis of the frequently appearing keywords in the dataset (Figure 5).

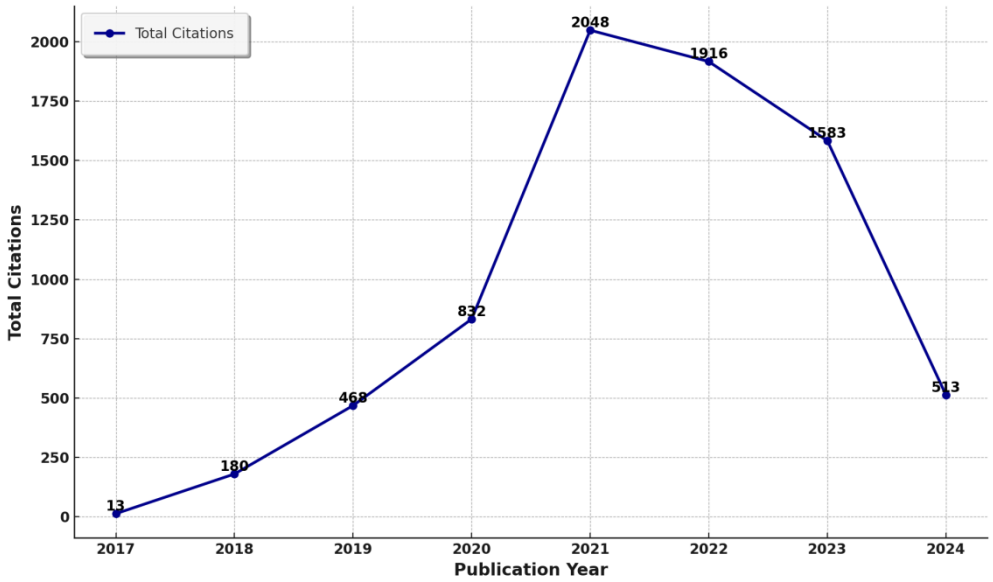


Figure 5. High-frequency keywords
Source: Scopus Database

The analysis showed that Industry 4.0, circular economy, digital transformation, and life cycle are research directions that continue to be active in this field. Before 2020, most research in this field focused on using big data to improve the sustainable development of the manufacturing industry. After 2020, it quickly expanded to multidisciplinary fields such as artificial intelligence, smart cities, energy efficiency, management decisions, and Industry 5.0. This significant change highlights the expanding interdisciplinary influence and continuously improving innovation activity of digital twin technology in the field of sustainable development management while also demonstrating some of the future research directions in this field: interdisciplinary research across engineering, management, and other disciplines, the use of DTs to replace humans in decision-making and management, and the combination of DTs with AI and machine learning.

Through the analysis of the corresponding data sets, we have determined the following future research directions in this field:
(1) Cross-domain collaboration: Further explore the comprehensive application framework of DT technology in different fields (such as smart cities, smart agriculture, and manufacturing) to promote knowledge crossover and innovation among multiple disciplines.
(2) Technology optimisation and standardisation: Research how to reduce the economic cost of DT system deployment and improve data standardisation methods to improve the applicability and scalability of the technology.
(3) Social and ethical challenges: Strengthen research on the impact of DT technology on data privacy, ethical controversies, and social governance to address potential risks in the application of technology.
(4) Integration of climate and ecological models: Explore the application of DTs in predicting global climate change and ecosystem sustainability and strengthen its role in natural resource management, risk prevention, and control.

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(5) Integration of artificial intelligence: Deeply integrate DTs with artificial intelligence (AI) and machine learning technologies to enhance their predictive and decision-making capabilities and solve complex problems.

RQ3. In which journals do researchers mainly publish their articles?

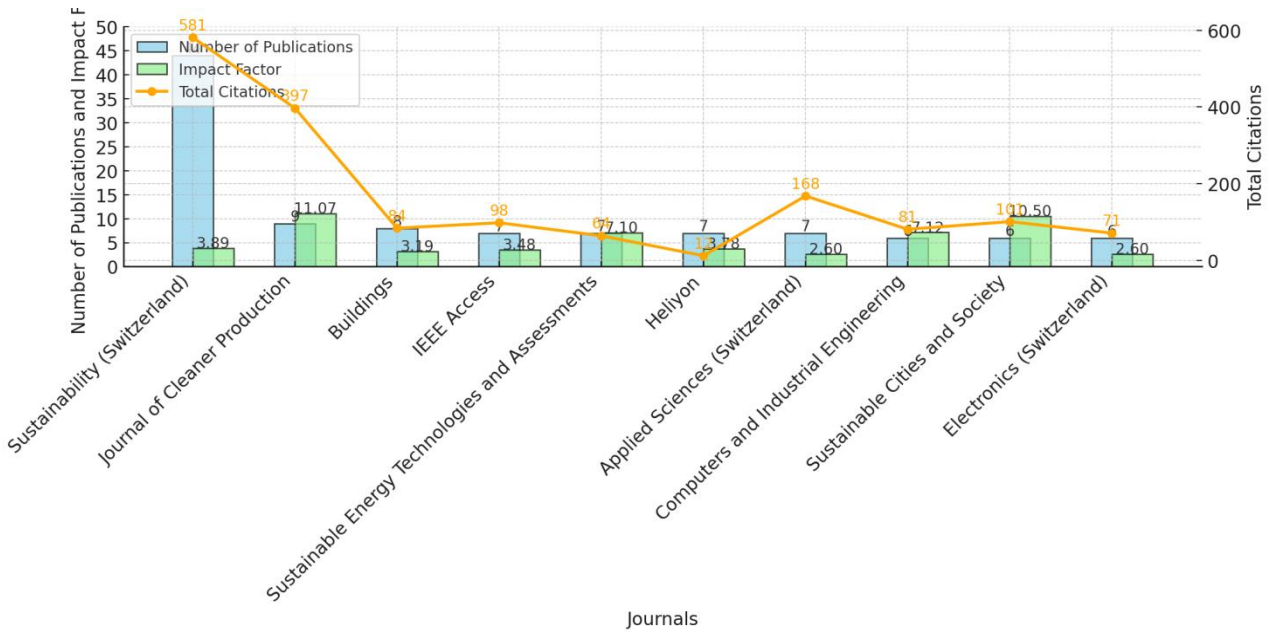


Figure 6. Influence and respectability of Top Ten Journals
Source: Scopus Database

The Scopus dataset provides a comprehensive overview of academic journals in a specific research field, revealing their respective contributions and impact on academia (Baas et al., 2020). Notably, "Sustainability" is the most prominent journal, with 44 publications and 581 citations. The aforementioned indicates that academia recognises the journal's content highly. In addition, the impact factors, especially those of journals such as the "Journal of Cleaner Production" (impact factor 11.072) and "Sustainable Cities and Society" (impact factor 10.05), are also very prominent, highlighting the influence and respectability of these journals (see Figure 6 above). These indicators provide valuable insights for researchers to navigate the academic field and enable them to identify important and relevant journals to their research.

Table 2 below illustrates the search results in the Scopus database (search options: Search within / Article title; Search documents / 'digital AND twin'; Year range 'From 2025 to 2025'; Filter by subject area / Business, Management and Accounting). The search criteria were refined to include only Articles. Finally, a dataset of 40 documents was obtained:

Table 2. The search results: Business, Management and Accounting

	Journal	Autors, who published in year 2025
1.	Applied Stochastic Models in Business and Industry	Bleistein, T., Paulus, M., Gani, K., Becker, R., Werth, D.
		Oksuz Gurdal, B., Testik, O.M.
2.	Architectural Engineering and Design Management	Chen, W., Hu, C., Zou, R., Yang, Q., Chen, Y., Xing, J., Mou, C.
3.	Benchmarking	Srivastava, G., Bag, S.
4.	Business Strategy and the Environment	Kilinc, T., Sjödin, D., Parida, V.
5.	Cities	Luo, J., Liu, P., Xu, W., Zhao, T., Biljecki, F.
		Diaz-Sarachaga, J.M.
6.	Construction Management and Economics	Miraj, P., Wang, T., Koutamanis, A., Chan, P.

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7.	Engineering, Construction and Architectural Management	Ohueri, C.C., Masrom, M.A.N., Habil, H., Ambashe, M.S.
8.	Global Business Review	Sharma, A.K., Srivastava, M.K., Sharma, R.
9.	Global Journal of Flexible Systems Management	Hossain, M.I., Talapatra, S., Saha, P., Belal, H.M.
10.	International Journal of Clothing Science and Technology	Moskvin, A., Moskvina, M., Kuzmichev, V.
11.	International Journal of Engineering Business Management	Al-Qirim, N., Majdalawieh, M., Bani-hani, A., Al Hamadi, H.
12.	International Journal of Logistics Management	Singh, R.K.
13.	International Journal of Logistics Research and Applications	Shoaib, M., Zhang, S., Ali, H., Ahmad, M.S., Khan, M.A
14.	International Journal of Pharmaceutical and Healthcare Marketing	Avinash, B., Joseph, G.
15.	International Journal of Precision Engineering and Manufacturing - Green Technology	Cho, H.-S., Sohn, J.-H., Han, J.-B., Yeu, T.-K.
16.	International Journal of Production Economics	Lee, J., Chua, P.C., Liu, B., Moon, S.K., Lopez, M.
17.	International Journal of Production Research	Cheng, Y., Liu, H., Qi, Q., Tao, F.
		Zhang, C., Tao, F., Qi, Q., Cheng, Y., Cheng, J., Wang, B., Nee, A.Y.C.
		Zhu, X., Liao, B., Shen, Y., Kong, M.
		Werner, A., Schuseil, F., Hämmerle, M., Schaper, S., Hölzle, K.
18.	Internet of Things (The Netherlands)	Bozkaya-Aras, E., Onel, T., Eriskin, L., Karatas, M.
		Iqbal, M., Suhail, S., Matulevičius, R., Shah, F.A., Malik, S.U.R., McLaughlin, K.
		Suhail, S., Iqbal, M., McLaughlin, K., Lee, B., Imtiaz, B.
		Burattini, S., Mariani, S., Montagna, S., Picone, M., Ricci, A.
		Okegbile, S.D., Gambo, I.P.
		Özkan, E., Kök, İ., Özdemir, S.
19.	Journal of Advanced Manufacturing Systems	Love, A., Behseresht, S., Pastrana, O.A.V., Sakai, J., Park, Y.H.
20.	Journal of Cleaner Production	Piron, M., Bovo, E., Lucchetta, G., Manzardo, A.
21.	Journal of Construction Engineering and Management	Yan, H., Liu, C., Yang, X., Feng, K.
22.	Journal of Environmental Accounting and Management	Jia, R., Jia, L., Jiang, H., Wang, P., Deguchi, Y., Zhang, J.
23.	Journal of Innovation and Knowledge	Cao, J., Spulbar, C., Eti, S., Horobet, A., Yüksel, S., Dinçer, H.
24.	Journal of Management in Engineering	Yan, J., Lu, Q., Li, N., Pitt, M.
25.	Journal of Modelling in Management	Mharzi, R., Ben Kacem, A., Elouadi, A.
26.	Journal of Research in Marketing and Entrepreneurship	Nyquist, A.-M., Farshid, M., Brown, T.
27.	**Logistics**	Roman, E.-A., Stere, A.-S., Roșca, E., Radu, A.-V., Codroiu, D., Anamaria, I.
		Rinaldi, M., Caterino, M., Riemma, S., Macchiaroli, R., Fera, M.
28.	Production Engineering Archives	Elqabli, Z., Kamach, O., Chater, Y.
29.	TQM Journal	Chalipour, A., Noorzai, E., Golabchi, M., Hosseini Nourzad, S.H.

RQ4.What are the top institutions involved in digital twins and innovations in sustainability management?

The dataset reveals significant differences in the research output and impact of institutions, as measured by the number of citations and the average number of citations per article. King Saud University leads the way with 15 papers published, achieving an impressive total of 179 citations and an average of 11.93 citations per paper. LUT University and The Hong Kong Polytechnic University followed closely behind, with 13 and 12 publications, total citations of 117 and 89, and average citations of 9 and 7.42, respectively. This observation indicates that these institutions have produced numerous research results that have powerfully impacted their respective academic circles.

Although the University of Cambridge has only published seven papers, its educational influence is unique. Their papers have been cited 242 times, with an average of 34.57 citations each, which indicates the institution's important position in academia. The University of Johannesburg and Zhejiang University also have seven publications each, with 151 and 71 citations, respectively, and an average of 21.57 and 10.14, respectively. Figure 7 highlights the contribution of these two universities as leading institutions conducting

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research and generating resonance within their academic fields. The University of Chinese Academy of Sciences published six paper. Although the average number of citations per paper was 7.5, indicating a medium level of impact, it demonstrates the global reach of its research. The Norwegian University of Science and Technology achieved an impressive 730 citations from just five publications, with an average of 146 citations per paper, demonstrating the institution's excellence in this field of research.

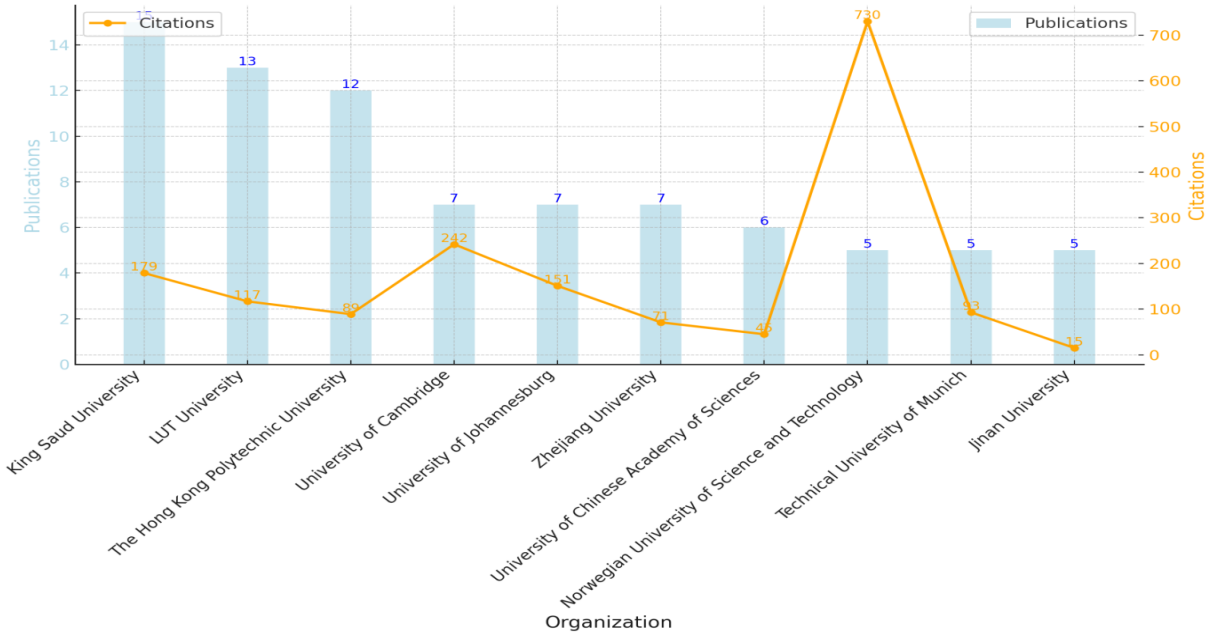


Figure 7. Top Ten Institutions
Source: Scopus Database

Similarly, the Technical University of Munich, with five papers published, also has a respectable average of 18.6 citations. Finally, with an average of just three citations, Jinan University still has five publications that indicate significant contributions to academic research.

RQ5. How is literature distributed geographically? Is there a digital divide?

This dataset reflects the diversity and richness of research results in various countries. China ranks first with 218 papers and 1,610 total citations, highlighting its essential position in the global research community.

Notably, India and the United Kingdom follow closely, with 96 and 89 papers published, respectively. Still, their total citations reach 1,003 and 1,145, respectively, further demonstrating the significant influence of both countries in academic research. The United States ranked fourth with 77 papers published. Research activities in European countries such as Italy,

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Spain, Germany and Portugal were also active, with the number of papers published ranging from 27 to 68. Germany is particularly noteworthy, with 887 citations, reflecting its essential contribution to related research fields. In addition, Saudi Arabia is the only non-European or non-American country (excluding China) in the top ten, with 27 papers demonstrating its potential as an emerging research force (Figure 8).

When examining the distribution of relevant data in depth, it is not difficult to notice that there is a significant digital divide between different countries within the academic research fields of digital twins and sustainable development. Specifically, China, the United States, and many European countries have played a significant role in digital twin technologies (DTs) research. With their strong technical capabilities, abundant resource reserves, and relatively complete scientific research systems, they have produced many influential research results in this field. In contrast, many developing countries have relatively weak technological conditions and lack resources; therefore, they have not invested enough in research on digital twins and sustainable development.

This imbalance in the quantity and impact of research results between different countries, i.e., the digital divide, has, to a certain extent, constrained the widespread popularisation and practical application of digital twin technology (DTs) at the global level (Allam & Jones, 2021).

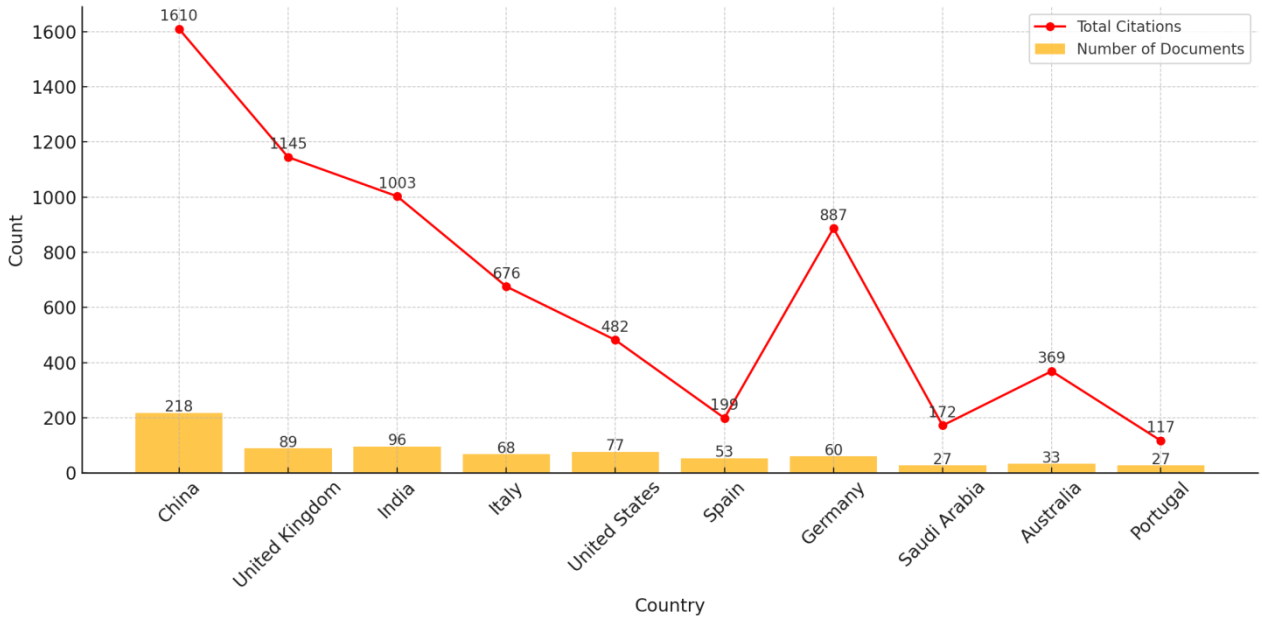


Figure 8. Top Ten Countries
Source: Scopus Database

Further analysis of the data presented in the dataset shows that countries with low publications in this field are often relatively economically underdeveloped. The above shows that the dataset not only clearly shows the significant gap in research impact between countries worldwide in digital twins and sustainable development but also reveals that the digital divide has become a serious challenge to applying digital twin technology in achieving the Sustainable Development Goals.

RQ6. Which authors have been most productive in the field of digital twins and sustainability management innovation? What challenges do DTs face from the perspective of sustainability management innovation?

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We extracted the 10 most influential authors in digital twins and sustainability management innovation from the dataset. While studying the authors' contributions to the field, we explored the challenges DTs face from the perspective of sustainability management innovation by conducting an in-depth reading of the literature of these 10 authors (see Table 3).

Table 3. Top Ten Authors

Individual Authors	Total_Publications	Total_Citations
Jones, D.S.	2	491
Allam, Z.	2	491
Li, J.	5	437
Mikalef, P.	1	413
Kristoffersen, E.	1	413
Blomsma, F.	1	413
He, B.	2	411
Bai, K.-J.	1	398
Bibri, S.E.	2	381
Verdouw, C.	2	317

Source: Scopus Database

This study focuses on the relevant literature of ten authors. After careful screening, some documents that are highly relevant to the topic are selected for in-depth analysis. The study found that digital twin technology (DTs) faces a series of challenges that need to be urgently addressed in the process of practical application of innovation in sustainable development management:

(1) Data management and technical complexity: The core of digital twin technology lies in its ability to accurately obtain, efficiently process, and deeply analyse real-time data. However, when faced with complex systems, integrating data from multiple sources with heterogeneous characteristics poses a significant challenge (Verdouw et al., 2021). At the same time, data integrity and accuracy play a critical role in digital twin technology's predictive and decision-making functions. However, under specific resource-constrained conditions, existing data collection and transmission technologies often cannot fully meet these stringent requirements for data quality (Allam & Jones, 2021).

(2) Infrastructure and resource constraints: The effective deployment of digital twin technology depends on powerful computing capabilities and sufficient storage capacity, which undoubtedly sets high standards and requirements for infrastructure construction. Unfortunately, many developing countries and regions with relatively limited resources generally lack the technical support and economic guarantees (Kastratovic et al., 2024) necessary to implement digital twin technology. This situation seriously restricts the widespread promotion and popular application of digital twin technology worldwide (Wang et al., 2023; Vilks et al., 2024). Especially in the era of Industry 4.0, the manufacturing industry's implementation cost of digital twin systems has increased significantly, further exacerbating the application difficulties caused by infrastructure and resource constraints (He & Bai, 2020).

(3) Environmental and economic sustainability: Although digital twin technology can theoretically help improve resource utilisation efficiency, the high cost associated with its development and operation stages poses a severe test for sustainable economic development. In addition, since digital twin systems usually require high-performance computing resources to maintain their operations, the resulting energy consumption and corresponding carbon footprint have become significant challenges regarding environmental sustainability that cannot be ignored (Tian, 2022; He & Bai, 2020).

(4) Social and governance issues: The widespread application of digital twin technology inevitably involves many complex social issues and governance challenges. Data privacy protection issues, ethical controversies, and the need for cross-organisational collaboration are particularly prominent among them. These issues significantly affect the social acceptance of digital twin technology and put forward new requirements and challenges for existing governance models (Allam et al., 2022). Therefore, striking a reasonable balance

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between the development process of digital twin technology and actual social needs remains a core issue that researchers and practitioners must focus on and explore in depth in the current and future periods.
(5) Specific challenge areas in application scenarios: The demand characteristics and challenges faced by digital twin technology in different professional fields are significantly different. For example, in the specific field of smart agriculture, the ability to accurately simulate complex and ever-changing ecosystems using digital twins has become a key bottleneck restricting the practical application of this technology. In smart manufacturing, the sustainable management of the entire product life cycle has become the current research focus (Verdouw et al., 2021; He & Bai, 2020).

Conclusions and recommendations for future research

Through a bibliometric analysis, this study explored the current research status and application potential of digital twin (DT) technologies in sustainable development management. The study shows that DTs play an important innovative role in sustainable development fields such as smart cities, circular economies, and Industry 4.0. Still, they face implementation challenges such as the digital divide, high costs, data privacy protection, and technical complexity. By analysing 421 papers, we have summarised the key challenges of digital twin technology and proposed future research directions, including integration with artificial intelligence, cross-domain collaboration, technology optimisation and standardisation, social and ethical challenges, and integration of climate and ecological models. Deepening these studies will promote the application of DT technology in sustainable development management and provide new ideas and paths for the global realisation of sustainable development goals. The research also revealed that the research results of digital twin technology in different countries are unevenly distributed, highlighting the digital divide. The literature suggests that despite the breakthroughs in digital twin technology in multiple fields, it has not yet received sufficient attention in the global sustainable development agenda. Future research and policy must explore how to use digital twins to achieve sustainable development goals fully.

In summary, this research is a stepping stone for future research. It encourages scholars to delve into all aspects of DTs' applications and their impact on the SDGs. By addressing these key issues, researchers can play a key role in shaping a more sustainable environment.

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KEY FACTORS INFLUENCING THE GROWTH OF SMALL AND MEDIUM-SIZED BUSINESS IN EMERGING ECONOMIES: THE CASE OF KAZAKHSTAN

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Abstract. This paper explores the key factors affecting the development of small and medium enterprises (SMEs) in emerging economies, specifically focusing on Kazakhstan. The primary goal is to identify key facets of the institutional environment that positively affect the development of SMEs and to assess the challenges and opportunities faced by these businesses in the Kazakhstani context. The study uses a mixed-methods approach that combines quantitative data analysis from national economic reports with qualitative insights gathered through interviews with SME owners and stakeholders. The results indicate that while SMEs in Kazakhstan contribute significantly to economic development, they encounter barriers such as limited access to finance, regulatory hurdles, and market competition. However, the findings also highlight emerging opportunities in digital transformation and government support initiatives to foster entrepreneurship. This research contributes to the understanding of SME growth in emerging markets and offers policy recommendations to enhance the sustainability and competitiveness of SMEs in Kazakhstan.

Keywords: SMEs; economic development; governmental support; institutions; entrepreneurship

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1. Introduction

Entrepreneurship is an initiative economic activity of business entities associated with the implementation of a certain strategy for the sake of obtaining profit by providing goods and services that satisfy market needs, with personal risk, innovative in nature, aimed at achieving a planned economic and social effect, carried out through the use of entrepreneurial talent and using resources available to the business entity.

Creating favourable conditions for the development of entrepreneurial activity is one of the factors in the successful development of the national economy, increasing its competitiveness. Therefore, the essential function of the state is the creation and improvement of an appropriate environment that stimulates the growth of entrepreneurial activity (Marquez et al., 2023; Choong et al., 2023; Standaert, Collewaert & Vanacker, 2024; Mohamed et al., 2024).

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Regulation of entrepreneurial activity involves considering the internal socio-economic nature of any enterprise or entrepreneurial structure. Still, issues of formation and improvement of the institutional environment of entrepreneurship occupy the most crucial place in the regulatory activity of the state.

The institutional environment of entrepreneurship is determined by the legal and administrative infrastructure within which entrepreneurs and business structures, companies, and the government interact to create the nation's welfare. In a broad sense, the institutional environment is a set of institutions. Institutions are understood as historically established norms and rules of social behaviour, which are expressed through a set of laws, regulations, and restrictions that are mandatory for execution (formal level) or through a set of moral attitudes, principles of social behaviour, traditions, etc. (informal level) (Quillas et al., 2024; Bendig et al., 2024).

At the same time, institutions are both formal and informal organizations that determine the relevant laws, rules and regulations of social behaviour and ensure the order of activities of specific population groups. The institutional structure is one of the most critical components of the economic infrastructure. A special role in it belongs to state institutions as instruments of support for the global competitiveness of the state economy (Independent Association of Entrepreneurs of Kazakhstan, n.d.; Medase, Ahali, & Belitski, 2023; Mollick, & Sui, 2023; García, 2023; Demirdag & Eraydin, 2024).

The importance of state institutions is not limited to the creation of a legislative framework and control functions. The optimal organization of the activities of state institutions plays a significant role in ensuring the effective functioning of the market and in observing the rights of economic entities: too large an apparatus and bureaucratic obstacles, excessive state regulation, corruption, dishonesty in the preparation and execution of state orders, lack of transparency and reliability, inability to provide businesses with the necessary services, political dependence of the judicial system lead to high economic costs and slow down the development process.

By interacting with each other, institutions ensure the formation of an institutional mechanism, which is a system of relationships between formal and informal institutions, as well as institutions that facilitate the harmonization and adjustment of interests of various social groups and coordinate joint activities towards achieving the declared development goals in the field of entrepreneurship.

Thus, for Kazakhstan, as for any other country, the development of entrepreneurship cannot occur without going through the institutional environment, which is the basis for supporting and coordinating such development, ensuring and regulating both the country’s economy as an environment for entrepreneurship and the actions of business entities in this economic environment.

The mechanisms of state regulation of entrepreneurship development can be generally presented as follows (see Figure 1 below):

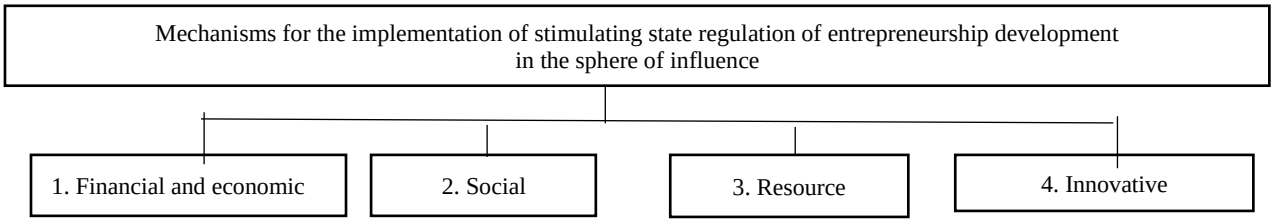


Figure 1. Mechanisms for implementing stimulating state regulation of entrepreneurship development by sphere of influence
Source: developed by the authors (based on the dissertation of Candidate of Economic Sciences Baitursunov A.A. "Improving the system of state incentives for priority areas of small and medium-sized businesses (on the example of the Republic of Kazakhstan)": dissertation of the Candidate of Economic Sciences.... Candidate of Economic Sciences: 08.00.05. M., 2019. 181 p.)

1. Financial and economic mechanisms:
1.1. Financial policy:
- establishment of a system of financial benefits, saturation of the market with necessary goods and services, mobilization of financial and material resources;

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- budget subsidies, attracting entrepreneurs to innovative projects and programs.
1.2. Financial lending:
- creation of equal access for enterprises to financial resources, creating a competitive environment;
- mortgage lending, risk insurance, alternative lending.
1.3. Tax policy:
- provision of tax benefits in the form of full or partial exemption from taxes, application of tax credits;
- adaptability, flexibility, the ability to quickly respond to the dynamics of market conditions;
- accelerated depreciation.
2. Social mechanisms:
2.1. Social policy:
- social protection of the population, job provision, creating jobs for socially vulnerable segments of the population, freedom of entrepreneurial activity;
- ensuring civil liberties, performing social functions, freedom of investment and full protection of investors.
3. Resource mechanisms:
3.1. Formation of financial, human, and material resources for business development;
- redistribution of resources between economic entities;
- creating new channels for the movement of resources.
4. Innovative mechanisms:
4.1. Innovation policy:
- stimulating the development of knowledge-intensive industries;
- the introduction of new technologies, the development of new types of products, the formation of demand for innovation, transfer to practice and consolidation of new high-tech solutions in it;
- openness, receptivity, ease of entering the market with innovative solutions;
- mobilization of scientific and technical resources.

It should be noted that in terms of the financial component, in terms of tax policy, given that the state has now taken significant steps towards liberalizing taxation for SMEs, incentive methods should be combined with controlling ones since in a situation where considerable benefits are available, attempts will be made to take advantage of preferential taxation by understating profits or using unofficial (shadow) employment, etc. Specific standards should be developed so that the profit rate can be determined in accordance with income (expenses) and the employment rate in accordance with industry characteristics and business turnover for the reporting period. This will allow benefits to be addressed in accordance with planned indicators, which will make it possible to take them into account when forecasting tax revenues to the budget. In the event of a discrepancy between the indicators of an SME entity and the limits of permissible standards, tax benefits can be provided partially.

This article examines the impact of key economic growth factors on the development mechanism of small and medium-sized businesses in an emerging economy. This article aims to find optimal solutions to ensure the financial sustainability of small and medium-sized enterprises in Kazakhstan.

2. Literature Review

Support for small and medium-sized enterprises (SMEs) is an essential element of economic policy, where various forms of assistance, such as financial assistance, grants, tax incentives and other measures, are used to stimulate the growth of these enterprises. (Onyekwel et al., 2023; USA Funding Applications, n.d).

In recent decades, European policy has targeted specific measures towards SMEs. The recently concluded Horizon 2020 Programme, under the Europe 2020 Strategy, has provided economic support to stimulate competitiveness and boost the economy of member states by focusing on innovation. Zarbà et al. (2022) discussed the effects of support on agri-food SMEs in Italy post-COVID-19.

Abu, da Silva, and Vieira (2024) analyze government support for SMEs in the Fintech Era. The article highlights the role of politicians in creating favourable conditions for the growth of small and medium-sized businesses

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using fintech technologies. Mogensen (2024) claims that states have to act as innovation business partners to stimulate SMEs' innovative activities.

Stimulating economic growth is one of the most important tasks of economic policy since economic growth contributes to improving the population's well-being. Small and medium-sized enterprises (SMEs) are among the factors that contribute to economic growth. The role of SMEs is indispensable in addressing the most pressing economic, social and environmental issues (Kozubikova et al., 2023). Without requiring significant expenditures from the government, SMEs help create a "healthy" competitive environment, establish market equilibrium, create new jobs, form a middle class, and meet various needs of the population, ultimately leading to sustainable economic growth. Gallotta, Baranova and Paterson (2023) and Lutfi et a. (2023) point to the need for governmental programs offering pro-environmental support to SMEs. Aassouli and Ahmed (2023) emphasize the importance of programs supporting the financial literacy of SMEs. Montero and Parga (2023) suggest constructing a special tax regime to foster innovation. Hosono et al. (2023) found that tax incentives alleviate capital constraints and initiate investments in SMEs. Coricelli et al. (2025) highlight the importance of financing aims for SME development.

The experience of leading countries in the modern world demonstrates the necessity of having a highly developed and efficient small business sector in any national economy. Therefore, Kazakhstan's economic breakthrough cannot be achieved without the corresponding development of this sector, as it is the element that drives economic and social development (OECD, 2023; Nurumov et al., 2023; Bekzhanova et al., 2023; Zarubina et al., 2024; Syzdykova & Azretbergenova, 2025).

Today, a situation has arisen where small entrepreneurship must leverage its flexibility, mobility, and market objectivity to find its place in the innovative economy rapidly. The government, in turn, must create favourable conditions for the implementation of entrepreneurial initiatives and focus its support on those small enterprises with the most significant potential in terms of competitiveness and enhancing the scientific and technological capacity of the country. Therefore, it is natural that the governments of these countries pay primary attention to supporting this sector. In principle, Kazakhstan's SMEs are moving in line with global trends; however, their share in the economy still significantly differs from international standards.

Despite numerous types of research on types of support, there is still a gap related to better tuning support to the needs and capabilities of SMEs. This research aims to fill this gap by identifying current research problems of Kazakh enterprises and juxtaposing them with a system of provision of governmental functions. The ultimate aim is to offer directions of support accomplishment to tackle the needs of enterprises better.

3. Research Methodology

The Institutional Index of Effective Business Development (IEBD) assessment will encompass all negative trends in international rankings and the current state of the socio-economic environment. The system for forming the Index of Effective Business Development includes the following stages:
- Collection of statistical information about the enterprise, analysis of current business challenges, and evaluation of government functions in supporting business development based on a developed expert questionnaire for SMEs;
- Processing of the obtained results (identifying the most significant business problems and assessing the effectiveness of government support functions for business development);
- Determining areas for qualitative business development (formulating solutions to problems and evaluating expected outcomes).

To identify the needs of Kazakhstani businesses and to construct the Index of Effective Business Development, a questionnaire for SME representatives has been created, which is proposed for completion by owners and participants of SMEs. Enterprises can gain potential benefits from the results of the IEBD processing, as the Index of Effective Business Development takes into account practical significance for developing mechanisms for state regulation of SME development and is directly formed based on the expert questionnaire, including the following sections:

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- General information about the enterprise (current state of the enterprise, its resource potential, and development goals);
- Current business problems (studying relevant practical business issues);
- Government functions in supporting business development.

The section "General Information about the Enterprise" includes the following questions:
- Year of establishment of the enterprise;
- Form of ownership;
- Main types of economic activities;
- Source of fixed assets at the time of establishment;
- Main sources of financing for the enterprise;
- Financial and economic situation (decline, stability, growth);
- Priority use of the enterprise's profits;
- Level of expenditure on innovative projects (% of total);
- Main goals of the enterprise for the near future;
- Number of employees;
- Employee motivation system (absent/present - describe the elements of the system);

Percentage of employees with higher education (% of total number).
The section "Current Business Problems" includes:
- Problems in the political sphere;
- Problems in the economic sphere;
- Problems in the social sphere;
- Problems faced by the enterprise during its establishment;

Current problems of the enterprise under study.
The section "Ensuring Government Functions to Support Business Development" (rated from 1 to 100, where 100 is the highest score) includes: In the political sphere:
- Protection of property rights;
- Anti-corruption activities;
- Provision of quality conditions for the establishment, operation, and liquidation of businesses;
- Tax policy;
- Transparency of government institutions' activities;

In the economic sphere:
- Government support for SMEs;
- Involvement of enterprises in innovative projects and programs;
- Support for foreign economic activities;
- Dissemination of new technologies;
- Development of the financial market;
- Support for competition.

In the social sphere:
- Ensuring civil liberties;
- Freedom of entrepreneurial activity;
- Fulfillment of the state's social functions;
- Freedom of investment and protection of investors.

Thus, the SME representative survey includes 32 questions divided into 3 blocks: input information (general information about the enterprise), information for processing (current business problems), and output information (provision of government functions to support business development).

The data collected from the survey will reflect the subjective assessment of the most critical parameters affecting the effectiveness of government incentives, as perceived by business representatives, depending on their industry affiliation and the effectiveness of management within the enterprise itself. Therefore, a sufficiently broad survey will allow for grouping issues specific to certain industries, regions (clusters), and so on. Consequently, conducting research provides an opportunity to formulate priorities for further business stimulation by identifying necessary directions.

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4. Results and Discussion

The authors surveyed small business representatives in Astana during different periods (the sample size was 150 respondents) in the outsourcing accounting services industry. The survey results were summarized in an average score.

As can be seen, in March 2017, the highest ratings were given to such aspects of state support as ensuring property rights (average score – 84), the performance of social functions of the state (average score 89), freedom of investment and investor protection (average score 87). In essence, the parameters of the social block are highly rated, which reflects the state strategy focused on high social priorities. At the same time, such indicators as anti-corruption activities (average score 46), ensuring optimal conditions for creating, running and liquidating a business (average score 37), are associated with a low level of stimulation of competition due to hidden industry cartelization), attracting small businesses to innovative projects and programs (average score 43), are rated relatively low.

In March 2023, the assessment of the SME support system in the Republic of Kazakhstan practically coincides with the 2017 profile. Some improvement occurred in the indicators of legal protection of business entities and support for foreign economic activity, as well as in targeted state support for SMEs (most of all in state support for SMEs: +10 points and in support for foreign economic activity: +14%). The respondents noted a deterioration in such indicators as the state's anti-corruption activities, transparency of state institutions' activities, support for civil rights and freedoms, support for competition, and market development (-10 points, -9 points, -8 and -17 points, respectively). See Figure 2 below.

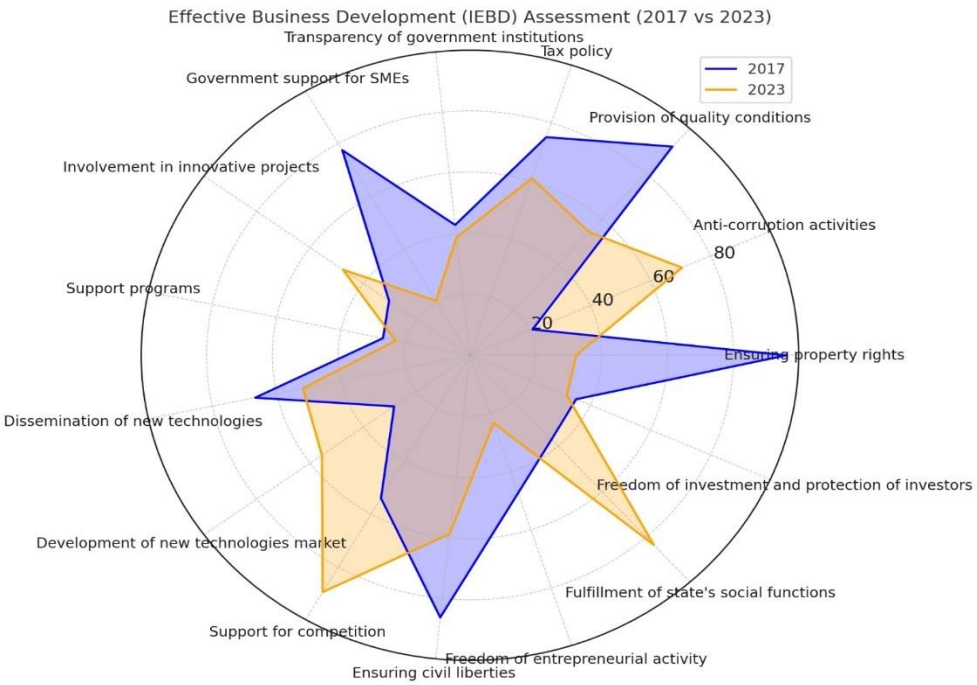


Figure 2. Effective Business Development (IEBD) Assessment Map in 2017 and 2023
Source: the authors

The assessment of business representatives' direct state regulation functions is the most important. This speaks of the absolute necessity and importance of state regulation of practically all aspects of entrepreneurship development, and it can be assumed that this necessity is characteristic not only of Kazakhstan but also practically, taking into account the specifics of the socio-economic situation of any country. The state's participation is seen as especially important in connection with the need to adapt the economy to new conditions of the global market situation.

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As mentioned above, there is a fairly extensive structure of support for entrepreneurship in the Republic of Kazakhstan, which includes state and state-initiated organizations, non-governmental organizations, and commercial organizations. They provide regulatory, financial, informational, analytical and consulting support, although they are not fully coordinated (see Figure 3).

The central bodies implementing the state policy of supporting entrepreneurship today are the Ministry of National Economy of the Republic of Kazakhstan and the Ministry of Investment and Development of the Republic of Kazakhstan. The second level of the state institutional structure supporting entrepreneurship is local executive bodies represented by the Offices of Akims of the regions and the cities of Almaty and Astana. The departments (Administrations) of Entrepreneurship and Industry have been created under the Akimats, including the Entrepreneurship Departments, to implement the state policy in the development and support of entrepreneurship at the level of central executive bodies, the Council of Entrepreneurs under the President of the Republic of Kazakhstan has been created to organize such "feedback" of entrepreneurs.

The organizations that perform these functions include government technology and financial companies. Non-governmental organizations act as intermediaries between the state and citizens in solving social problems and forming a civil society, which is one of the mechanisms for regulating public relations. Such organizations include the National Chamber of Entrepreneurs of Kazakhstan "Atameken" (National Chamber of Entrepreneurs of Kazakhstan "Atameken", n.d.) and the "Forum of Entrepreneurs of Kazakhstan".

Separately, it is necessary to mention microcredit organizations (MCOs), which provide microloans to business structures to replenish working capital and leasing companies, with the help of which business structures replenish and update their fixed production assets. In general, the institutional structure of entrepreneurship development in the Republic of Kazakhstan is traditional for a market economy, except for the significant share of state participation in entrepreneurial activity and the management and regulation of entrepreneurship.

The power in the Republic of Kazakhstan is highly centralized. Therefore, the specificity of the interaction between the government and business in Kazakhstan is that the dominant role in the relations belongs to state institutions and not to structures that are public or private organizations and represent the interests of business. At the same time, the institutional system of state regulation and stimulation of entrepreneurship looks balanced; it includes both structures that control business activities, bodies responsible for developing entrepreneurship, and institutions representing business interests in the government. The institutions implementing the state policy on entrepreneurship development are, if not directly, under indirect subordination to the presidential power. These include the Customs and Financial Control Committees of the Ministry of Finance; Tax Committee of the Ministry of Finance; the Agency for Regulation and Supervision of the Financial Market; Agency for the Regulation of Natural Monopolies, Protection of Competition and Consumer Rights; Agency for Combating Economic Crime and Corruption.

There are also bodies responsible for developing private businesses in state power. The central executive body of power in this activity segment is the Ministry of National Economy of the Republic of Kazakhstan, whose structure includes the Department of Entrepreneurship Development, which implements functions on the formation of state policy and legal regulation in the development and support of entrepreneurship. The Department's main tasks are creating conditions for the development of entrepreneurship, developing measures to attract investment, and taking measures on appeals and complaints from entrepreneurs about illegal actions of officials. At the regional level in the republic, departments of entrepreneurship and industry have been created under the akimats.

The National Chamber of Entrepreneurs of the Republic of Kazakhstan was created "Atameken" to organize "feedback" at the level of central executive bodies. The main tasks of the chamber are the protection of the rights and interests of entrepreneurs, ensuring broad coverage and involvement of all entrepreneurs in forming legislative and other regulatory rules for business operations. The National Chamber's activities aim to improve the business and investment climate, stability and development of business conditions in the country for both national and foreign investors.

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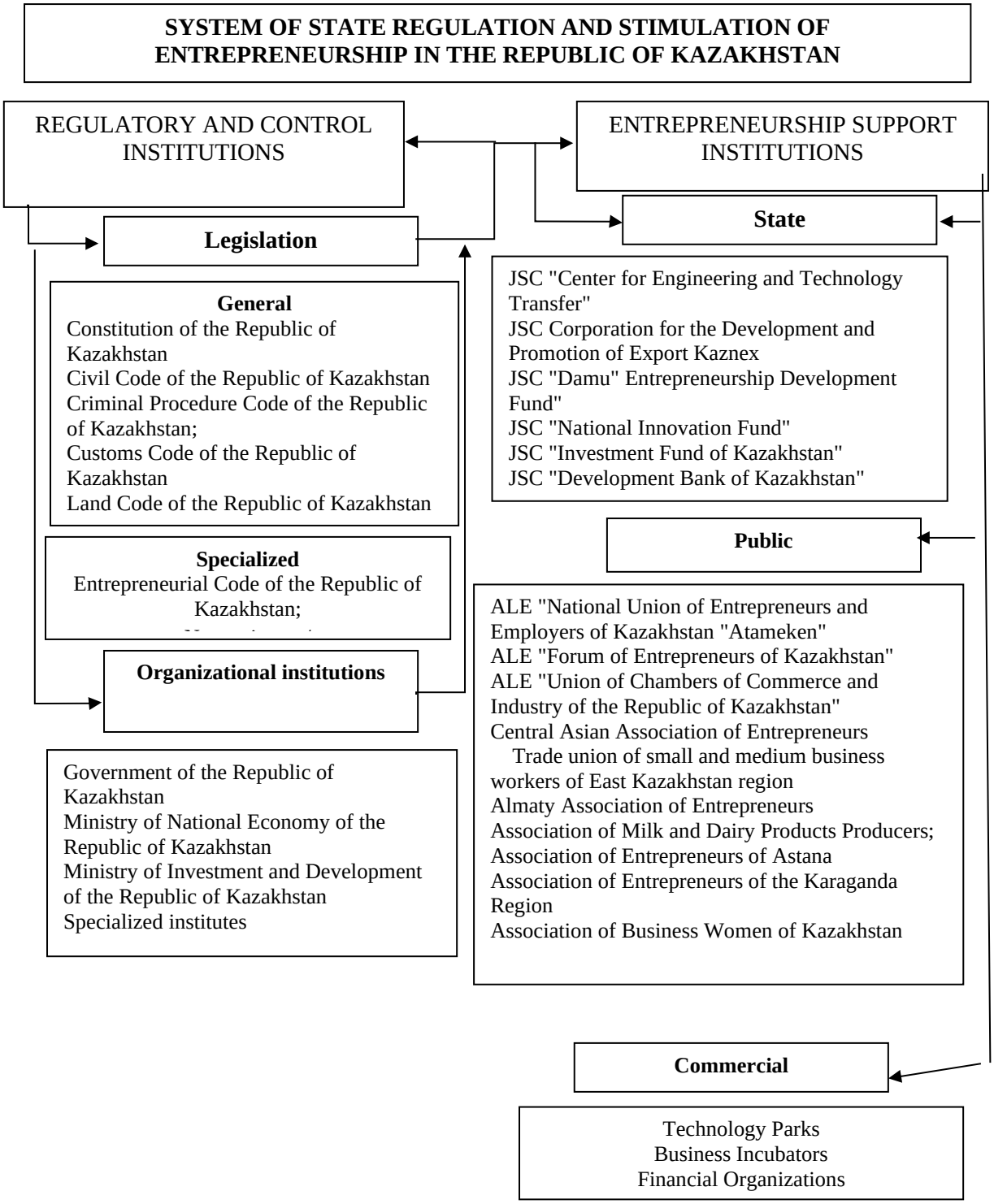


Figure 3. Institutional system of state regulation and support of entrepreneurship in the Republic of Kazakhstan
Source: the authors

In addition, the executive branch often initiates the creation (as well as controls the formation) of institutions designed to represent the interests of business (business associations, of which there are more than 30). Such structures include the Council of Foreign Investors, a consultative and advisory body headed by the President of the Republic of Kazakhstan, created on his initiative.

This Council aims to ensure direct dialogue between the authorities and foreign investors operating in Kazakhstan.

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The permanent members of the Council from the Kazakh side are the Prime Minister of the Republic of Kazakhstan; the Chairman of the National Bank of the Republic of Kazakhstan; the Deputy Head of the Administration of the President of the Republic of Kazakhstan; the Deputy Prime Minister of the Republic of Kazakhstan; the Ministers of Foreign Affairs, Industry and Trade, Economy and Budget Planning, Finance of the Republic of Kazakhstan; the Chairman of the Investment Committee of the Ministry of Industry and Trade of the Republic of Kazakhstan. The Council's foreign members are formed from among the top managers of international financial organizations and foreign companies.

In addition, a network of expert councils on entrepreneurship issues has been created in the Republic of Kazakhstan under central state and local executive authorities (ministries, akimats). The councils include both representatives of executive officers and members of industry entrepreneurial structures.

These consultative and advisory structures aim to obtain expert opinions and develop recommendations on draft regulatory legal acts affecting the interests of the business. Only accredited private entrepreneurship entities may be members of the Council, and their number is limited, in accordance with paragraphs 3-4 of Article 25 of the Law "On Private Entrepreneurship in the Republic of Kazakhstan", only one association of private entrepreneurship entities may be accredited from each region or area. A structure with a larger number of employees in an organization receives priority in accreditation. Such restrictions on accreditation reduce the importance of expert councils to the role of formal channels for representing business interests.

In addition to the above-mentioned bodies and departments, the Kazakhstan Center for Public-Private Partnership "KazCenter PPP" (colloquial) has also been created (Kazakhstan Center for Public-Private Partnership, n.d.). Its activities aim to conduct research and assess and examine the implementation of investment projects in the field of PPP. "KazCenter PPP" provides consulting support to projects, facilitating their implementation. This Center interacts with legislative and executive bodies, national companies and international public organizations at all levels. The Center acts as an initiator and organizer of popular discussion platforms, which, in addition to current issues of PPP development, make expert recommendations for solving the main socio-economic problems. PPP sees its mission as "creating conditions for partnership between the state and business, developing and combining their potential for the implementation of PPP projects and increasing investment in the country's economy."

In the Republic of Kazakhstan, several organizations have industry significance and are largely independent within a clearly defined range of their functions. The following should be considered independent entrepreneurship organizations in Kazakhstan: the Independent Association of Entrepreneurs of the Republic of Kazakhstan (Independent Association of Entrepreneurs of Kazakhstan, n.d.), the European Business Association of Kazakhstan (Eurobuck) (European Business Association in Kazakhstan Eurobak, n.d.). and several other industry business organizations. Meanwhile, non-governmental organizations called upon to act as intermediaries between the state and business are often created on the President's or executive authorities' initiative (e.g., the National Chamber of Entrepreneurs of Kazakhstan "Atameken").

In 1997, the Entrepreneurship Development Fund "Damu" was established in the Republic of Kazakhstan on the state's initiative. At present, this structure has the status of a national development institute and a state fund, the goals of which are stimulating the formation and economic growth of small business entities and increasing the efficiency of using state financial resources aimed at supporting small businesses. Of course, this structure is entirely subordinate to the state: 100% of the Fund's shares are owned by"National Management Holding "Baiterek", a holding that manages national development institutions and companies. It was created to optimize the management system of development institutions, financial organizations and the development of the national economy by the Decree of the President of the Republic of Kazakhstan dated May 22, 2013 No. 571. This Fund provides information on the implementation of a number of educational projects and the provision of consulting services to SMEs.

Target parameters for the development of small and medium-sized businesses are presented below in Figure 4.

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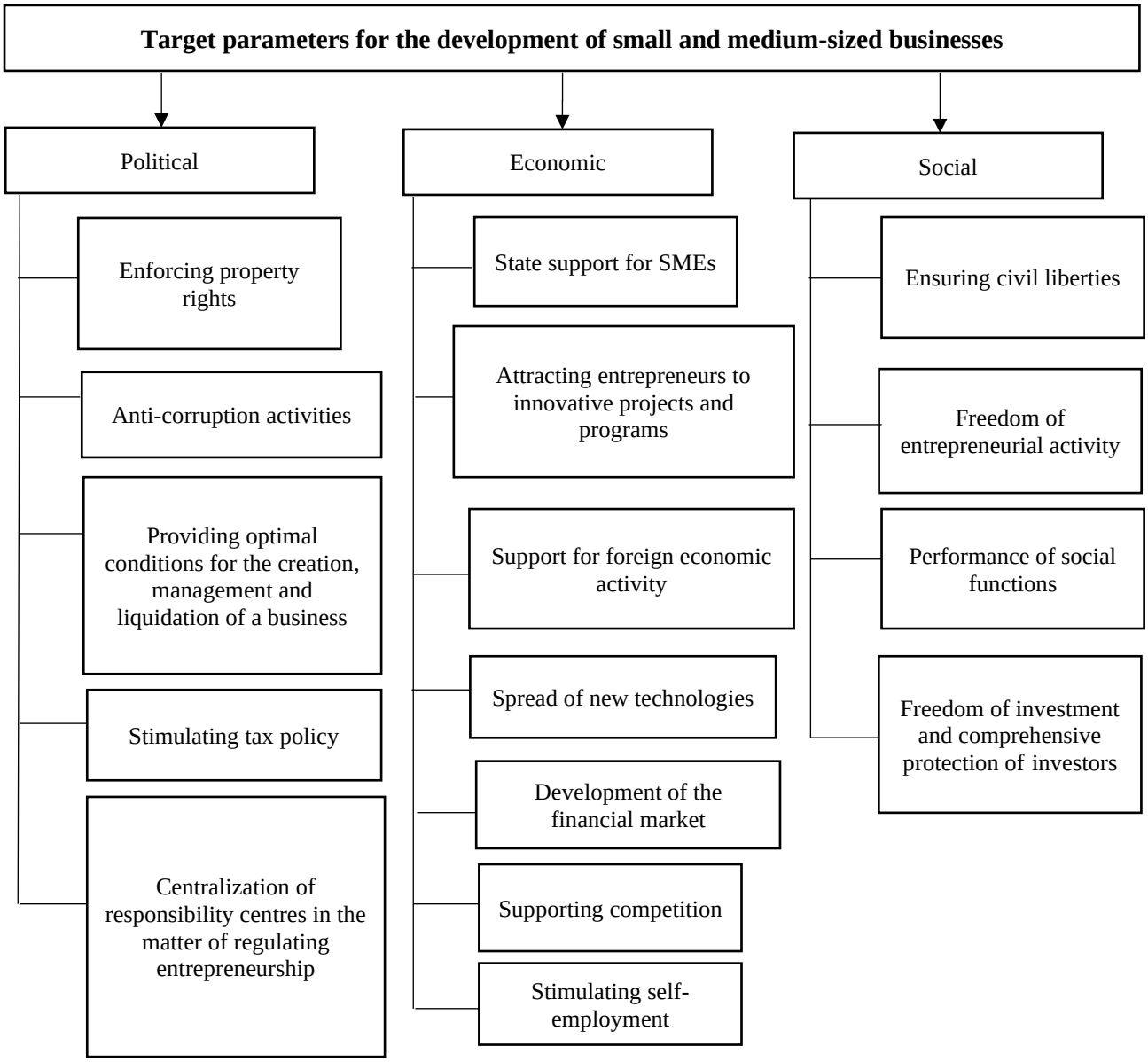


Figure 4. Target parameters for the development of small and medium businesses for the Republic of Kazakhstan
Source: the authors

A summary of the results of modern research in the field of entrepreneurship shows that the quality of the institutional environment significantly influences the competitiveness of business entities, affects investment decisions and the organization of production, and affects economic growth.

The institutional environment for entrepreneurship is determined by the legal and administrative infrastructure within which entrepreneurs and business structures, companies, and the government interact to create the nation's welfare.

The formation of a unified state regulatory policy in the sphere of entrepreneurial activity should be based on the presence of a single responsibility centre that would coordinate and direct the entire process by the planned performance parameters. At the same time, it is necessary to determine the parameters for the effective development of small and medium-sized businesses in the Republic of Kazakhstan. When creating development programs and projects, in our opinion, it is necessary to focus on the specified parameters, as well as the achievements and lags of our state, since it is they, focusing on international development indices, that influence the modern economy and business to a greater extent. These parameters look generalized, but their observance

ensures the effective development of entrepreneurship. Some of them are fully ensured in the Republic of Kazakhstan (for example, the protection of investor rights and property rights, support for foreign economic activity, stimulation of self-employment and the performance of social functions by the state are the strengths of the state in the direction of developing entrepreneurial initiative in the country), but many are not sufficiently ensured.

Conclusions

The main obstacles that may hinder the effective development of small and medium-sized enterprises (SMEs) and, consequently, the economy of Kazakhstan are:
- Insufficient financial support;
- Lack of a developed innovative business sector;
- Dispersed centres of responsibility regarding the regulation of entrepreneurship development;
- Insufficient transparency of government institutions and ineffective anti-corruption policies.

Although the analysis above addressed the overall state of the institutional system for stimulating and supporting SMEs in Kazakhstan, it is essential to prioritize stimulating innovative activity among SMEs. Improving the system as a whole will also ensure the stimulation of SMEs operating in the innovation sector. Given the rapid global scientific and technological development trends, government regulation should be directed towards innovation. However, there is currently a problem with the development of innovative enterprises that needs to be addressed through active infrastructure development; market resource flows are being directed into creative projects, and innovative products are being implemented.

Furthermore, it is advisable to focus not only on the quantitative increase of infrastructure supporting business innovation but also on their qualitative improvement, which can lead to achieving leading positions for small and medium enterprises in the global arena. In this context, enhancing entrepreneurship's innovation level should be activated alongside the development of intellectual potential. The modern intellectual potential serves as the foundation for an information economy based on information technology and becomes the basis for qualitative development. Thus, the development of intellectual potential is a crucial direction for the strategic development of the state.

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DEVELOPMENT OF AUTOMOTIVE INDUSTRY TRENDS AND DEMAND FOR CRITICAL RAW MATERIALS WORLDWIDE

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Abstract. Innovative technological solutions appear in the economy as a response to expected social, economic, technological and environmental changes. Modern ideas can become a driving force for new investments and the spread of innovative ideas. One of the greatest challenges of modern times is environmental protection, which drives change and development in many sectors of the economy. The response to environmental protection by reducing exhaust fumes is the development of electric car production. With the growing demand for electric vehicles, the demand for key critical minerals has increased dramatically. However, their production is associated with an adverse impact on the environment. Furthermore, the production of critical minerals is limited to a few countries, with China being the leader. The article examines the problems of sustainable development, considering the often contradictory effects of environmental protection activities. It also addresses the issue of the stability of supply chains of critical minerals necessary for the implementation of modern technological solutions.

Keywords: critical minerals; environmental protection; electric cars

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JEL Classifications: Q30, Q32

1. Introduction

The world economy is driven by the need for innovative products that meet current quality and environmental requirements. Focusing on industrial trends, one can see their dominant role in the automotive industry and the production of various everyday appliances. In particular, the development of automobiles is one of the fastest-growing areas of the economy, drawing innovations from technological advances. A comparison of cars from 30 years ago to those in use today clearly shows that the progress in this field is enormous. Several main directions of automotive development can be distinguished. These are electromobility, autonomous vehicles, automatic transmission, equipment individualization, and car operation intuitiveness. The demand for new solutions requires significant economic outlays and achievements in electronics and computer engineering. Research is launched in connection with implementing new ideas in line with current trends, and numerous institutions and industrial plants are involved, where staff of people, professionals, scientists and engineers are employed, thanks to which new and increasingly innovative cars are created.

The environmental aspect of new automotive production significantly impacts emerging technical solutions. It should be noted that all automotive solutions always require different types of metals and other materials, fuel

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and electronic instrumentation (Schmid, 2020)—various energy sources power vehicles. The materials, components and instrumentation used by the automotive industry require the extraction of certain minerals, their metallurgical processing and the development of industrial production. These activities are closely related to environmental protection and the pursuit of a circular economy.

Internal combustion engines, for example, have undergone a spectacular transformation over the past few years, with the primary goal of protecting the environment (Bielaszyc et al., 2013; Razek et al. 2023). Engines have been equipped with exhaust gas filtration systems. There are four fractions of particulate matter in diesel engine exhaust: (1) soot, (2) SOF (soluble organic fractions; heavy hydrocarbons), (3) sulfur compounds, and (4) ash. Diesel engine exhaust particulate emissions depend on a number of parameters, including engine type, engine operating conditions, and fuel and lubricating oil composition. Studies have shown that particulate formation occurs when exhaust gases are cooled and diluted in the atmosphere (Bielaszyc et al., 2013; 2003). The exhaust of vehicles equipped with a particulate filter in emission tests achieved particle counts below the standard of European Euro 5/Euro 6 regulations for passenger cars and light commercial vehicles (Filippo & Maricq, 2008). The example of neutralizing the harmfulness of exhaust gases is a spectacular success of innovative technological solutions forced by European directives on ecology. In this case, ecological trends, the original source of which was not related to automobiles, have tremendously impacted the development of modern automotive technologies.

Electric car production has developed due to strong pressure to protect the environment (Szumska & Jurecki, 2023). Today, it is already a strongly developed industry with a significant share in the economy of many countries. Automotive industry sources materials and components from various fields of the economy. It is the driving force behind such productions as sheet metal, engines, car components such as seats, windshields, catalytic converters, filters, batteries and many others. It engages the surface engineering industry through body painting and protective coating of drivetrain components and exhaust components.

The growth of the automotive industry is due to the increasing demand for passenger, transportation, military and other vehicles. The global proliferation of vehicles for both business and personal use has created one of the dominant industries in the economy and a source of powerful income for automakers. The introduction of environmental standards has forced the automobile industry to continually progress and develop more environmentally friendly vehicles such as electric cars.

Automobile transportation is mainly responsible for the production of nitrogen oxides, carbon dioxide (exhaust emissions), and particulate matter (non-exhaust emissions) (Wojtal, 2018; Su, 2022). Vehicles are not the main cause of environmental pollution but remain a significant part of it and a source of many pollutants (nitrogen and carbon oxides) and noise. It is expected that reducing the number of vehicles on the streets and introducing electric vehicles will translate into better air purification.

Further research into improving vehicles, particularly in terms of meeting environmental requirements, constantly continues. However, the carbon footprint of vehicle production and use is never zero. The manufacture of components and the materials from which they are produced runs on energy sources that often come from non-renewable sources. According to the World Health Organization, the energy sector accounts for about 60% of global greenhouse gas emissions. The biggest "polluters" are the U.S. and China, which emitted more than 250 gigatons of CO_2 from 1970 to 2021 (Paddison & Choi, 2024). Russia is third on the list and responsible for about 100 gigatons of CO_2 emissions. Of the remaining countries, Japan, for example, emitted more than 50 gigatons of carbon dioxide into the atmosphere.

China has the largest CO_2 emissions in the world and the second largest population. For a fair comparison of emissions, one would have to analyze emissions in terms of CO_2 per capita. The automotive industry is an essential branch of the EU economy. The automotive industry (directly and indirectly) employs 12.7 million Europeans, accounting for 6.6% of all jobs in the EU. 11.5% of manufacturing jobs in the EU - about 3.5 million - are in the automotive sector. The automotive industry generates a trade surplus of 76.3 billion euros for the European Union. Turnover generated by the automotive industry accounts for more than 8% of the EU's GDP.

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The demand for metals in the automotive industry has a very strong impact on the world economy. In particular, the transition to electric cars has dramatically increased the demand for some metals, which have been designated as critical. This group includes rare earth metals (RRE).

2. Literature review

Gases such as carbon dioxide, carbon monoxide, sulfur dioxide, nitrogen oxides, hydrocarbons and particulate matter (CO_2, SO_2, NO_X, CO, HC, PM) suspended in the air cause an increase in the earth's temperature, which manifests itself in global warming (Razek et al., 2023). Emissions of these pollutants are largely related to the use of internal combustion vehicles. One way to improve the environment is to introduce green fuels. Studies have shown that the use of biofuel made from waste cooking oil reduces vehicle emissions (Ibeto & Ugwu, 2019). A paper (Pilusa et al., 2012) presents the purification of the exhaust gas of cars with a Diesel engine through the use of a South African patented filter (Whale filter is a South African patented secondary diesel filter designed by Mr. Hennie Joubert. This diesel filter design is currently filed under patent number 2005/08375).

In 2019, Europe's average new passenger vehicle produced 122 grams of carbon dioxide per kilometre of mileage (Peyravi et al., 2022). The 2020/21 CO_2 target for the passenger car fleet in the European Union was 96 grams per kilometre (Statista Research Department). It should be noted that electric car registrations in the EU have grown rapidly since 2020, accounting for about 11% of newly registered passenger vehicles, which promotes the realization of environmental protection and the reduction of harmful emissions.

In the past few years, many materials have been developed that reduce the overall weight of cars, improve their performance, and increase driving safety while reducing the emission of polluting gases (Asghar et al., 2025). Studies on these cars have shown that reducing the weight of a car by 10% can save up to 8% of fuel consumption. One of the key materials for producing lightweight cars is aluminium alloys. In particular, aluminum alloys with Si and Mg admixtures are used. Due to the inclusion of Si and Mg among critical metals, the latest research trend is to reduce or possibly replace these elements in aluminium alloys with other elements. However, even the works initiating this very interesting direction state that due to the unique nature of the influence on properties, there is a small probability of replacing Si and Mg in aluminium alloys with other elements (Asghar et al., 2025).

Aluminum is recognized as the choice material for clean technology, especially in uses involving renewable energy, electrical systems, batteries, resource-efficient packaging, and even energy-efficient buildings—and of course, aluminium alloys for cast automotive parts (Djurdjevic et al., 2023). Changing the alloying additions content in aluminum alloys, including Mg, can their strength properties. The mechanical properties of these alloys can also be further improved by appropriate heat treatment processes (T5, T6 and T7).

The year-on-year increasing production rates of electric vehicles lead to an increasing demand for critical materials (Schmid, 2020; Vidal et al., 2013). Critical raw materials (CRM) are also a potential bottleneck in the transformation process of the automotive industry (Ziemann et al., 2013; Olivetti et al., 2017; Ortego et al., 2018). A smartphone, for instance, contains up to 50 different kinds of metals, such as indium in its touch screen and silicon in the many chips it contains. Permanent magnets made of rare earth elements (REEs – a family of 17 elements with exceptional magnetic properties, composed of scandium, yttrium and the lanthanides) are critical in the health sector for magnetic resonance imaging and in low carbon technologies for generators in wind turbines and motors in electric vehicles (Ragonnaud, 2023)

One of the directions of development of the automotive industry is the modular method of vehicle construction (Pandremenos et al., 2009). Modular design divides the design task into separate production units. This increases the potential for outsourcing significantly, especially in car body design. Separate tasks are also associated with using different materials from different sources. This may involve diversification of supply.

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In the pursuit of improved fuel economy, the automotive industry is embracing lighter materials in vehicle manufacturing (Auto House, 2024). High-strength steel, aluminium, and composite materials are used to reduce vehicle weight, improve performance, and reduce environmental impact. According to a report by the American Chemistry Council (ACC), the use of plastics in cars increased by an average of 16% between 2012 and 2017 (Microban, 2024). Using lighter materials such as plastics or aluminum in cars reduces carbon dioxide emissions, energy consumption, and fuel costs.

Aluminium is characterized by a high strength-to-weight ratio, high plasticity, corrosion resistance and complete recyclability. These features make aluminum alloys a priority for their use in car construction (Miller et al., 2000). The global automotive lightweight material market size is expected to reach USD 112.50 billion by 2030, registering a CAGR of 3.2% from 2023 to 2030 (Research and Markets, 2024). A rise in demand for weight reduction in passenger cars and commercial vehicles to support fuel efficiency is expected to increase the demand for lightweight materials over the forecast period.

Aluminum is a standard component in batteries used in electric cars, but it's also a supply crunch point. Demand is shifting from traditional aluminium castings to extrusions, high-quality castings, and even foil sheets, which are the easiest to recycle. New forms require aluminium with fewer impurities, which impacts scrap costs and can require higher additions of primary aluminium to alloys (Pope, 2024). There are significant obstacles to the development of reprocessing of bauxite residue, also known as red mud and other mining waste. The reasons are likely low-profit margins, long payback periods, high planning risks, and high sensitivity to operational excellence. This affects investment, which means that the mineral recovery market is not supported to the extent that it would be expected. Research conducted by S&P Global Mobility in 2023 showed interest in refining waste for mineral recovery, but there was difficulty in finding enough investors.

Advanced High Strength Steels (AHSS) are among the metals used in vehicles due to their high energy absorption potential, reduced vehicle weight resulting from the use of thinner high-strength steel sheets, and increased passenger safety due to improved crashworthiness (Kuziak et al., 2008; Perka et al., 2022; Hu & Feng, 2021; Kučera, 2023). The global automotive advanced high-strength steel market size was estimated at USD 16.95 billion in 2023 and is projected to grow at a CAGR of 6.4% from 2024 to 2030 (Market Analysis Report, 2024). Rising demand for lightweight vehicles is increasing the need for advanced high-strength steels (AHSS) in the automotive industry, driving market growth. The latest grades of AHSS have the potential to significantly reduce vehicle weight by 35.0-40.0% compared to that of traditional steel.

An analysis of the passenger car market indicates the increasing adoption of electric cars, driven by the realization of environmental trends (Figure 1) (Global EV Outlook, 2024).

New technologies related to the development of electromobility have caused strong demand for rare earth metals and critical metals (Habib et al., 2020; Haq et al., 2022; Richert et al., 2023; Tvaronavičienė, 2024). Metals such as steel, aluminium, critical metals, and rare earth metals are mostly extracted and processed in selected countries that supply the automotive industry. China is the leader in rare earth metal production (Hynek, 2023; Wendling, 2024).

The largest producer of electric cars is China, which experienced the dire effects of smog in Beijing, among other things, due to the accumulation of internal combustion engine exhaust from 2002-2003 and beyond (Jóźwiak, 2015). Since 2006, China has emitted more CO_2 than any other country in the world. In addition to coal-fired power plants and industrial plants, automobile exhaust, which accounts for about 50% of all pollution, was and still is a very troublesome source of contamination in Chinese cities (China - a general introduction…, 2020). A similar situation to Beijing has also been reported in Shanghai, Wuhan, the Pearl River Delta, and other major cities in China (Report, 2021). The response to catastrophic pollution has been to reduce the use of internal combustion vehicles and introduce electric vehicles. In 2023, China had more than 20 million plug-in electric cars, and by the end of June 2024, there were 440 million vehicles in China, including 345 million passenger cars, of which 24.72 million were electric and hybrid vehicles (18.134 million EVs, fully electric cars), accounting for 7.2% of all vehicles. A total of 31.4 million vehicles were sold in 2024 in the world's

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biggest market by sales, up 4.5% compared from a year earlier, the China Association of Automobile Manufacturers reported (Swift, 2025). Experiencing the effects of air pollution has made policymakers and the Chinese people aware of the need to change their approach to transportation, heat sources, industrial emissions and other causes of environmental disaster. It is difficult to predict whether China's air pollution prevention measures will bear fruit and over what period of time a significant improvement in the situation can be expected. In 2015, China announced a policy to "combat smog" and joined the Paris Agreement (Przychodniak, 2018).

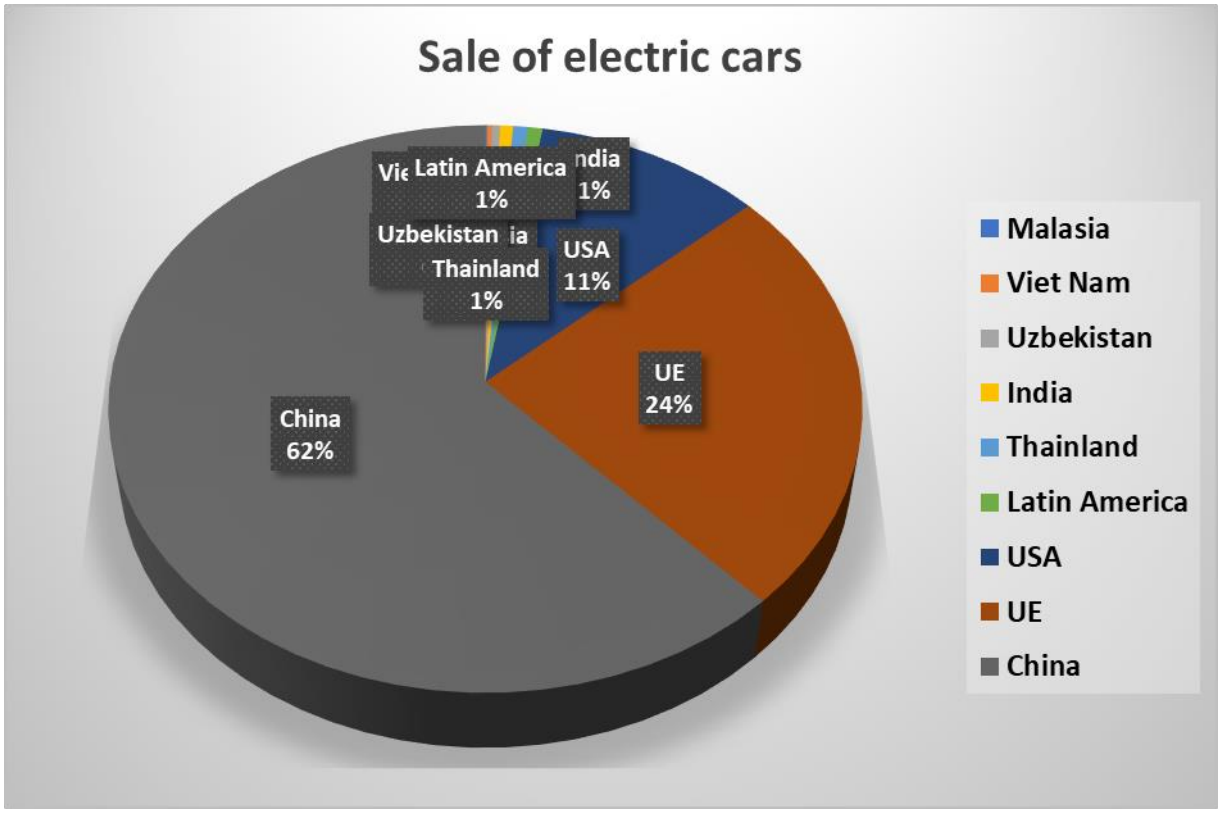


Figure 1. Percentage of electric car sales by countries (Global EV Outlook, 2024)

Electric passenger car sales are predicted to reach 45% of global passenger car sales by 2030 (Rovito, 2024). This will be the result of environmental trends and the growing awareness of environmental protection among car users and the introduction of zero-emission car regulations. Battery efficiency and EV charging infrastructure continue to improve, which will encourage drivers to use electric vehicles. There has been continued progress in battery design, as well as a decline in battery prices. Battery manufacturers CATL and BYD believe that the price of these batteries could drop by as much as 50% by the end of 2024. This could make EVs competitive with ICE vehicles. The range of EVs is increasing, and manufacturers Chevrolet, Hyundai, Jaguar, Kia, Nissan, Tesla and others are offering affordable EVs. The latest trends in automotive materials also include the use of plant-based leather, recycled steel, wood and antibacterial materials, which will reduce the need for potentially polluting cleaning agents (Rovito, 2024).

The growth in electric car production is and will continue to be associated with increasing demand for key metals used in their production, such as high-strength steels, aluminum and critical metals, including rare earth minerals. Decarbonization strategies require renewable energy generation and encourage the use of electric vehicles and low-voltage manufacturing of appliances, which can reduce energy consumption. Adopting these strategies worldwide can help achieve a low-carbon planet (Gbadeyan et al., 2024).

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The aim of the study is to analyze the international market and potential sources of key materials for the automotive industry.

The research was conducted using an objective combination of primary and secondary information, including available data from key industry participants reported publicly. A market outlook and analysis of possible sources of key materials for the automotive industry are provided.

The article contains 8 chapters that present data on raw materials and analyze their prospective sourcing in the European Union (EU). The first chapter is "Introduction" introducing the issue at hand. The second chapter is "Literature review". Next, third section is "Methodology" The fourth chapter is titled "Steel in road transport" and illustrates the sourcing of steel for the automotive industry. The fifth chapter is titled "Aluminum in road transport" and illustrates the sources of aluminum production. The next, sixth chapter is: "Critical minerals" discussing the production of critical minerals, in which rare earth metals play a large role. The seventh chapter is "Discussion," which presents a discussion and analysis of the data presented. The eighth chapter, "Conclusions," summarizes the results into several main conclusions relevant to the issues discussed.

3. Methodology

The article is a review article. It includes an overview of the available knowledge and trends in the use of metal materials in the automotive industry. In particular, it refers to the use of metals in electric cars. The conducted research consisted of using data obtained from a systematic literature review. It was a review based on which existing research and review papers related to the automotive industry and the use of metal materials in this industry were developed and analyzed.

The data collection method included collecting information from existing literature, including research articles, industry reports, market data, standards and publications from academic societies and journals related to materials science, automotive engineering and manufacturing, as well as automotive market development forecasts and management. The sources used are listed in the Literature section.

In the article, qualitative and descriptive data analysis methods were used to develop and summarize the results. The authors conducted systematic bibliographic research.

They reviewed, analyzed and systematized information obtained from various sources. Based on the conducted, comprehensive review of current trends, development prospects and research information, they presented their own opinion on future opportunities and limitations of obtaining metals for car production, in the context of sustainable development of the automotive industry.

The research scope is limited to the key metals currently used in automotive construction - steel, aluminum and critical metals, with a special focus on rare earth metals. The review focuses on the sourcing, applications, constraints and supply chain risks of these materials.

4. Steel in road transport

One of the key factors affecting fuel consumption and thus the amount of harmful exhaust gases produced is the weight of the car. The choice of materials for the construction of cars and its components therefore has a very strong impact on the ecology of vehicle use.

The basic material for car bodies is steel. The European steel industry is a world leader in innovation and environmental protection. It achieves a turnover of 130 billion euros and directly employs some 300,000 highly skilled workers in the EU (Statista Research Department, 2024). The steel industry in Europe is concentrated in more than 500 steel production facilities, in 22 EU member states.

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Iron ore is mined in about 50 countries ma the world. Most iron ore come from Brazil, Australia, China, India, the US and Russia. Australia and Brazil account for about one-third of global iron exports (González and Kamiński, 2011). The steel industry accounts for 7 - 9% of global CO_2 emissions, so this issue is currently receiving a lot of attention (Basson, 2024).

The largest steel producers in 2023 and previous years were China, followed by India, Japan, the US, South Korea and Germany. China's dominance of steel production has persisted for a long time (Figure 2). Referring to China's population, it seems natural that steel production is highest in China, as it is simultaneously associated with high demand for steel products. An example is the demand for cars counted in millions.

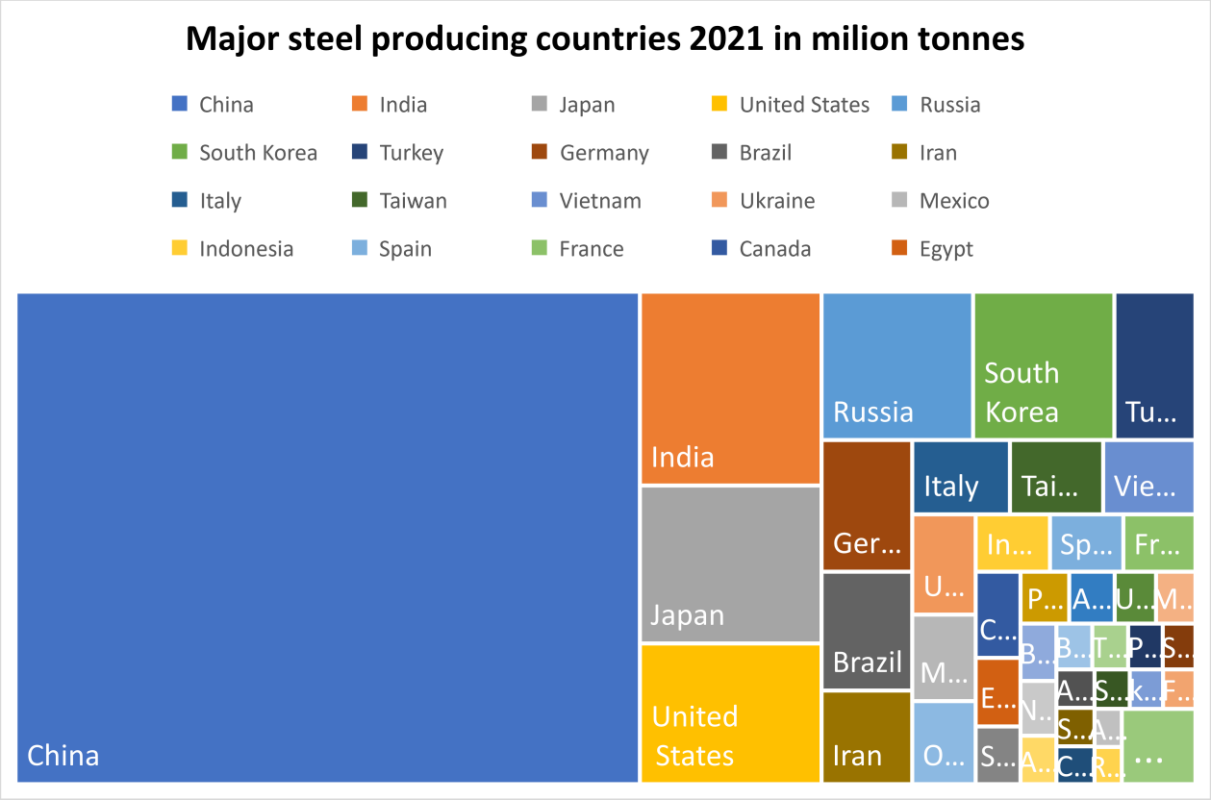


Figure 2. Major steel producers (Basson, 2021)

In 2022, 97.65% of the metallurgy's raw materials were processed into steel products or by-products. According to the Worldsteel Association steel production has been stable since 2020 (The European Steel Association, 2022). Globally, 219 kg of steel was used in new products per person in 2023. Top steel-producing companies in 2023 are: China Baowu Group (China), ArcelorMittal (India), Ansteel Group (China), Nippon Steel Corporation (China), HBIS Group (China), Shagang Group (China), POSCO Holdings (South Korea), Jianlong Group (China), Tata Steel Group (India), Delong Steel (China). As can be seen from the data presented, the vast majority of steel is produced in industrial plants in China and India, where environmental concerns are not a priority. China is currently the world's largest producer of steel and also its largest consumer. However, buyers are increasingly asking about environmental indicators and want to buy so-called green steel.

The concentration of heavy metallurgical industry in countries with low concern for environmental protection is characteristic. Europe, through the introduction of strict environmental directives, is influencing the development of the industry, including energy-intensive metallurgical plants processing primary iron ore. Through restrictive environmental regulations, the EU has opened the way for competition, not only in the steel industry.

There are 9 iron ore-producing member states in the EU, including Sweden, Norway, Austria, Slovakia and Germany. However, Sweden and Norway are the only countries where economically significant amounts of iron

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ore are mined. Sweden is the largest iron ore producer in the EU and the 11th largest in the world. The rest of the producers import the raw material. Russia is a large supplier of iron ore to the EU. Supplies are used by Germany, Finland, Slovakia, France and the UK, among others, and in smaller quantities by Serbia, Austria and the Czech Republic.

About 75% of steel is still produced mainly in coal blast furnaces, which emit large amounts of carbon dioxide into the atmosphere. Huge amounts of energy are also needed to heat the furnaces to temperatures well above 1,000°C, which is required by iron ore metallurgy technology (iron has a melting point of 1,650^{0}C). According to the International Energy Agency (IEA), emissions associated with steel production must be reduced by about 50% by 2050, and should continue to decline thereafter to meet global climate targets. Some of the world's largest manufacturers plan to reduce their carbon footprint by increasing the use of electric furnaces. However, a report by the NGO Global Energy Monitor shows that the transition from traditional blast furnaces to electric arc furnaces is very slow and well behind targets for decarbonizing steel technology.

Calculations show that a capital expenditure (CAPEX) of 2 to 3 trillion euros will be required to build the capacity necessary to bring EU "green steel" production to the forefront (Stamm & Naujok, 2023). Despite the enormity of this investment, the changes will only involve converting capacity in the iron and steel sector, not building the necessary sources of green energy to power production. The shift toward green energy will require another trillion euros.

On the one hand, a total product carbon footprint (PCF), which includes emissions across 3 supply chains (according to EU company reporting regulations), is considered a leading KPI for assessing "how green" a steel product can be. This KPI must be determined through a thorough cradle-to-gate life cycle analysis (LCA) according to globally accepted standards (e.g., ISO 14067), and then verified by a third party.

In order to multidimensionally assess the "environmental performance" of a steel product, many other ESG criteria must be taken into account, such as social justice, human rights, lack of child labor, other environmental detriments such as water consumption, land use and circular economy.

H2 Green Steel and Fortum companies have signed a framework agreement for the supply of emission-free electricity for H2 Green Steel's operations in northern Sweden (Fortum will use green energy with Swedish H2 steel, 2023). Initially, the annual volume of green steel produced at H2 Green Steel's Boden plant will be 2.5 million tons. In the second phase, the company will increase production to about 5 million tons.

For comparison, global steel production in 2023 was 1,885 million tons, and China's steel production in 2023 was 1,018 million tons (World Steel in Figures, 2023). This means that despite H2 Green Steel's laudable goals, the share of green steel in global steel production is negligible.

So far, one of the more successful ventures has been steel recycling, which has even reached an impressive 90 percent in many parts of the world. However, the amount of scrap steel currently available is only enough to meet a quarter of the world's demand (Anderson, 2024). Increasing pressure to advance the sustainability trend will encourage a shift to more sustainable steel production, particularly using renewable minerals. However, it is difficult to assess how quickly the changes, which require significant financial resources, will take place.

The market size of iron and steel is estimated to be USD 1,599.4 trillion in 2022 and is projected to reach 1,928.6 trillion by 2027 at GAR of 3.8% (Iron and Steel Market, 2024). The largest growth in steel demand is projected in construction, transportation and heavy industry. The greatest growth and development in this industry will be in China and Asian countries, regions with low environmental awareness (Table 1, Figure 3).

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Table 1. Crude steel production by process, 2021 (Basson 2021)	
	million tons
New Zealand	0.6
Australia	5.8
Africa	20.4
Middle East	45.8
Central + South America	46.3
rest UE	52.3
Russia + Ukraine	105.4
USMCA	117.2
European Union (27)	152.6
Asia	1403.4
Above countries in total	1949.8

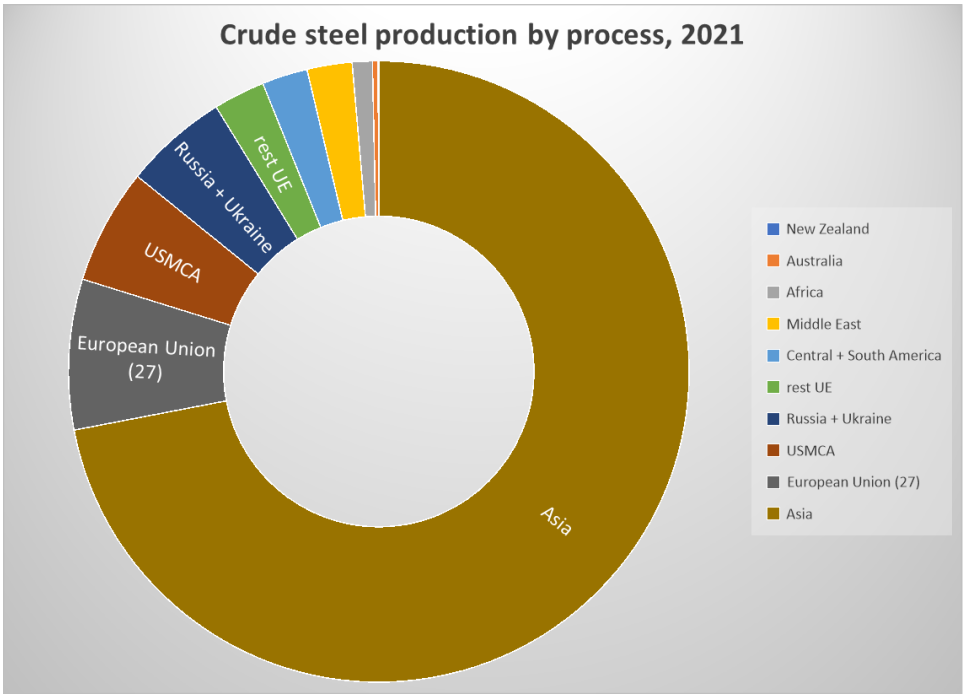


Figure 3. Crude steel production by process in 2021 by countries (Basson 2021)

5. Aluminium in road transport

At present over 130 kgs of aluminum goes into the average European car, and this is rising steadily (UK Aluminum Industry, 2024). The transportation sector across the world is estimated to use 26.7 million tons of aluminum in 2022. The passenger car segment is the major end user sector among other transportation sectors with an estimated consumption of more than 16.5 million tons of aluminum in 2022. Many structural and functional automotive components which were previously made of steel are now being fabricated using aluminum. In the EU, aluminum use in transportation is projected to increase from 0.6 million tons to 1.6 million tons between 2022 and 2027 (Future of Aluminum in Transportation Sector, 2024). The global automotive aluminum market size was valued at USD 73.21 billion in 2021 and is predicted to reach at USD 156.53 billion by 2030, increasing at a CAGR of 8.81% from 2022 to 2030. The production of greenhouse gases associated with aluminum recycling is many times lower than obtaining the metal from bauxite. Recycling aluminum is about 60 to 95% cheaper. On top of that, aluminum does not lose its properties during recycling and we can recycle it indefinitely.

The most common use of aluminum is in cans and food packaging. Aluminum material is also used in the automotive and aerospace markets to produce a variety of parts.

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Recycling aluminum (Kuchariková et al. 2016) and steel (WorldSteel Associaton, 2022) saves resources and uses less energy than producing these metals from raw materials. Aluminum can be recycled many times without losing its quality. The European aluminum market was estimated to be worth USD 54.59 billion in 2023. It is expected to reach USD 74.75 billion by 2030, with a compound annual growth rate (CAGR) of 3.9% between 2024 and 2030. According to the International Aluminum Institute (IAI), Europe has the highest recycling efficiency rate (RER) in the world, recovering 81% of available aluminum scrap by December 2020 (International Aluminum Institute, [2024]). The report by Triton Market Research predicts that the European aluminum market will advance with a CAGR of 4.92% in the forecast years from 2023 to 2030 (Europe Aluminum Market 2023-2030). However, China is the largest producer of recycled aluminum (Figure 4). The recycling rate remains stable at a high level (Dai et al, 2019). The target is 100 percent by 2030. In terms of aluminum recycling rate, the leading countries are: Austria (59%), Wales (59%) and Taiwan (53%) (Statista, Recycled aluminum production worldwide in 2021, by main territory, 2024). The larger exporters of aluminium waste and scraps were countries such as: USA, Germay, Canada (Figure 5).

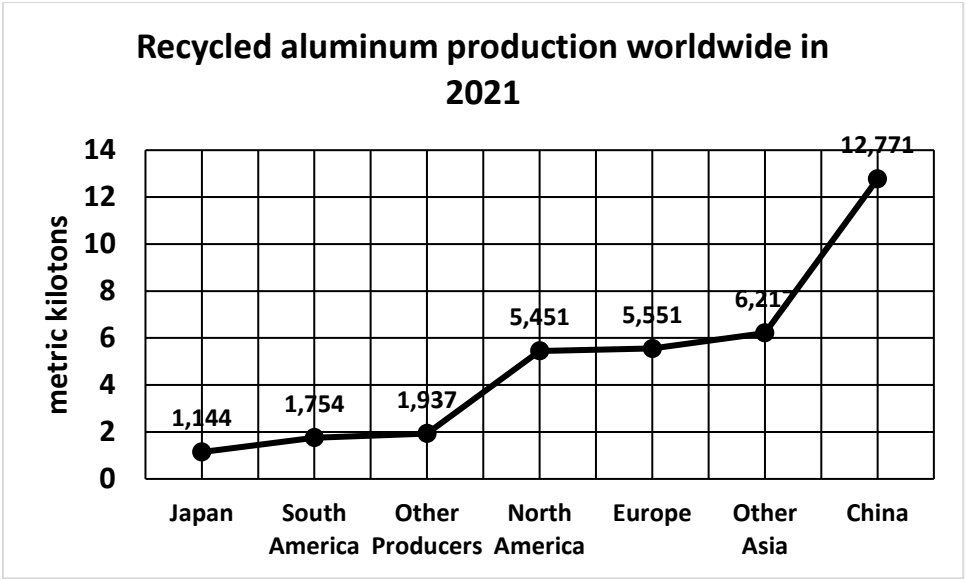


Figure 4. The largest exporters of aluminum waste in 2023 (Top Exporters of Aluminium Waste and Scrap in 2023).

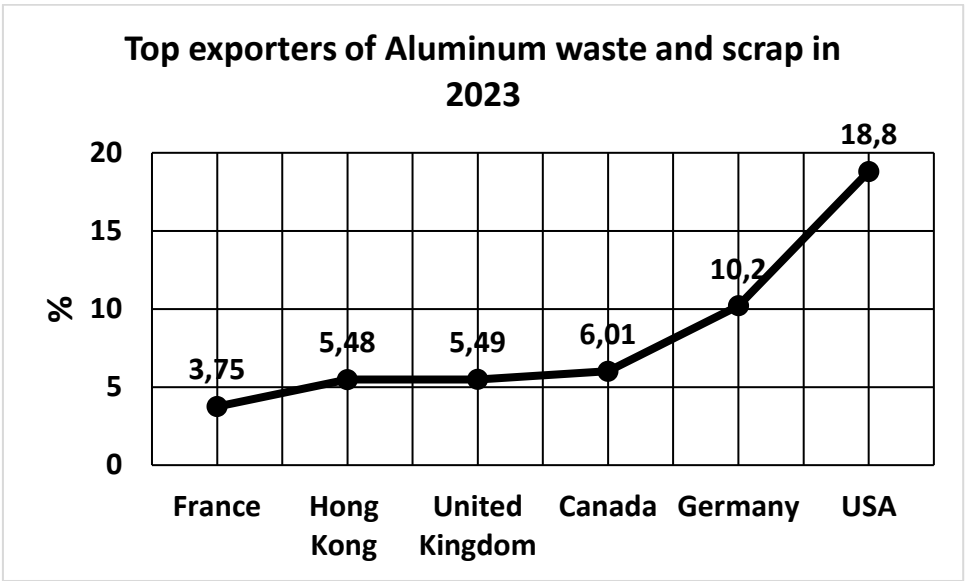


Figure 5. Top Exporters of Aluminium Waste and Scrap in 2023 (Business Research, Aluminum Recycling Market Report Overview, 2024)

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In 2023, global imports of "aluminum waste and scrap" exceeded USD 19.8 billion. The largest importers of aluminum waste and scrap in 2023 (Trend Economy, Aluminium waste and scrap | Imports and Exports | 2023) were India - 18.2%, and other countries in the global import of aluminum scrap are: (USD 3.62 billion), China - 17.3% (USD 3.44 billion), Germany - 8.62% (USD 1.71 billion), the US - 5.97% (USD 1.18 billion), Italy - 5.344% (USD 1.06 billion) (Figure 6). China imports aluminum scrap from countries such as Japan, Malaysia, Thailand, the UK and the US. India, on the other hand, imports aluminum scrap from Saudi Arabia and the US.

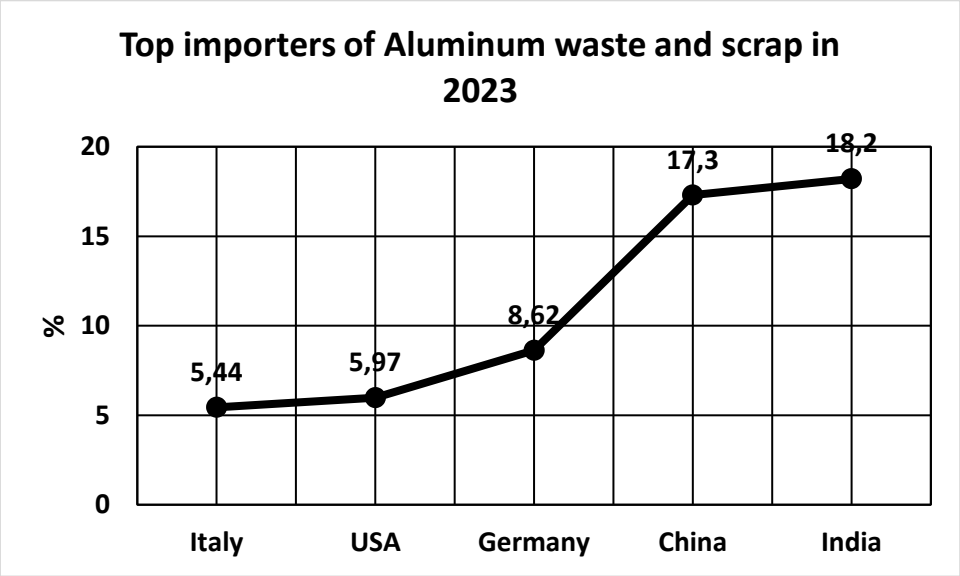


Figure 6. Top importers of aluminum waste and scrap (Trend Economy, Aluminium waste and scrap | Imports and Exports | 2023).

Europe accounts for more than 15% of global aluminum consumption, and the main market for aluminum in Europe is Germany, home to the world's largest automakers. Germany accounts for 25% of Europe's total aluminum consumption, hence the growth of the global aluminum industry is heavily dependent on this market. The German automotive industry has great potential for growth as it exports cars around the world, satisfying the growing consumption of motor vehicles.

German aluminum producers and processors produce about 560,000 tons of aluminum. This includes about 260,000 tons of primary aluminum and 300,000 tons of recycled aluminum.

Since 2002 the EU has continuously been a net exporter of aluminum scrap year-on-year. On the other hand, the EU's high level of scrap exports threatens the development of the recycling industry and the closed-loop economy in Europe. More than 80% of scrap produced in the EU goes to Asia, with 37% going to China and 28% to India

The global aluminum recycling market size was valued at USD 100165.8 million in 2023 and will reach USD 136566.08 million in 2032, with a CAGR of 5.3% during 2023-2032 (Business Research, Aluminium Recycling Market Size, Share, Growth, And Industry Analysis, 2025). The global aluminum recycling market size was USD 107.09 billion in 2023 and is projected to grow from USD 112.03 billion in 2024 to USD 160.83 billion by 2032, exhibiting a CAGR of 4.62% during the forecast period. Asia-Pacific holds leading position in aluminum recycling market share in 2023 (Business Research, Aluminium Recycling Market Report Overview, 2025).

The most common form of transportation worldwide is by car. However, because the automobile industry is more concerned with improving CO_2 emissions, fuel efficiency, and design, aluminum is playing a bigger role in modern cars. The expansion of automotive production and the greater usage of aluminum in contemporary vehicles are the primary drivers of this development. The usage of aluminum helps lower the weight of vehicles

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by one kilogram overall. The primary factor anticipated to drive the market expansion is the increased usage of aluminum in the automotive industry and the rise in the use of aluminum recycling procedures.

According to Cognitive Market Research, the global aluminum scrap recycling market size will be USD 5814.2 million in 2024. It will expand at a compound annual growth rate (CAGR) of 8.80% from 2024 to 2031 (Cognitive Market Research, 2025). America held the major market share with more than 40% of the global revenue with a market size of USD 2325.68 million in 2024, which will grow at a compound annual growth rate (CAGR) of 7.0% from 2024 to 2031.

- Europe accounted for a market share of over 30% of the global revenue with a market size of USD 1744.26 million.
- Asia Pacific held a market share of around 23% of the global revenue with a market size of USD 1337.27 million in 2024 and will grow at a compound annual growth rate (CAGR) of 10.8% from 2024 to 2031.
- Latin America had a market share of more than 5% of the global revenue with a market size of USD 290.71 million in 2024 and will grow at a compound annual growth rate (CAGR) of 8.2% from 2024 to 2031.
- Middle East and Africa had a market share of around 2% of the global revenue and was estimated at a market size of USD 116.28 million in 2024 and will grow at a compound annual growth rate (CAGR) of 8.5% from 2024 to 2031.
- The diesel generator category is the fastest-growing segment of the aluminum scrap recycling industry

6. Critical Minerals

Critical minerals and their extraction are closely linked to the development of the environmental megatrend, which is forcing new transportation solutions such as electric cars and the development of green energy to power industries that produce materials and components for the transportation industry.

Critical minerals are essential for the development of the modern electric car industry, as well as renewable energy generation. The extraction of critical minerals and their subsequent processing is mostly carried out in non-European countries with little emphasis on environmental protection. These are raw materials that are of great importance in the economy but have a high risk of bottlenecks in supply chains, with the possibility of breaking them (European Commission, 2020; Leon and Daphne, 2023).

Despite the risks, economic analysis of the market indicates a relatively stable development of macroeconomic exchange and distribution of critical minerals. Demand for these raw materials is growing year after year. Demand for critical minerals experienced strong growth in 2023, with lithium demand rising by 30%, while demand for nickel, cobalt, graphite and rare earth elements all saw increases ranging from 8% to 15% (IEA Global Critical Minerals Outlook, 2024).

For the six key energy transition minerals - copper, lithium, nickel, cobalt, graphite and rare earth elements in some cases a significant increase in demand is forecast (Figure 7). The global increase in demand for rare earth elements is shown in Figure 8 (Watari et al., 2020).

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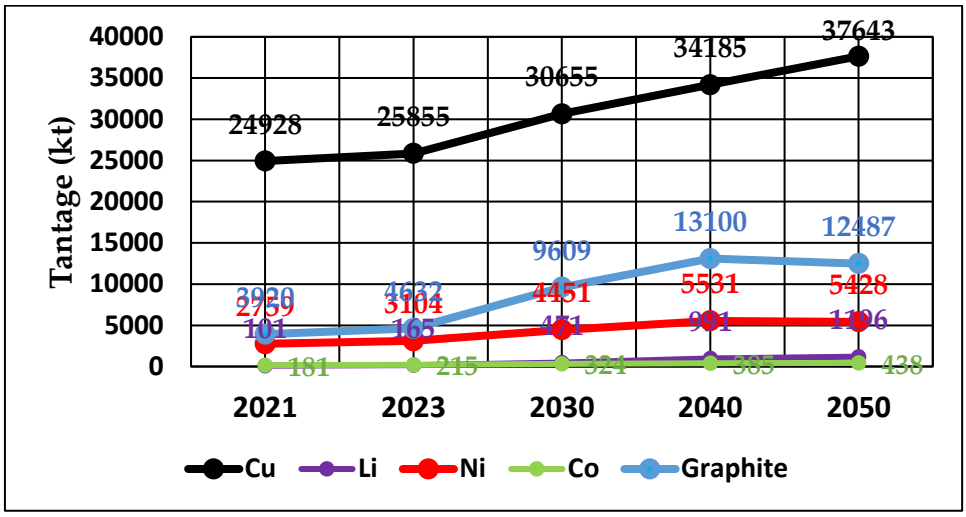


Figure 7. Projected growth in demand for Cu, Li, Ni, Co and graphite until 2050 (IEA Global Critical Minerals Outlook, 2024)

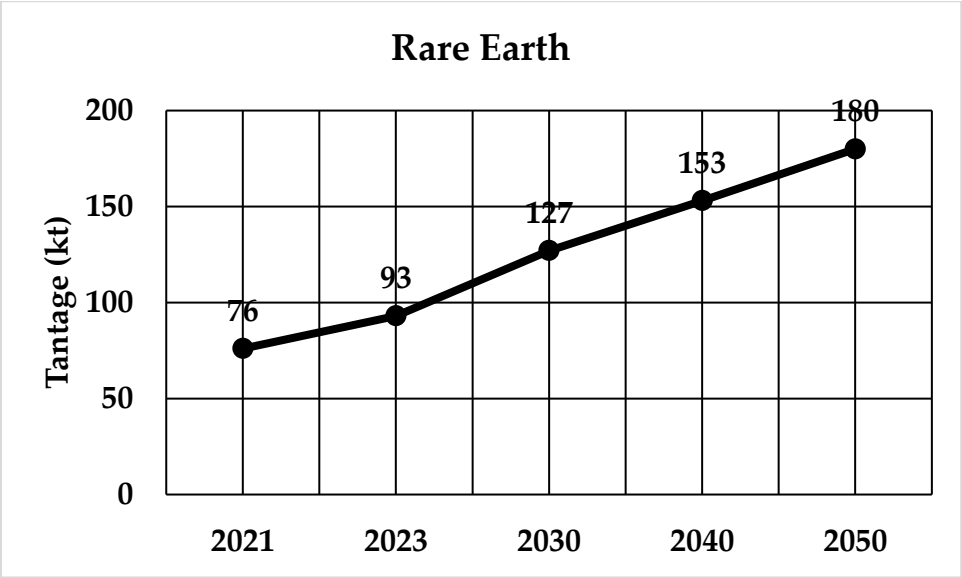


Figure 8. Projected global growth in demand for rare metals (IEA Global Critical Minerals Outlook, 2024)

Table 2 shows 10 critical minerals and their use in energy and transportation technologies (Firestone and Garofalo, 2022; Namibia Critical Metals INC 2017; Müller et al. 2025). Modern transportation and energy technologies cannot be developed without these minerals. Therefore, these are the minerals that have caught the attention of industry, science and economic managers alike.

Table 2. Use of critical metals (Firestone and Garofalo, 2022)

Vanadium	redox flow batteries
Cobalt	EV batteries and wind technology
Indium	solar technology
Chromium	wind technology
Titanium	EVs and batteries
Graphite	Evs and batteries
Tungsten	rocket engines and microwaves
Antimony	flame retardants, as alloys for car batteries and bullets
Rhenium	turbine blades in fighter jet engines and electrical components
Dysprosium	permanent magnets, data-storage devices, nuclear reactors as a cermet

In addition to the critical minerals listed in Table 4, U.S. and EU government studies list about 50 minerals that they consider critical. Some of these are shown in Table 5. Critical raw materials are called commodities of

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great economic importance whose supply shows a high risk of disruption due to concentration of sources and lack of good, affordable substitutes (Eurostat, 2024).

The following critical minerals can be mentioned (US Department of Energy, 2023). The Secretary of the Interior, acting through the director of the U.S. Geological Survey, published in 2022 final list of critical minerals that includes the following 50 minerals: aluminum, antimony, arsenic, barite, beryllium, bismuth, cerium, cesium, chromium, cobalt, dysprosium, erbium, europium, fluorspar, gadolinium, gallium, germanium, graphite, hafnium, holmium, indium, iridium, lanthanum, lithium, lutetium, magnesium, manganese, neodymium, nickel, niobium, palladium, platinum, praseodymium, rhodium, rubidium, ruthenium, samarium, scandium, tantalum, tellurium, terbium, thulium, tin, titanium, tungsten, vanadium, ytterbium, yttrium, zinc, and zirconium.

This list is based on the latest U.S. Department of Energy (DOE) critical materials assessment entitled DOE Critical Materials Assessment 2023.

The final list of critical materials for 2023 includes all materials that have been assessed as "critical" or "near-critical" in the short to medium term - with the exception of uranium (EU https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52011DC00250).

Article 7002(a) of the 2020 Energy Law limits the list of critical materials to "any mineral, element, substance or material that is not fuel." In the usual understanding of fuel, uranium used in commercial nuclear reactors is a fuel material. Since the DOE's 2023 critical materials assessment only covers the use of uranium as a fuel, the DOE did not identify uranium as a critical material in the final 2023 critical materials list.

The EU relies on the supply of critical minerals because it has no sources of these minerals of its own. Table 3 shows the countries where critical minerals are sourced and the countries from which the EU imports them. China's dominance in both sourcing and importing these minerals to the EU is evident. China is an economic powerhouse and a leading country in the production of materials necessary for the development of the transportation and energy industries. The stability of this country determines the stability of the supply of critical raw materials.

Table 3. Critical minerals, production, imports into the EU (Eurostat, 2024)

Mineral	Main producers	EU imports
Antimony	China (78%), Vietnam (11%), Russia (4%), Tajikistan (4%)	China, Tajikistan, Vietnam, South Korea, Türkiye, and Thailand
Berylium	United States (60%), China (23%), Kazakhstan, Brazil, Mozambique, Canada, Namibia, Portugal, and Zimbabwe, Uganda, Rwanda, Madagascar	Kazakhstan, United States, China
Cobalt	China (70%), Democratic Republic of Congo, Indonesia, Russia, Madagascar, Philippines, Cuba, New Caledonia, Papua New Guinea, Turkey	Democratic Republic of Congo (DRC) and Zambia, China, Australia, Russia and Canada
Fluorspar	Mexico, Mongolia, South Africa, Vietnam	China, Mexico, Pakistan, South Africa, Morocco, Turkey, Mongolia, Thailand, United States
Gallium	China (98%), Japan, Republic of Korea, Russia,	China, Japan, United States, United Kingdom, Switzerland, Canada, Korea Rep., Singapore
Germanium	China (60%), Canada (25%), United States, Russia, Finland	China
Graphite	China (77%), Madagascar, Mozambique, Brazil, South Korea, Russia, India, North Korea, Norway, Tanzania,	China, Tanzania, and Mozambique

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Indium	China (40%), South Korea (31%), Canada (9%) and Japan (9%)	United Kingdom (13% of EU sourcing), United States (5% of EU sourcing) and China (4% of EU sourcing)
Magnesium	China (85%), Russia, United States, Israel, Australia, Turkey, Brazil, Austria, Spain, Kazakhstan	China (97%), Israel
Niobium	Brazil (60-70%), Canada, Congo, Russia	Brazil (84%), Canada, Korea
Platinum group metals	South Africa, Russia, Zimbabwe, Canada, United States, China	South Africa (71%)
Rare earths	China (69%), United States (12%), Myanmar (11%), Australia (5%), Thailand, India, Russia, Madagascar, Vietnam, Brazil	China (40%), Malaysia (31%), United States
Tantalum	Democratic Republic of Congo (45%), Rwanda (17%), Brazil (16%), Nigeria (11%), China	Democratic Republic of Congo (36%), Rwanda (30%), Ethiopia (6%), Nigeria (5%)
Tungsten	China (83%), Vietnam, Russia, North Korea, Bolivia, Spain, Rwanda, Austria, Australia, Portugal	United States (29%), China (28%), United Kingdom (10%), Switzerland, Turkey, India, Canada, Kazakhstan, Japan, Thailand
Dysprosium		

The EU produces only 1% of all battery raw materials. The global mine production of antimony was estimated at 83.000 metric tons (Anderson, 2019) China is the largest producer of antimony. In addition to China, smaller quantities are produced in several other countries (Figure 9).

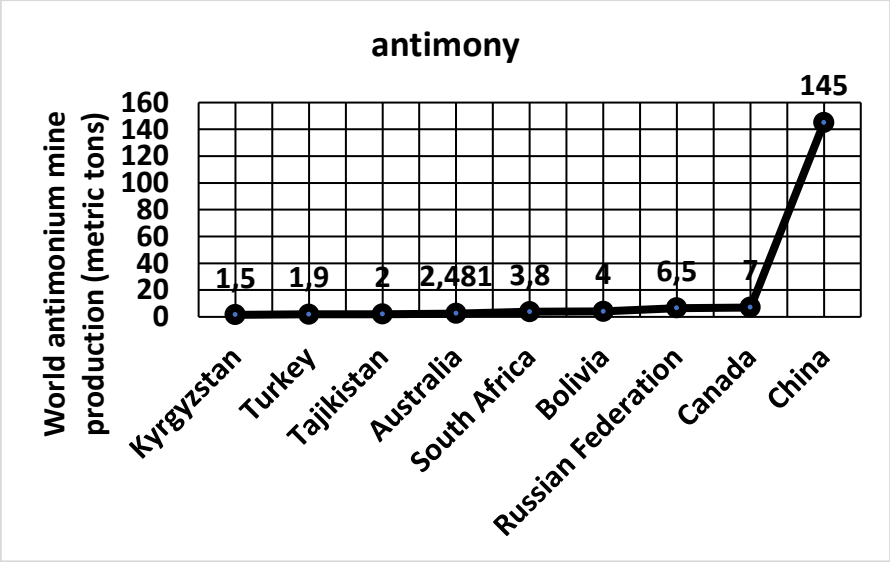


Figure 9. World mine production of antimuonium by country (metric tons) (United States Geological Survey (USGS) Minerals Resources Program, Antimony Production by Country)

The United States is the world's largest beryllium mine producer by far, with production amounting to an estimated 190 metric tons in 2023 (Figure 10) (Kramer, 1999; Top beryllium producing countries; Beryllium unwrought powders, 2024; Jaganmohan, 2024). The automotive industry utilizes beryllium as a connector material for high – temperature and battery application (Beryllium Market Growth Drivers & Opportunities, 2023) . China was distantly the second-biggest producer in the world, with an output of 74 metric tons. Beryllium-bearing pegmatite districts occur in Brazil, Canada, China, Mozambique, Namibia, Portugal, and Zimbabwe.

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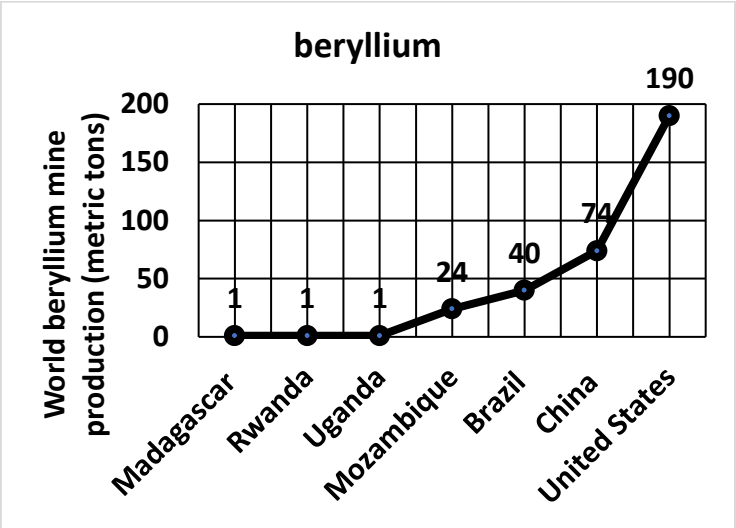


Figure 10. World mine production of beryllium by country (metric tons) (Kramer, 1999; Top beryllium countries)

The 54% of global cobalt mine production comes from the Democratic Republic of Congo, followed by China (8%), Canada (6%), New Caledonia (5%) and Australia (4%) (Figure 11). Refined cobalt comes from China (46%), Finland (13%), Canada and Belgium (6% each) (European Commission, Critical materials for strategic technologies and sectors in the EU - a foresight study, 2020)

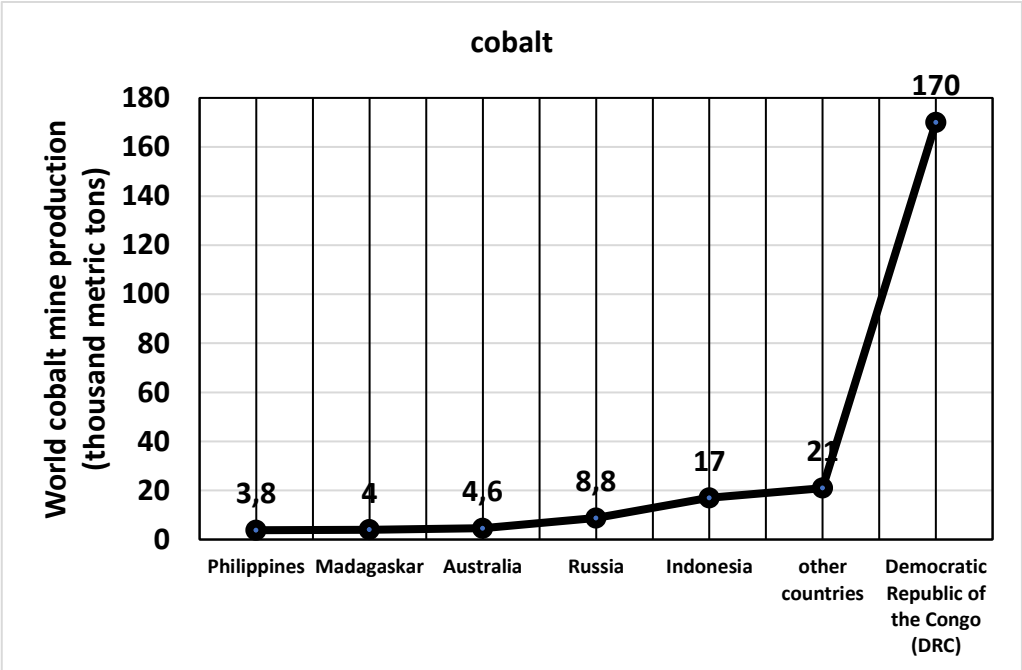


Figure 11. World mine production of cobalt by country (thousand metric tons) (European Commission, Critical materials for strategic technologies and sectors in the EU - a foresight study, 2020)

China is the world's largest mine producer of fluorspar, with an estimated output amounting to 5.7 million metric tons in 2023 (Figure 12) (Statista, Global fluorspar production by country, 2023; Londono, 2024; Iha, 2023). World production of fluorspar was estimated to have increased by 6% in 2023, primarily from increased production in Mongolia. Mines in Canada, Germany, Italy, Spain, and the United States, some of which had been idle for decades, were preparing to restart operations. Synthetic fluorspar may be produced from neutralization of waste in the enrichment of uranium, petroleum alkylation, and stainless-steel pickling; however, undesirable impurities constrain use. Primary aluminum producers recycle HF and fluorides from smelting operations. Fluorspar demand from the lithium ion battery sector is expected to exceed 1.6 million tons

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by 2030, representing a significant portion of the overall market, according to Benchmark's Fluorspar Market Outlook.

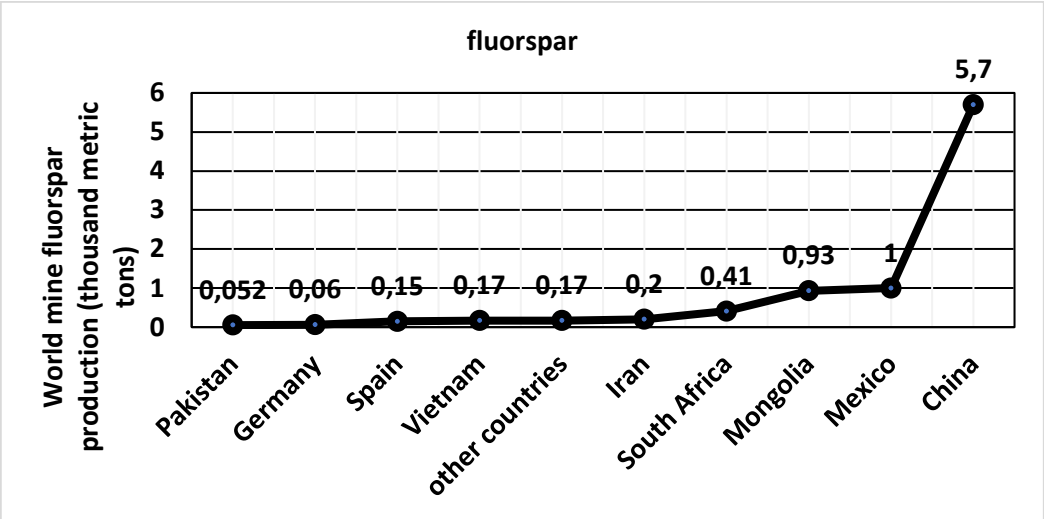


Figure 12. World mine production of fluorspar by country (metric tons) (Statista, Global fluorspar production by country, 2024)

In 2022, China was the largest primary producer of gallium in the world, with production having amounted to 600 metric tons (Figure 13) (Jaskula, 2024). Russia was the second-largest primary producer of gallium that year with a distant five metric tons. Current world production of gallium is about 200 mt per year, with the main producing nations being China, Germany, Kazakhstan and Ukraine. Gallium is found in trace amounts in zinc ores and in bauxite, and gallium metal is produced when processing bauxite to make aluminum. Around 80% is produced in China, according to the CRMA. Gallium is used to make gallium arsenide for use in electronics. Gallium is found in trace amounts in zinc ores and in bauxite, and gallium metal is produced when processing bauxite to make aluminum. Gallium occurs in very small concentrations in ores of other metals. Most gallium is produced as a byproduct of processing bauxite, and the remainder is produced from zinc-processing residues. The average gallium content of bauxite is 50 parts per million. Some domestic zinc ores contain up to 50 parts per million gallium and could be a significant resource, although no gallium is currently recovered from domestic ores. Gallium contained in world resources of bauxite is estimated to exceed 1 million tons, and a considerable quantity could be contained in world zinc resources. However, less than 10% of the gallium in bauxite and zinc resources is potentially recoverable. According to the CRMA, around 80% is produced in China. Gallium is used to make gallium arsenide for use in electronics.

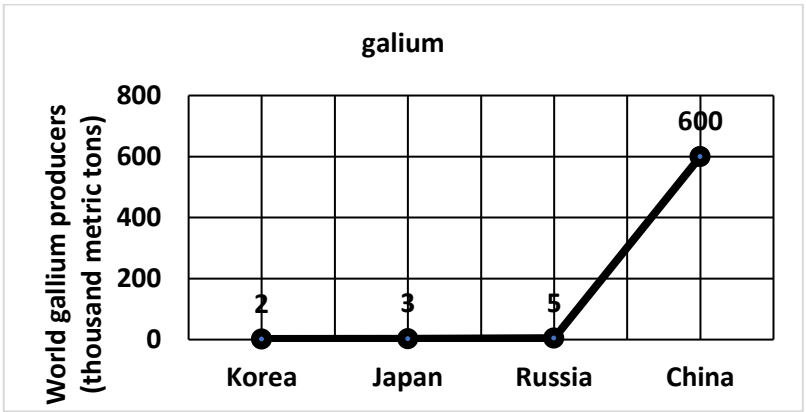


Figure 13. World production of gallium by country (metric tons) (Jaskula, 2024)

Global germanium refinery production and recycling data were limited, and available estimates were difficult to verify (Nagrale, 2025; Germanium Market Size, 2024). China continued to be the leading global producer and exporter of germanium in 2023. Exports of germanium metal (China's export codes 8112.92.10 and

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8112.99.10) for the year through September increased by 34% to 34,600 kilograms compared with those in the same period in 2022. These exports were mostly sent to Russia (21%), Germany (19%), Hong Kong (18%), the United States (17%), Belgium (9%), and Japan (8%). Major germanium producers in China included Yunnan Chihong Germanium and Zinc Co. Ltd. and Yunnan Lincang Xinyuan Germanium Industry Co. Ltd (U.S. Geological Survey, Mineral Commodity Summaries, Germanium, 2024).

China was the world's largest graphite producer in 2024, producing 1.27 million metric tons of the metal (Leading graphite producing countries worldwide in 2024, Graphite Mining Market Analysis by Reserves, 2024) (Figure 14), 50 percent higher than the amount it produced in 2021. Graphite is an essential component for lithium-ion batteries and other energy storage solutions. Future demand for graphite is projected to be high as interest in battery-storage technology rises.

In 2023, the world's total production of natural graphite amounted to an estimated 1.6 million metric tons. China accounted for the highest Graphite reserves, followed by Brazil and Mozambique. Global natural graphite production is expected to grow by 4.3% to 1,677.4 thousand tons (kt) in 2024, backed by an anticipated growth in supply from Madagascar, Tanzania, Mozambique and Canada. China, Madagascar, Mozambique, Brazil and Canada are the world's top five producers of natural graphite, accounting for 94.0% or 1,512.0kt of the global total in 2023 (Global Graphite Mining Industry Report 2024-2030). Looking further ahead, global natural graphite production is expected to grow steadily through to 2030 with a compound annual growth rate (CAGR) of 10.2% to reach 3,007.9 kt. Growth will be primarily supported by output from Tanzania, Mozambique and Canada.

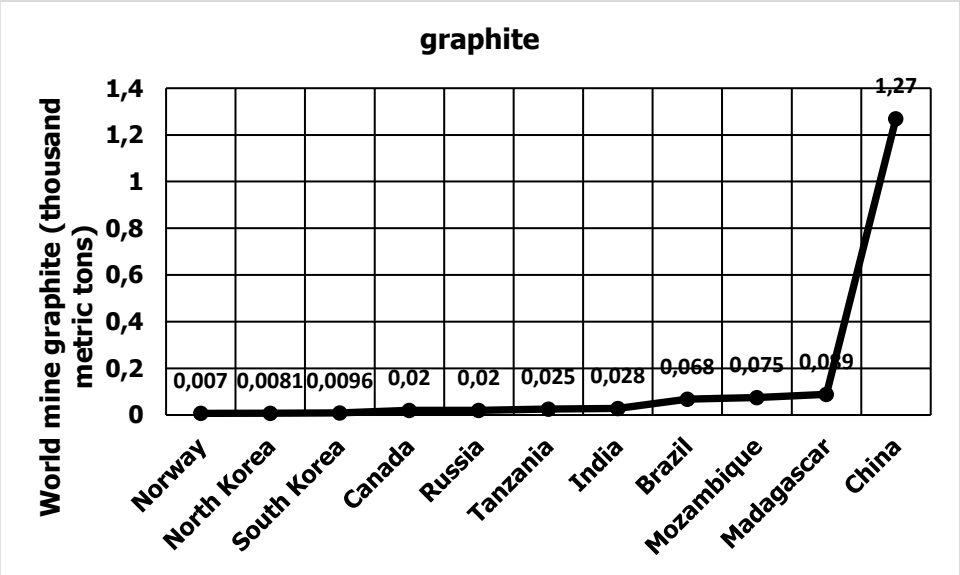


Figure 14. World production of graphite by country (metric tons), (Leading graphite producing countries worldwide in 2024)

The vast majority (~90%) of indium is obtained as a by-product of zinc mining (Global Indium Market, 2023; Indium Market Size, 2025; Pangarkar, 2024). The main producers of indium are China (40%), Korea (31%), Canada (9%) and Japan (9%) (Figure 15). There is no indium production in the United States. Indium is relatively rare, with its content in the Earth's crust estimated at about 0.1 parts per million. In contrast, it is commonly found in zinc ores and is mainly produced from residues generated during the processing of zinc ores.

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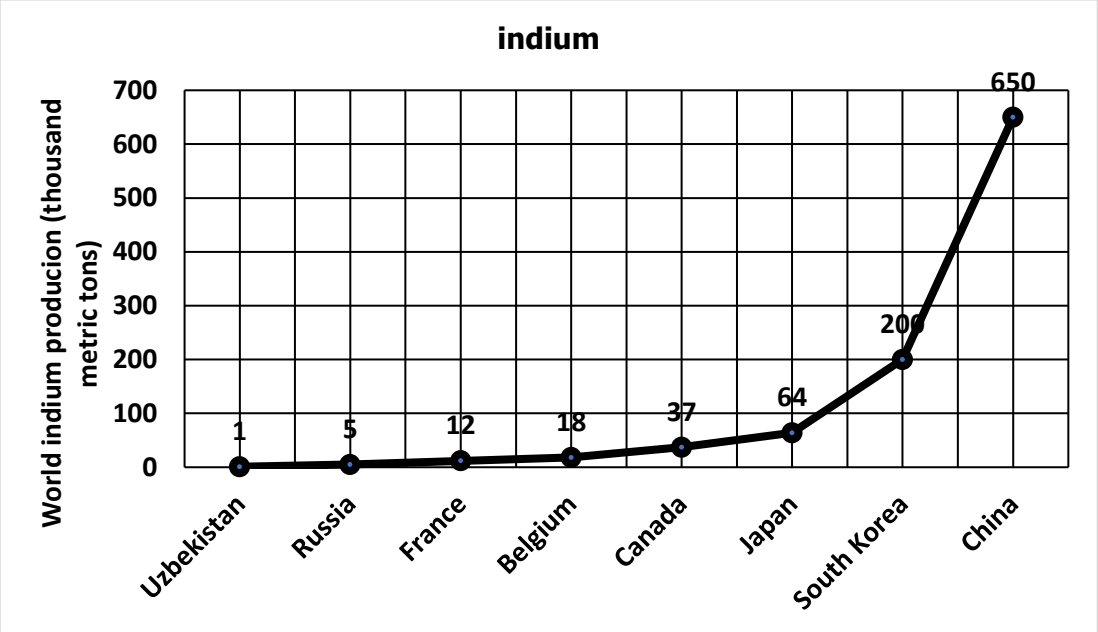


Figure 15. World production of indium by country (metric tons) (Leading countries based on production of indium worldwide in 2023)

China accounts for 85% of Mg production (Figure 16). Almost 95% of all magnesium imported into the EU is from China. Magnesium finds its main application in the automotive industry (Kulkarni, 2024; Magnesium Metal Market, 2024; Magnesium Market Size, 2024; Magnesium Market Analysis APAC, 2024).

The dominant production method is electrolysis. Global magnesium production has grown at a rapid pace (5% to 7.5% per year on average), driven by the continued growth of magnesium production in China (Metal Magnesium Market Size & Share Analysis - Growth Trends & Forecasts, 2024), where magnesium is produced by a thermal reduction process "the so-called Pidgeon process."

Magnesium demand and supply are expected to grow in the long term. Battery production could be one of the important drivers of demand (European Commission, 2020; Metal Magnesium Market Size & Share Analysis - Growth Trends & Forecasts, 2024). Given the wide availability of magnesium resources (e.g., dolomite and magnesite resources in the EU), raw material availability is unlikely to be a limiting factor for future supply growth (Magnesium Market Annual Review, 2024). However, magnesium production has been pushed out of the EU. The last of the older smelters in Europe closed in 2001, as European-based smelters were unable to compete with low-cost Chinese production.

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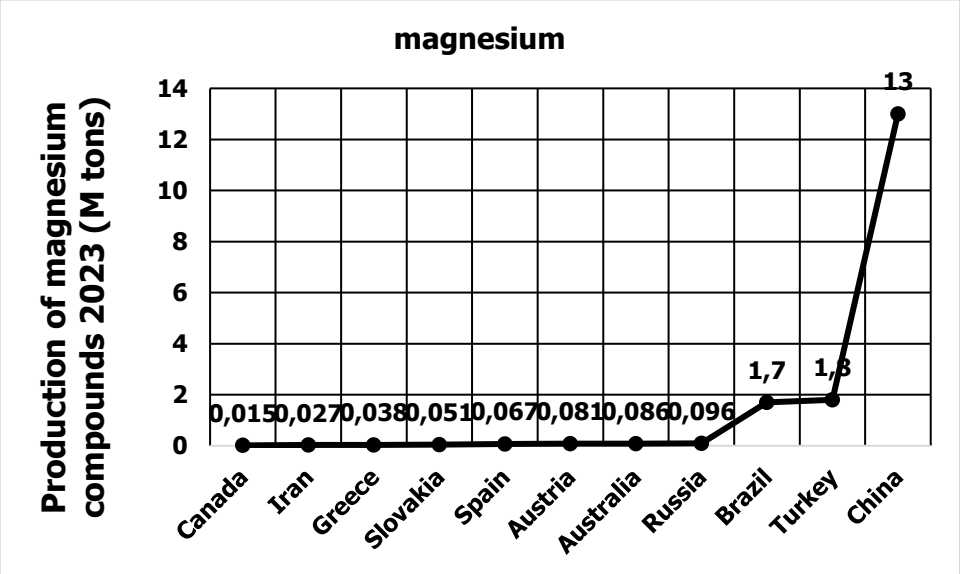


Figure 16. Magnesium production (tons) (Magnesium Production by Country, 2025)

Brazil is the leading producer of niobium and ferroniobium an alloy of 60-70% niobium with iron (Figure 17) (Niobium Market Size & Share Analysis, 2024; Jha, 2024; Gałaś et al., 2024; Mine production of niobium worldwide in 2023 by country). Niobium is used mostly in alloys, the largest part in special steels such as that used in gas pipelines. The Niobium Market size is estimated at 106.85 kilotons in 2024, and is expected to reach 171.49 kilotons by 2029, growing at a CAGR of 9.92% during the forecast period 2024-2029 (Niobium Market Size & Share Analysis - Growth Trends & Forecasts (2025 - 2030)).

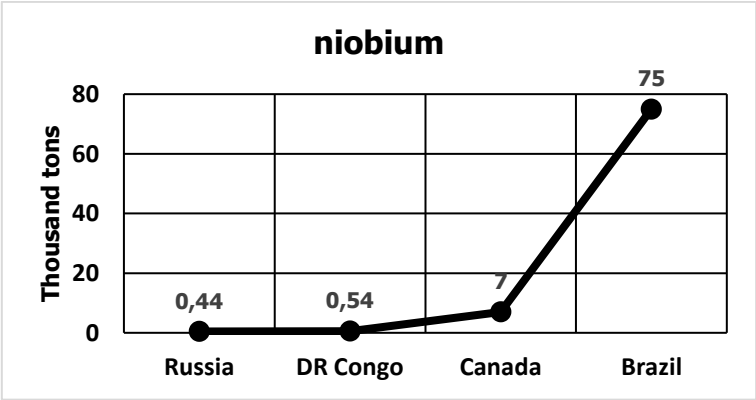


Figure 17. Mine production of niobium worldwide in 2023 by country, (Niobium Market Size & Share Analysis - Growth Trends & Forecasts (2025 - 2030))

South Africa is by far the largest producer of platinum in the world, with production amounting to an estimated 120 metric tons in 2023 (Figure 18) (Raymond, 2024; CME Group, 2025; Liguid, 2024; Platinum Market by Form). Russia came in a distant second place, having produced some 23 metric tons that same year. Platinum is used in vehicle catalytic converters, often in conjunction with palladium and, at times, rhodium. Within a catalytic converter, platinum expedites chemical reactions without undergoing consumption itself. As exhaust gases from an engine pass through the catalytic converter, platinum enables a series of chemical transformations. These reactions minimize harmful pollutants such as nitrogen oxides (NO_x), carbon monoxide (CO), and unburned hydrocarbons, transforming them into less detrimental substances, namely nitrogen (N_2), carbon dioxide (CO_2), and water vapor (H_2O). Given its pivotal function in the automotive industry, approximately 61% of platinum group metals (PGMs) are allocated for use in this sector.

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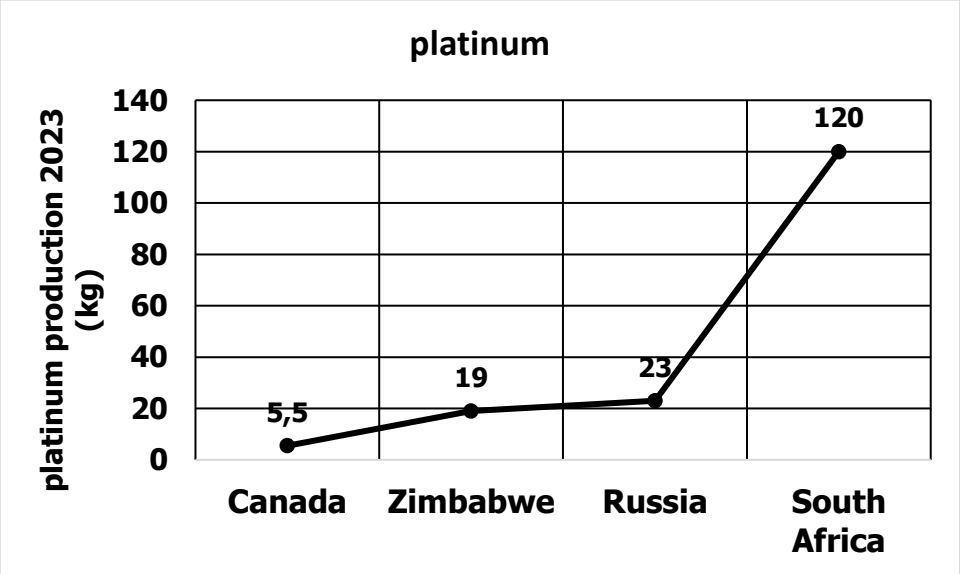


Figure 18. Platinum producer top countries (Platinum Production by Country, 2025)

Tantalum producers are shown in Figure 19 (Tantalum, 2024). Tantalum is the rarest stable element in our entire solar system, with just one atom of tantalum for every 181 billion atoms of other elements (Tantalum Market, 2024; World-Tantalum-Market Analysis, 2020). That makes tantalum far less abundant than gold, or any of the traditional precious metals.

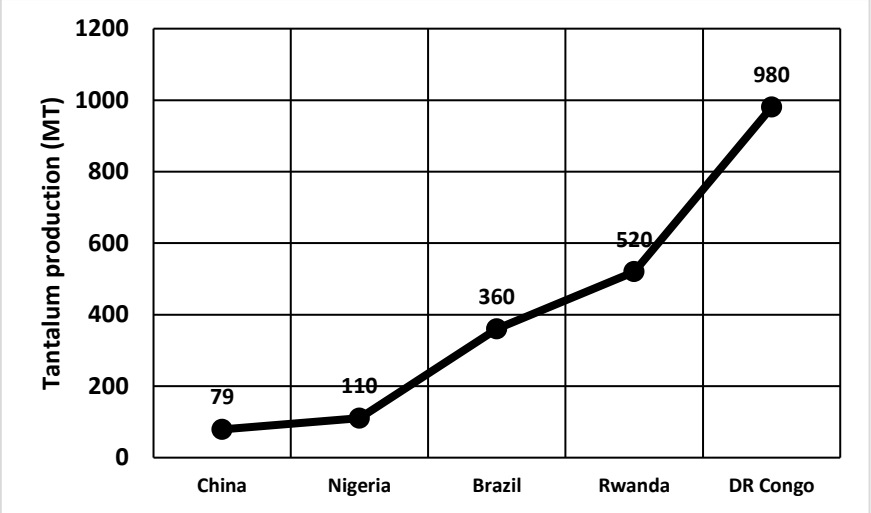


Figure 19. Main producers of tantalum by country (Tantalum, 2024)

Tungsten is found in ores such as scheelite and wolframite. These ores are found around the world but the country that accounts for the most tungsten concentrate production is China, supplying about 83% of the tungsten concentrate produced globally (Figure 20) (Pistilli, 2025; Tungsten Market, 2025). Australia's Tungsten resources are the 2nd largest in the world, accounting for 12% of world economic demonstrated resources, but Australia's current production levels are negligible (Resources, About Tungsten, 2018). Tungsten is nearly as hard as diamond, has the highest tensile strength of all metals, has high electrical conductivity and is thermally and chemically stable. For this reason, tungsten alloys and some tungsten compounds cannot be substituted in its various applications. It is a critical component of engine valves, ballpoint pen tips, tungsten filaments in light bulbs, turbine blades, LCD panels, TV tubes, laser printers, window heating wires, car horns, electrical switch gear, airplane flaps, and is even used in golf clubs. It is also used in the vibrating mechanism of mobile phones, used in the manufacture of specific steels for jet engines, medical and dental equipment and high-temperature resistant alloys. It is a high-tech metal essential for all developed economies.

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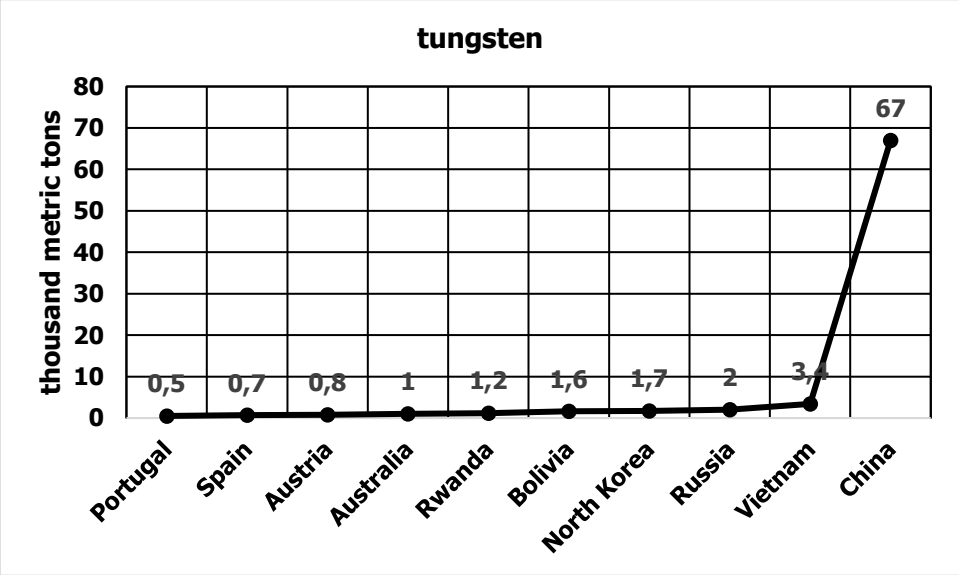


Figure 20. Tungsten main producers, (Pistilli, 2025)

Global dysprosium production was 708 tons in 2022. Of this, 1.13 tons were consumed in the EU. A total of 38,580 metric tons (t) of Dy had entered to the global mining phase, of which Mainland China contributed 87% (Eheliyagoda et al., 2023). Mainland China was the dominant trade partner and accumulatively exported 2,674 t of Dy primary products, 6,354 t of Dy intermediate products, and 3,897 t of Dy final products to the international market between 1988 and 2021. The global dysprosium compounds market was valued at USD 9.63 million in 2023 and is projected to reach USD 13.42 million by 2030, exhibiting a Compound Annual Growth Rate (CAGR) of 4.8% during the forecast period (2024-2030) (Dysprosium Compounds Market 2024-2030).

Dysprosium is used in alloys for neodymium-based magnets. This is because it resists demagnetization at high temperatures. This property is important for magnets used in motors or generators. These magnets are used in wind turbines and electric vehicles, so the demand for dysprosium is high. Dysprosium iodide is used in halide discharge lamps. The salt enables the lamps to emit a very intense white light. Dysprosium oxynitride (a composite material of ceramic and metal ceramics) is used in the control rods of nuclear reactors. It easily absorbs neutrons and does not swell or shrink after being bombarded with neutrons for a long time.

Furthermore, new trends such as electric mobility, clean energy, energy efficiency, and automation are projected to increase the usage of dysprosium, propelling the worldwide dysprosium market growth. Alternatively, different technical advances in dysprosium manufacturing are expected to provide profitable prospects for the development of the dysprosium market in the future years.

The major use of dysprosium is as an alloying addition to $Nd_2Fe_{14}B$ (Yan et al., 2010) permanent magnet materials (in which some of the neodymium is substituted with dysprosium) to increase both the Curie point and especially the coercivity and, therefore, improve the high-temperature performance of the alloy. The metal is also a component of magnetostrictive Terfenol D ($Tb_{0.3}Dy_{0.7}Fe_2$) (Mech & Kaleta, 2017). Dysprosium is used in control rods for nuclear reactors because of its relatively high neutron absorption cross-section. Its compounds have been used for making laser materials and phosphor activators, and in metal halide lamps.

China is the largest country producing rare earth elements, but it is not the only producer (Figure 21) (Pistilli, 2024). As at 2023, China produced more than two-thirds of the total global rare earth mine production. At a distant second place was the United States, accounting for a 12.29 percent share of the global rare earths production that year. The global rare earth elements market size was USD 3.39 billion in 2023 and is projected to grow from USD 3.74 billion in 2024 to USD 8.14 billion by 2032, exhibiting a CAGR of 10.2% during the

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forecast period (2024-2032). Asia Pacific dominated the rare earth elements market with a market share of 86.14% in 2023. As much as 98% of the rare-earth elements imported by the EU come from China. Extraction is also highly concentrated in other categories of raw materials: the EU imports 99% of the borate it consumes from Turkish mines, 71% of the platinum it consumes from South Africa, and 85% of the niobium it consumes from Brazil.

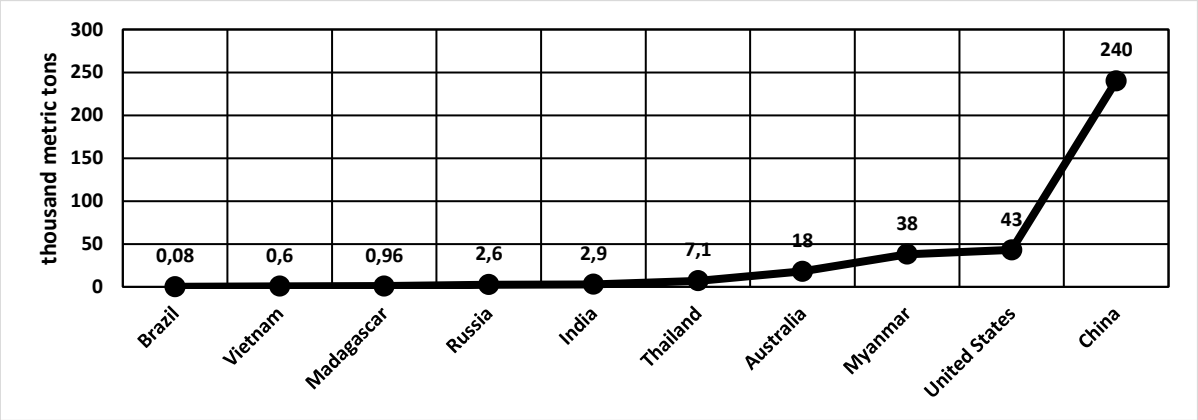


Figure 21. Main producers of rare earths metals (Pistilli, 2024).

Discussion

The market for metals used in the automotive industry is concentrated in several countries around the world. China is the largest producer of steel, aluminum and rare earth metals (Figures 2, 4 and 8) (Bela, 2025; Armstrong, 2023; Andrews-Speed and Hove, 2023; Pistilli, 2024).

In terms of area, China is the third country in the world (9.6 million km^2) (Figure 22). In terms of population, the order of countries is as follows: India, China, EU, US, Indonesia, Pakistan, Nigeria, Brazil, Bangladesh, Russia. Economically, China ranks second after the United States of America.

Rare earth metals are a family of 17 metals that includes two scandiums (scandium and yttrium) and all lanthanides (lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium and lutetium). They co-occur in minerals and have similar chemical properties. They are obtained from bathnaesite (China and the US) and monazite (India and, to a lesser extent, Brazil, Malaysia, Vietnam and Australia), as well as loparite (Russia). They are not as rare as their name would suggest (they account for a seventh of all elements found in nature). The problem is that the deposits rarely occur in high concentrations. Moreover, the process of extracting them and converting them into usable materials is costly and harmful to the environment. This is because the waste generates radioactive water, toxic fluoride and acids (Śleszyńska, 2023).

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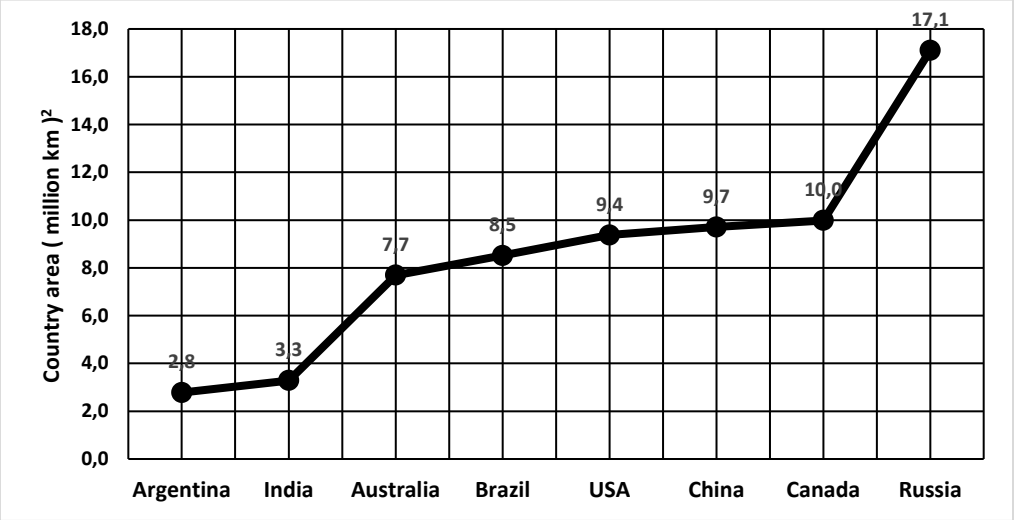


Figure 22. The largest countries in the world in terms of area (Statista, The 30 largest countries in the world by total area)

The concentration of production of critical metals in a few countries around the world leaves economically important raw materials at risk of supply disruption or even interruption. There is also a global dependence on suppliers. The current state of the economy and management of raw materials is due to the search for the cheapest possible materials. The result of this approach is the production of materials sought by the automotive industry mainly in China, which has cheap labor and is not overly burdened by strict environmental directives.

Rare earth metals are also used, among other things, to make lasers, battery electrodes, magnets, magnetic resonance contrast agents, catalysts, precision weapons, satellite technology, and are also used in unmanned vehicles and advanced communications systems (Cieślik, 2022). China has already mastered almost all of the world's supply of rare earth elements and accounted for 92 percent of global production in 2012. This is due to its huge investment in the industry, low production costs and low environmental standards. In 2010 -2014, China, as a result of the incident with Japan, reduced the supply of these metals which caused a strong increase in prices. This critical incident prompted the search for alternative suppliers. One of them could be Australia, which considered the mining and production of rare earths as a strategic activity. The U.S., too, has changed its approach to sourcing critical materials and has begun to invest in the mining and processing of rare earth metals on its territory. The production of these metals is very much related to the growing demand of the automotive industry focused on the production of electric vehicles. It is predicted that the growth of the automotive industry is likely to result in a several-fold increase in demand for rare earth metals (Figure 8).

Rare earth elements are mined by open-pit mining. This process not only consumes huge amounts of energy, but can also cause environmental problems, such as water pollution and radioactive waste generation, as well as ecosystem disruption (León & Daphne 2023). This is why the US, Australia and other countries did not develop exploration for deposits of these metals until their supply chains collapsed.

Rare earth metals are crucial to economic development. Without them, technological progress would not be possible. Their potential scarcity significantly limits any economy's ability to grow its GDP.

The vast majority of resources of these key raw materials for the world's development are found in China. In addition to China, the largest resources of these elements are found in the US, Australia, India and Russia. There are no sources of these raw materials in the EU. Possible potential sources of rare earth elements in the EU are mainly secondary raw materials, e.g. apatite phosphogypsum, waste electrical and electronic equipment. Due to demand and the need for rare earths in key industries, the search for sources of these raw materials is also underway in the EU.

Vanadium deposits have been discovered in Norway (cire.pl, 2025). In addition, it has been found that 70-80 billion tons of phosphorite ore exist in the studied region. These would be the world's largest phosphorite

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reserves, ahead of Morocco (about 50 billion tons) and China (about 3 billion tons). In Norway's Telemark region, 8.78 million tons of rare earth metals have been discovered (Kowal 2024), including neodymium, as well as praseodymium oxide (cire.pl, 2025).

Nickel and cobalt are found in Poland. The use of minerals such as cobalt and nickel, among others, necessary for the production of electric vehicles and energy storage will increase more than 50 times by 2050 (TVN24 Biznes, 2024). Poland can also potentially obtain critical raw materials from waste, e.g. apatite phosphogypsum, waste electrical and electronic equipment. Fly ash from coal combustion also appears to be a prospective secondary source of rare earth elements (Jarosinski, 2016).

In 2008 the European Commission proposed the implementation of the so-called European Raw Materials Initiative, on the premise that "access to and extraction of minerals is essential for the well-being of the EU economy" (Salamon, 2023). In turn, in 2011 the European Commission (EC) identified rare earth elements on the EU's List of Basic Raw Materials and announced its readiness to cooperate with any country that contributes to their mining. In 2013 the European Innovation Partnership Minerals announced a Strategic Plan for their extraction.

Demand for rare earth metals is expected to increase sevenfold by 2040, and for lithium by up to 42 times (Wesołowska, 2023). Currently, the European Union's demand for these metals is met by China, which is the source of as much as 98 percent of the rare earth metals imported by the European Union. The EU is making efforts to ensure a stable and secure supply of key rare earth elements (Secure European Critical Rare Earth Elements, 2022).

Critical raw materials are a loosely defined broader group of chemical elements that includes all rare earth elements. They are raw materials that are critical to industrial and economic development and without which no major large-scale technological achievement in the 21st century will be possible.

Mining and refining rare earth ores present considerable technological challenges and are often harmful to the environment. Ores that contain metals must first be finely crushed. This requires the use of large quantities of toxic chemicals. The process generates hundreds of thousands of liters of toxic wastewater per day, which contains radioactive thorium and uranium, among other things. This is compounded by greenhouse gas emissions and progressive pollution of air, soil, water, leading to environmental destruction. The production translates into health effects for mining workers and a higher incidence of serious diseases among the local population. In addition, intensive exploitation of rare earth ores leads to gradual depletion of deposits. This in turn makes their extraction require more and more energy and chemicals.

The Middle Kingdom has an extensive program of investment in rare earths projects around the world, including in Australia, Canada and Tanzania. Currently, the key region in the world for rare earth elements and the acquisition of what are termed critical raw materials in general is Africa. The interests of not only China but also the United States intersect in Africa.

Africa is home to about 30% of the world's deposits of critical minerals, as well as larger quantities of other minerals (Dadura & Pikuła, 2024). The Democratic Republic of Congo alone has as much as 70 percent of the world's cobalt deposits. Nearby Gabon has the second-largest manganese deposits in the world and is now the third-largest producer. Countries in need of these precious minerals are struggling with diminishing or no resources on their territory, as is the EU. At the same time, countries whose territories contain deposits of valuable raw materials are so underdeveloped that they are unable to either extract them effectively, let alone use them. In addition, the situation is aggravated by the weakness of the political systems of these countries, which are either shaky democracies or dictatorships. China in 2022 alone imported rare earth minerals from Africa with an average value of about USD 10 billion. African countries see China as a desirable partner for mining operations not only because of the huge sums the Middle Kingdom is willing to invest on their soil. Chinese investments usually do not come with any restrictions or requirements regarding human rights or sustainable development, which often accompanies cooperation with Western countries. That's why today the

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extraction of critical minerals in Africa is dominated by Chinese mining companies. China is by far the dominant player in the African mining sector. It has invested more than USD 25 billion in its global Belt and Road Initiative since 2020 alone.

Rare earth metals are mostly sourced outside the European Union, which means that the European community will never be able to achieve self-sufficiency in this area. The only solution to avoid the risk of supply collapse is to diversify the sources of supply of critical raw materials. For the time being, the European Union depends almost exclusively on China for some key raw materials.

Critical raw materials are linked to virtually all industries and at all stages of the supply chain in the EU economy. These include the rapidly growing technologies from the defense and space sectors, which, given the strategic threat to Europe from Russia, gives the issue great importance.

EU arrangements stipulate that at least 10% of the EU's annual consumption of critical raw materials is to come from extraction in the EU; at least 40% of the EU's annual consumption is to come from processing in the EU; at least 25% of the EU's annual consumption is to come from internal recycling; and no more than 65% of the EU's annual consumption of each strategic raw material at the relevant processing stage is to come from a single third country (Ministry of Climate and Environment PL 2024).

The opacity and unpredictability of the rare earths market is compounded by the fact that their largest producer is one country, the People's Republic of China, which dominates the market and can dictate to the entire world the terms of their purchase (Wiejaczka & Wilczyński, 2021).

The intensification of the green deal in the EU, the lack of sources of critical raw materials and the low recovery from recycled materials result in dependence on external supplies.

The environmental trends prevalent in the EU are a significant barrier to manufacturing activity, a source of increased production costs and reduced product competitiveness. The EU tries to prevent the competitiveness of cheaper products by imposing tariffs, which in turn causes political friction between countries and economic retaliation.

Thus, it can be concluded that the policies of countries significantly affect their economies. Despite the apparent independence of the market, it is strongly controlled by political ideologies, ecological approaches to the economy and the resulting regulations.

In light of the facts presented, the assumptions of the introduction of a green deal in the EU, manifested in trends in the automotive industry, and especially the huge time pressure for their introduction, will not be conducive to the development of the economy. The production of electric cars, which requires the use of critical metals, includes non-organically sourced components and raw materials, hence, in principle, does not meet the environmental criterion (The World Bank, 2022). Production itself is expensive and not everyone can afford these cars. The question arises as to whether the mode of economy chosen by the EU is correct. The ecological trends currently prevailing in the EU impose many restrictions on the conduct of technological processes that, on the one hand, benefit the environment and protect against pollution (Zgnilicki, 2025). On the other hand, they reduce competitiveness due to higher production costs. It is necessary to balance leading to sustainable development that ensures the most favorable production conditions while protecting the environment. It is difficult to assess to what extent environmental trends should influence automotive development and whether the chosen direction of electromobility will actually lead to meeting the requirements of green production. It seems that multidirectional measures involving innovative cleaning of exhaust gas from combustion cars, production of electric and hydrogen-powered cars should proceed in parallel. None of the solutions exhausts the assumptions of green transportation, but neither do any of the solutions have zero environmental impact in terms of the entire manufacturing and product life cycle, including recycling and waste disposal.

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The conducted research on the subject literature and data obtained from studies of the most important institutions analyzing the world economy lead to the conclusion that the source of basic raw materials decisive for technological progress are several countries, with China occupying the decisive position as the producer of the most important critical minerals. The practical value that arises from this proposal is the awareness of the need to make significant changes leading to greater EU independence from supplies of critical minerals. It is clear that the current distribution of mineral sources is not possible to change quickly. This is particularly true for the European Union, which is fully dependent on supplies from other continents. This is associated with supply risks and the prospect of economic dependence. Building supply diversification, and even more so independence in obtaining critical metals, in conditions of Chinese hegemony, is practically impossible. The EU does not have a developed flexible strategy for supply and sources of the necessary minerals. The technological policy to date has caused delays in the search for critical mineral deposits in the EU. China not only processes domestic minerals but also raw materials from other countries, which is why it is a monopolist, e.g. in lithium production. Investments in the processing industry in the EU are hampered by EU environmental protection directives. This policy does not allow for the creation of competition with foreign production and independence from supplies, and is also associated with high risk. Greater openness to the possibilities of processing minerals obtained from countries outside the EU, intensive search for deposits, which is already beginning to be observed, is the expected direction of development of the EU. It is certain that in order to meet the current economic challenges, a flexible and open approach to multidirectional solutions based on various technological possibilities that shorten supply chains to the maximum is necessary.

Conclusions

The influence of the environmental megatrend extends throughout the global economy, affecting the production of consumer goods in different countries of the world to varying degrees. In this context, focusing on the automotive industry, there are some specific factors affecting its development.

1. Environmental megatrends in the automotive industry have spearheaded the development of electric car production, which involves the need for critical raw materials, which the EU does not have deposits of and must import.
2. Automobile production in the EU depends on the supply of critical raw materials from China and other countries, sourced and produced in violation of environmental and ecological standards.
3. Growing awareness of the need to protect the planet is influencing the search for green industrial solutions, but progress has been slow and requires huge investments.
4. The simultaneous production of electric vehicles and technically innovative conventional vehicles is potentially the most favorable prospect for individual mobility

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AUTOMOTIVE INDUSTRY AND SUSTAINABILITY: HOW TO PROMOTE GREEN TRANSPORTATION*

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Abstract. In the context of societal pressures, legislative standards, regulatory requirements, and the demonstrable negative environmental impact of the automotive industry, companies are facing increasing pressure to integrate sustainability into their management practices. Due to increasing pressure from shifting stakeholder behavior and expectations, sustainability and corporate social responsibility play a crucial role in management practices. For many organizations such as automotive, logistics, sports organizations, educational institutions etc. this process is still a challenge. This paper aims to identify gaps in the implementation of sustainability in the automotive industry and provide recommendations for the effective integration of sustainability and the promotion of green transport. The research is based on a comparison of sustainability implementation practices in the largest automotive companies in Slovakia. In addition to enhancing competitiveness, financial sustainability, and market position, such implementation has a broader societal impact, contributing to systemic change in green transportation. The research identifies gaps and opportunities to optimize the implementation of sustainability, provides recommendations for companies that have not yet adopted sustainability practices, and offers guidance for effective implementation. The study reveals that although companies implement sustainability measures, significant gaps and inefficiencies remain. Addressing these gaps could enhance the effectiveness of sustainability initiatives, enhance organizational performance, contribute to mitigating societal problems related to transportation, reduce negative environmental impacts, and improve the quality of life.

Keywords: automotive; sustainability; green transportation; Slovakia; management

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JEL Classifications: M21, Q50, Q56

1. Introduction

As air quality and human health continue to deteriorate, pressure is mounting on individual companies to take responsible action and implement policies and strategies to improve this situation (Saman & Pauna, 2023). Increasingly stringent legislative standards and regulations to achieve sustainability are complicating the management of organizations as they attempt to adapt to them (Chiki et al., 2025). In addition to these external pressures, organizations face demand from customers driven by shifting expectations and evolving needs.

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Companies are adapting their strategies to meet these expectations and enhance their social responsibility. (Singh, 2024) The implementation of sustainability and social responsibility practices has become crucial for companies operating in various fields - from non-profit organizations, and sports organizations, to education institutions or services, manufacturing, and industry. The long-term issues being addressed primarily include slowing the process of global warming, reducing the ecological footprint, promoting health to preserve the quality of life on Earth, and ensuring the efficient use of scarce resources.

The automotive industry is one of the most significant contributors to global warming, particularly in the context of internal combustion engines. (Abro et.al., 2019) These engines emit carbon dioxide, nitrogen oxides, and particulate matter and may also result in the leakage of petroleum substances, including oil and fuels, into groundwater. The European Union and its institutions are currently working to enhance the management of sustainable development, issuing regulations and recommendations to facilitate the implementation of sustainable practices. The automotive industry is one of the most addressed and affected sectors in terms of restrictions. The challenge for automotive companies lies in successfully integrating sustainability requirements into their strategic plans while minimizing impacts on the economic performance and prosperity of individual organizations. While it is in the interest of companies to promote environmentally friendly transportation and production, none wish to jeopardize their business operations.

This thesis explores the potential pathways for successfully integrating sustainability into the management of companies within the automotive industry. It also compares the implementation of key sustainability elements across major automotive sector players. The research primarily focuses on Slovak automotive companies. The automotive industry in Slovakia accounts for the largest share of the country's GDP and exports and provides a significant portion of employment through automotive plants and their suppliers. (Augustin et al., 2024) Thus, implementing sustainability is not only an option but a necessity. This is not only due to legislative and public pressure but also to enhance competitiveness, improve performance, attract new investment, and meet evolving consumer expectations, as demonstrated in previous research. (Hermundsdottir & Aspelund, 2022) To maintain their position, companies must respond effectively to these influences. Based on the findings, gaps in the implementation of sustainability within corporate governance are identified, and recommendations are provided to optimize these efforts. Implementing sustainability elements requires integration into business operations, clear communication, and alignment with corporate policy and strategy, along with the provision of transparent information to key stakeholders. The implementation of sustainability depends on the capabilities of organizations, including their financial and technological resources, as well as the availability and development of innovation. From this standpoint, implementing sustainability is crucial not only for organizations but also for society. Research guides effectively incorporating sustainability elements to advance green transportation. This research also serves as a source of inspiration and guidance for companies yet to adopt sustainability practices or seek to improve their current implementation. It also maps the market position of individual organizations, offering valuable insights for potential investors. The paper lays the groundwork for further research aimed at achieving sustainability and promoting green transportation.

2. Theoretical background

In recent decades, rapid industrial development and the shift toward a consumer lifestyle have contributed to a decline in quality of life and have negatively impacted the planet as a whole. This raises the question of how long the current resources will be sufficient to meet the needs of today’s generation, and for how long we will be able to maintain a sufficiently high standard of living. It has become clear that, if we want to preserve life on Earth, individuals, businesses, and society as a whole must start acting responsibly and work toward achieving long-term sustainability. In literature, two distinct concepts are often encountered: sustainability and sustainable development. While some authors use the terms sustainability and sustainable development interchangeably, a subtle distinction exists. (Olawumi & Chan, 2017; Ruggerio, 2021; Sartori et al., 2014) However, some perspectives consider sustainable development a contradictory concept, as it may not be possible to sustain economic growth indefinitely on a planet with finite resources. (Sachs, 1999; Redclift, 2005; Tvaronavičienė, 2024) While sustainable development is a broader concept, both concepts share the same elements and principles, aiming towards the same goals. The principle of sustainability and sustainable development is the

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use of resources and meeting the needs of the present generation in a way that does not compromise the ability to meet the needs of future generations. (Brundtland, 1987; Hajian & Jangchi Kashani 2021)

The overall issue of sustainability is based on three fundamental pillars: the triple bottom line –comprising ecological, economic, and social pillars. According to the author of this concept, in the 21st century, it will be a business imperative, and society's performance will be measured precisely by social justice, economic prosperity, and environmental quality. (Elkington & Rowlands, 1999) Each pillar includes some specific elements of sustainability. The economic pillar includes long-term economic growth, resource efficiency, financial inclusion, and sustainable supply chain management. The environmental pillar focuses on emission reduction, fuel efficiency, sustainable production, the circular economy, recycling, renewable resources, and green infrastructure. The social pillar emphasizes fair wages, working conditions, equality, inclusion, ethical principles, community development, and education. One of the business sectors under the greatest pressure to implement sustainability is the industry, specifically the automotive industry, which is a major contributor to the deteriorating quality of the environment. All elements of sustainability should be integrated into corporate governance within the automotive industry to support public transportation and promote green transportation.

Each year, the number of newly registered passenger vehicles continues to increase. Passenger car transport is one of the most significant contributors to air pollution, and the automotive industry is one of the sectors with the most essential negative environmental impact. For this reason, individual companies must implement changes aimed at achieving long-term sustainability, such as improving fuel efficiency, transitioning to alternative fuels, reducing emissions, or adopting new engine technologies. (McAuley, 2003) Other trends have included automated driving, connectivity, and mobility services, which have brought about a lasting change in the environment. (Koers, 2014; Pischinger & Seiffert, 2016; Isopp et al., 2024) According to some authors, the future of transportation lies in autonomous vehicles (Šotek et al., 2021) or electromobility development (Koman et al., 2024; Redouani et al., 2024). These changes collectively promote sustainable transportation.

The European Union establishes standards and regulations in the automotive industry, which increases the need to integrate sustainability in these organizations. (Ostojic & Traverso, 2024) A crucial legislative step to ensure sustainable and environmentally friendly transportation was the limitation of emissions. In the EU, passenger road transport is one of the largest sources of pollution in transportation, accounting for up to 60.6% of total transport emissions. This is why the EU has proposed various measures to reduce emissions, including the adoption of alternative modes of transport, shared transportation, and measures for car manufacturers, such as increasing the efficiency of combustion engines and switching to a different type of fuel. In 2019, the most used fuels for passenger transport were diesel (66.7%) and petrol (24.55%). With the tightening of CO2 emissions regulations, electric cars have gained popularity. While there is a reduction in emissions when electric vehicles are operated, it is worth noting that the production and disposal of such cars are significantly more burdensome to the environment compared to other types of vehicles. The number of emissions from electric cars is linked to the source of the electricity used to charge them. (European Parliament, 2025) To reduce the emissions produced by road transport, emission targets were set, with a reduction goal for passenger cars to 95 g CO2/km from 2020 to 2024. Another essential legislative milestone was the adoption of the EU Climate Act in 2021, which aims to achieve climate neutrality by 2050. This law also applies to road transport and the automotive industry, as it includes requirements for transitioning to electric vehicles and reducing their carbon footprint during production and use. (European Commission, 2019)

However, the behavior of some companies does not always align with regulations. Many scandals, such as the reduction of CO2 emissions by electric motors and lightweight construction, have also sparked debate. (Wellbrock et al., 2020) This puts pressure on companies. External pressures have a positive impact on environmental and social sustainability but do not have a significant positive effect on financial performance. (Szász et al., 2021) Individual companies produce standardized financial reports that allow for comparison. However, a different situation arises in the case of sustainability reporting. (Tóth et al., 2022) Therefore, it is not possible to assess the impact of sustainability on its pillars or to compare these reports. The costs of implementing sustainability also include expenses for new technologies or innovation development, which impact financial indicators, as do fines associated with non-compliance with standards and recommendations.

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It is necessary to approach the implementation of sustainability elements comprehensively and understand the interrelationship between them. (Vilaya et al., 2024) While the ecological and economic elements dominate, the implementation of sustainability often overlooks the social elements. (Ajmal et al., 2018) In the social pillar, the key focus is on supporting cooperation between culturally and socially diverse groups, promoting social integration, and enhancing the quality of life. (Stren & Polèse, 2000; Davidson. 2010) Social responsibility within a company is also reflected in working conditions, employee support, educational development, health promotion, and the balance between work and personal life as well as emphasizing diversity, employability, and employee development. (Issopp et al., 2024) However, social responsibility includes community relations, consumer relations, and efforts to address social challenges related to transportation. (Dodd et al., 2024)

An organization must strike a balance between the individual elements of sustainability, ensuring that they have a positive impact on performance while maintaining financial sustainability.

3. Research objective and methodology

The study aims to identify gaps and opportunities to optimize the implementation of sustainability and to provide recommendations for more effective practices. The research is based on both qualitative and quantitative content analysis, as well as a comparison of approaches to sustainability in four large automotive companies in Slovakia. Although numerous studies address the implementation of sustainability through the analysis of individual elements, no comprehensive analysis of all three aspects (economic, environmental, and social pillar) within automotive companies operating in the Slovak market has been found.

The Slovak automotive industry holds a significant position in the national economy, as Slovak has become one of the world's leading car producers per capita. Consequently, any decline in competitiveness, performance, and production could have far-reaching consequences for the country. This study explores how companies implement sustainability to promote green transportation while supporting both business resilience and the Slovak economy.

The subject of the research includes four large automotive producers: Volkswagen Slovakia, Kia Slovakia, Stellantis Slovakia (PCA Trnava), and Jaguar Land Rover. Data are collected through content analysis and comparison of selected key indicators to understand how individual brands operate in the Slovak market and implement and communicate their sustainability strategies. Content analysis is a research method that is flexible and has a wide range of applications in studies and research with different objectives. (White & Marsh, 2006) is technique involves drawing valid and applicable conclusions from texts within their respective contexts. (Krippendorff, 2019) In short, it consists of generating answers to research questions by drawing on theoretical insights and transferring data from texts.

The research question in this study is: "How do automotive companies in Slovakia integrate sustainability principles into their management processes?"

The data are collected from annual company reports, available statistics, websites, and social media platforms. Annual reports published up to 2023 are used for analysis. From 2024 onward, companies reporting will be required according to uniform standards, which presents a challenge for automotive companies that are currently adapting to these new requirements.

The findings are divided into two parts – general and specific. The general part consists of management practices, approaches, implementation of sustainability into strategy, communication strategy, and ESG risk rating comparison. Obtained data in specific parts are analyzed following the three main areas of sustainability, commonly referred to as the "triple bottom line" model, and established key parameters and indicators are:

- Economic pillar – financial ratios, such as profit, sales, gross margin, etc.
- Environmental pillar – CO2 emissions, water consumption, production of electric vehicles, etc.
- Social pillar – labor condition, promotion of diversity, community support etc.

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Based on the collected and categorized data, it is possible to logically identify interrelationships among the three pillars of sustainability, evaluate the companies' approaches to sustainability implementation, and highlight differences between the various manufacturers to answer the research question, identify gaps and fulfill the study objectives.

4. Results

The obtained data were divided into two parts. The first part contains general information regarding the implementation of sustainability in management practices and corporate strategy. The second part presents specific findings related to the three main pillars of sustainability – economy, environmental and social. This division enhanced clarity and facilitated the comparison of sustainability integration, as well as the identification of potential shortcomings.

4.1 Analysis of management practices and communication

Slovak automotive companies face increasing pressure to integrate sustainability into their operations. This pressure arises not only from legislation and governmental requirements and expectations but also from customers, business partners, and investors who increasingly favor collaboration with socially responsible companies. Moreover, suppliers are likewise expected to comply with sustainability standards. In this context, the adoption of innovative technologies with minimal environmental impact has become essential. To ensure transparency and accountability, these companies are required to report their performance on both sustainability performance and financial outcomes regularly.

The findings indicate that only two out of the four analyzed companies published annual reports specifically addressing Slovak stakeholders, including information about sustainable-related activities. Several gaps were identified in the provided information. In particular, the absence of transparency and completeness may reduce credibility. Although companies often stated their sustainability goals and reported partial progress, they typically omitted crucial details such as investment in research and development, innovation, or penalties related to environmental and social issues. The disclosed information was usually part of broader annual reports, often lacking a unified structure or framework. Globally companies published sustainable reports. Most information with stakeholders occurred through websites or social media platforms. All analyzed companies have integrated sustainability into their strategy and managerial practices intending to meet legal standards and regulatory requirements. However, the two companies disclosed only limited information on their sustainability initiatives, community involvement, or achieved goals. This lack of disclosure may negatively influence stakeholders' and business partners' perceptions, potentially affecting the company’s reputation and trustworthiness.

Another crucial indicator of an organization’s commitment to sustainability, and a key factor for potential investors, is its ESG rating. ESG performance reflects how a company addresses environmental, social, and corporate governance issues. Specialized agencies assign ESG ratings based on established ESG criteria. For example, Sustainalytics provides a global ESG rating, evaluating more than 20,000 companies worldwide through a combination of quantitative data and qualitative analysis. (Sonko & Sonko, 2023) Table 1 presents the ESG Risk Rating of the compared organizations, focusing on their respective parent companies.

Table 1. ESG Risk Rating

Company	Kia Corp.	Volkswagen AG	Stellantis NV	Jaguar Land Rover Automotive Plc
ESG Risk rating	24.9	26.8	21.6	16.6
Industry Rank	Medium Risk (38 out of 88)	Medium Risk (52 out of 88)	Medium Risk (22 out of 88)	Low Risk (15 out of 88)

Source: Sustainalytics (2025)

Based on the data above, Jaguar Land Rover Automotive Plc has the lowest ESG risk among the companies compared, ranking fifteenth out of the 88 automotive companies surveyed. Companies with similar or lower ESG risk levels are primarily those specializing in the production of electric vehicles or the manufacturing of

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individual components. Among more significant and well-known automakers, Porsche AG, Renault SA, and Mercedes-Benz Group AG also achieved comparable rankings. (Sustainalytics, 2025)

4.2 Analysis by sustainability pillars

The concrete findings in this specific part were sorted into three main sustainability pillars – economic, environmental, and social. Based on this process, it was enabled to identify which pillar managers of companies perceive as more important.

4.2.1 Economic pillar

The economic pillar connected financial indicators and business investment in sustainability, innovation, new technologies, modern trends, and opportunities to fund science and research. Activities aim to improve the negative impact of production and car use on the environment and living conditions and promote green transportation. From the available sources, it was impossible to accurately identify the proportion of funding that individual companies invest in promoting sustainability, either through direct investment or investment in innovation and research in this area or penalties. However, it was possible to obtain information on financial indicators and performance and make a comparison. This comparison allowed us to partially assess the financial health of companies, the impact of sustainability implementation on their financial performance and stability, and the opportunities to invest in sustainability development and innovation. Table 2 presents a comparison of indicators, including profit, revenue, and gross margin, for each company, along with a year-on-year comparison.

Table 2. Financial ratios of the compared companies

	Kia Slovakia a.s.	**Volkswagen Slovakia a.s.**	**PCA Slovakia, s.r.o. / Stellantis Slovakia**	**Jaguar Land Rover Slovakia, s.r.o.**
Profit 2023	390 131 000	233 411 000	56 646 000	8 873 000
Profit 2022	175 506 000	202 405 000	34 314 000	10 846 000
Change	**122% ↑**	**15% ↑**	**65% ↑**	**18% ↓**
Sales 2023	8 065 938 000	11 757 330 000	3 284 362 000	373 018 000
Sales 2022	6 758 817 000	9 734 840 000	3 658 551 000	351 010 000
Change	**19% ↑**	**21% ↑**	**10% ↓**	**6% ↑**
Gross margin = Added Value / Total Sale	15,39%	8,72%	7,95%	77,10%

Source: Finstat.sk (2025)

Based on the above data, it can be concluded that despite the constraints and regulations related to sustainability, the companies compared have been relatively successful in generating profit. None of the companies reported a loss during the period analyzed. While Jaguar Land Rover experienced a decrease in profit, it saw an increase in sales. Notably, the company operates with a gross margin that is significantly higher than that of other companies in the Slovak automotive sector. Kia recorded the highest profit, with a 122% year-on-year increase, driven by a 19% rise in sales, and achieved the second-highest gross margin of 15.39%. (Finstat.sk, 2025)

The most significant sustainability restrictions were introduced by the European Union in 2019, followed by the onset of the global COVID-19 pandemic in 2020, which led to operational restrictions. The profit development from this period through to 2023 is presented in Figure 1.

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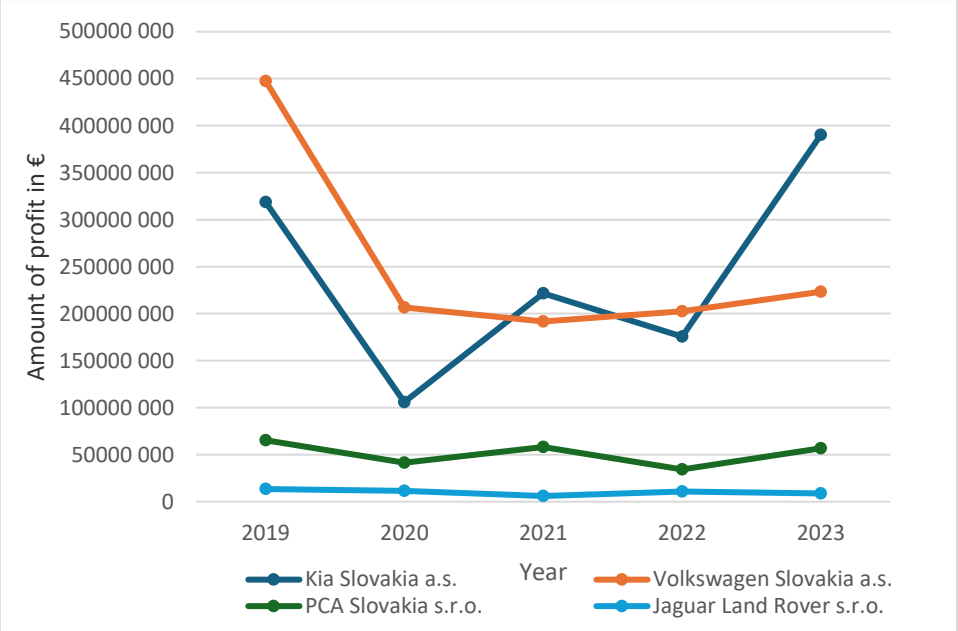


Figure 1. Profit of the compared companies from 2019

Source: Finstat.sk (2025)

In 2020, all companies experienced a decline in profit, likely due to the constraints imposed by the global pandemic and a weakening economy. For Kia, it is evident that by 2023, the company had achieved a profit level exceeding that of the pre-pandemic period in 2019. In contrast, Volkswagen has not yet returned to its pre-pandemic profit levels, remaining at a profit level similar to that of the years following the pandemic and the introduction of new European Union regulations. These changes in profit volumes may indicate that Kia Slovakia is adapting relatively quickly to new societal trends and market shifts.

The primary objective is to reduce the impact on air quality and the environment. Of the companies surveyed, only two – Kia Slovakia and Volkswagen Slovakia- publish annual reports specific to the Slovak market. The other companies do not provide annual reports for Slovakia; instead, they issue reports for their parent companies in Slovakia. One-year increase, driven by a 19% rise in sales, and achieved the second-highest gross margin of 15.39%. (Finstat.sk, 2025)

4.2.2 Environmental pillar

Kia aims to become a global leader in sustainable mobility. The company plans to have a fully electric product lineup in Europe by 2032 and in the remaining markets by 2040. Additionally, from 2028, Kia intends to focus on hydrogen fuel cell vehicles. By 2040, the company aims to utilize only renewable energy in all its plants. In terms of supply chain management, Kia is introducing a greenhouse gas management system. As steel suppliers, who are the most significant contributors to carbon emissions, collaborate to provide “green steel,” the company expects to reduce its carbon emissions by one-third. By 2030, Kia plans to incorporate recycled plastics in 20% of the plastic parts used in its vehicles. (Kia Slovakia a.s., 2023)

Volkswagen also communicates its sustainability efforts through annual reports. The company is committed to complying with all applicable legislative standards and regulations to protect the environment and provides transparent information on its sustainability activities. By 2025, Volkswagen aims to make its cars 45% greener than they were in 2010 and reduce its environmental impact by 59% in five key indicators (water consumption, CO2 emission, VOC production, waste production and energy consumption). By 2023, Volkswagen had already achieved a 67.5% reduction in its overall ecological burden compared to 2010, with improvements in energy use (60.38%), water consumption (65.64%), CO2 emissions (82.55%), volatile organic compounds (VOCs) (46.59%), and waste (72.38%). This progress allowed the company to surpass its set targets. By 2050,

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Volkswagen plans to produce vehicles with minimal negative environmental impact and achieve carbon neutrality. (Volkswagen Slovakia a.s., 2023)

For Stellantis and Jaguar Land Rover, it was not possible to obtain annual reports specifically related to the Slovak subsidiaries. Therefore, information from the annual reports of the parent companies was utilized. However, all brands provide at least some information on their sustainability activities on their websites. The following table (Table 3) summarizes the key factors within the sustainability pillar. It indicates whether each company incorporates these factors into its objectives, as presented in either its annual reports or on its website.

Table 3. The Presence of key environmental sustainability factors in annual reports and websites.

	Kia Slovakia a.s.	**Volkswagen Slovakia a.s.**	**Stellantis Slovakia, s.r.o.**	**Jaguar Land Rover Slovakia, s.r.o.**
Reduction of emissions, waste, chemicals, and greenhouse gases	✓	✓	✓	✓
Use of renewable energy sources	✓	✓	✓	✓
Long-term partnership in sustainability, transparent communication	✓	✓	✓	✓
Circular economy and resource efficiency	✓	✓	✓	✓

Source: Kia Slovakia a.s. (2023), Volkswagen Slovakia s.s. (2023), Stellantis (2023), Jaguar Land Rover (2025)

As shown in Table 3, all organizations address these key areas within the environmental pillar of their production processes, aiming to reduce their environmental impact while contributing to green transportation. However, some automotive plants face challenges in meeting specific standards, particularly concerning CO2 emissions. This leads to financial implications for the organization, such as fines, and necessitates innovation, technological changes, and adjustments to the production system. Most companies focus on reducing emissions by increasing the production of electric vehicles rather than traditional combustion engine vehicles. The rapid adaptation to these conditions provides companies with a significant competitive advantage. Table 4 presents the CO2 emissions from producing various car types at four car plants in Slovakia.

Table 4. CO2 Emissions of Passenger Cars (g CO2/km)

Year	**Kia**	**Volkswagen**	**Stellantis**			**Jaguar Land Rover**
			Opel	**Peugeot**	**Citroën**	
2019	124	124	124	106	110	173
2020	121	121	119	106	108	180
2021	108	98	111	99	105	162
2022	60	146	96	22	108	167
2023	55	133	88	40	93	146
2024	54	115	74	35	80	140
2025	50	107	69	32	74	127

Source: Statista (2025)

As shown in Table 4, Volkswagen and Jaguar Land Rover have failed to meet the target figure set by European Union legislation to reduce emissions to 95 g CO2/km by 2024, resulting in substantial fines from the European Union and a negative impact on the companies' financial indicators. From 2025 to 2029, emissions are expected to be reduced to 93.6 g CO2/km and even to 49.5 g CO2/km from 2030 to 2034. (European Commission, 2025) Volkswagen's plan to reach 93 g CO2/km is only for 2027, whereas Jaguar Land Rover's predicted figures for 2029 remain at 102 g CO2/km. (Statista, 2025) Consequently, from 2035 onwards, there will be a ban on the sale of new cars with internal combustion engines, which has compelled many companies in the automotive industry to modify their production methods and prioritize the production of electric vehicles.

In terms of fuel, in 2019, Kia produced almost 80% of gasoline-fueled cars, 5.62% of cars were electric, and the total number of cars with alternative or hybrid power was approximately 3%. In 2024, the share of electric cars was already almost 14%, and for 2029, the company plans to produce gasoline-fueled cars at 52.65% and

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electric cars at 39.44%. In 2019, Volkswagen primarily produced cars fueled by gasoline (60.42%) and diesel (36.7%), with electric cars accounting for just 1.77% of the total that year. In 2024, the share of cars fueled by gasoline (75.91%) and diesel (5.85%) decreased, while the share of electric cars increased to 15.2%. In 2029, the company plans to increase the share of electric cars to 33.01%. In 2019, Jaguar Land Rover primarily produced cars fueled by diesel (76.52%) and gasoline (18.92%), with electric cars accounting for 0.03%. In 2024, the share of diesel cars changed to 67.45%, and the share of electric cars increased to 10.79%. The prediction for 2029 is that the share of electric cars will reach 47.42% while the share of diesel-using cars will decrease to 36.85%. Stellantis in Trnava produces three car brands: Opel, Peugeot, and Citroën. In 2019, the Opel brand had 77% of cars burning gasoline, while electric cars accounted for just over 1%. By 2024, the share of electric cars had already increased to almost 35%, and gasoline cars made up just over 51%. The prediction for 2029 is that electric cars will account for 51.68% of production. The Peugeot brand primarily produced gasoline (60.28%) and diesel (38.9%) fueled cars in 2019; the share of electric hybrid and alternative fuel cars together was under 1%. In 2024, the share of electric cars was already higher (46.29%), while gasoline (32.87%) and diesel (18.68%) cars declined. In 2019, the share of electric cars is projected to increase to 58.02%. The Citroën brand primarily produced cars burning gasoline (62.81%) and diesel (33.66%) in 2019. In 2024, the share of electric cars is expected to increase to 19.33%, and by 2029, it is projected to reach 55.14%. This year, the share of diesel-burning cars is planned to decrease to 10.92%, and gasoline-burning cars are expected to account for 30.4%. (Statista, 2025)

The automotive industry and road transport have a significant impact on environmental degradation. As a result, companies operating in this market are adapting to evolving legislative standards and emerging trends. The comparison highlights that Stellantis and Kia are currently ahead of their competitors in terms of meeting sustainability goals and reducing environmental impact. Companies thus gain a significant competitive advantage and market position. It shows that all companies view the future in electromobility and alternative energy sources, actively working to increase the share of electric vehicles over combustion-engine cars.

4.2.3 Social pillar

The social pillar assesses key aspects, including working conditions, equal opportunities, and support for education and community development. Table 5 below outlines the main factors within the social pillar of sustainability and how each organization addresses them.

Table 5. Comparison of key indicators in the social pillar

The average wage of production employees	2408	2688	-	1936
Share of women	13%	-	-	35%
Education	✓	✓	✓	✓
Promoting diversity	✓	✓	✓	✓
Community support, foundation	✓	✓	✓	✓

Source: own

Kia and Volkswagen disclose information about their activities in the Slovak market through their annual reports. Given the ongoing labor shortage in Slovakia, these companies must support existing employees, enhance job satisfaction, and reduce turnover. Additionally, they aim to increase job attractiveness and support educational and talent development programs to create opportunities for potential employees. The relevant data were obtained from annual reports, company websites, and social media platforms supplemented by statistics and press releases.

Kia´s annual report provides detailed insights, including the number of employees, the proportion of women, and the average salary per position. The company actively supports employees, education, and community development. (Kia Slovakia a.s., 2023) Volkswagen, the largest employer among the companies compared,

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offers the highest salaries based on available data. While the proportion of women in its workforce was not explicitly stated, the company emphasizes its commitment to promoting women's employment in the automotive industry and fostering an inclusive and diverse work environment. (Volkswagen Slovakia a.s., 2023) Companies take a proactive approach to addressing social issues.

Stellantis employs nearly 4,000 people. However, information on average salaries and gender distribution was unavailable. (Stellantis Slovakia, 2025) Jaguar Land Rover employs 4,400 employees. Among the organizations compared, Jaguar Land Rover offers the lowest average salary but has the highest proportion of female employees. (TASR, 2024)

All companies are also involved in supporting Slovak educational institutions. Kia and Volkswagen have long-standing collaborations with these institutions, actively support academic initiatives, and promote sustainable mobility and green transportation by offering a bike-sharing service to the public. Furthermore, all organizations contribute to community development through various grant programs and foundations.

One of the key indicators in the social pillar is employee access and satisfaction. According to a recent employer survey, Volkswagen ranked second in the automotive sector. Employees cited benefits such as transportation reimbursement, holiday allowances, and childbirth allowances. Additionally, Volkswagen provides childcare support for children up to four years old in private facilities, access to children's camps, operational leasing options, free education, premium healthcare services, extended leave, and other employee benefits. The company is a signatory of the Diversity Charter, advocating for workplace inclusion and diversity. It actively combats discrimination and fosters a safe working environment as part of the Equality Initiative. Moreover, Volkswagen´s ExperKA project encourages young women to pursue careers in technical fields. (Najzamestnávateľ.sk, 2025)

Jaguar Land Rover ranked fourth in the same survey. Employees highlighted benefits such as holiday allowances, free training, premium healthcare, and rewards for life milestones. Other incentives include weekend access to iconic company vehicles and unlimited use of an in-house health and fitness center. The company has also established employee support programs, including grants, assistance for adverse life situations, and health promotion initiatives. (Najzamestnávateľ.sk, 2025)

Kia ranked sixteenth in the survey. Employees cited discounts on company products and services, premium healthcare, and free professional education as key benefits. The company provides a lump-sum employee bonus, a cafeteria system offering an annual allowance of €150 for purchases, and gifts for significant life events. Kia is also engaged in volunteer activities, supports local communities, and collaborates with the city of Žilina. Employees have access to health consultations at a rehabilitation center, as well as personal and legal advisory services. Stellantis was not ranked among the top 18 employers in Slovakia. (Najzamestnávateľ.sk, 2025)

5. Discussion

In recent years, sustainability has become a significant aspect of both everyday life and business practices, taking root across various fields. Its principles have been increasingly incorporated across diverse sectors, including sports organizations, educational institutions, manufacturing companies, and industry. Sustainability and the push for green transportation are gaining momentum across industries, particularly in the automotive sector. However, there is pressure on companies to implement sustainability. Still, they have not been provided with guidance on how to concretely integrate the different elements and what the effect on their business will be.

The study's results highlighted differences in the approach and implementation of sustainability within the automotive industry's organizations. While all the companies studied incorporate sustainability into their management strategies and comply with relevant legislative standards, only two dedicate a significant portion of their annual reports to sustainability. All companies also communicate their activities or objectives to their stakeholder groups on their websites. This finding aligns with the previous study and confirms the importance of sustainability reporting in the automotive industry with defined methods and frameworks for such reporting.

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(Kamińska-Witkowska & Kaźmierczak, 2024) It is recommended that organizations report their sustainable activities and goals on an annual basis. Such reporting should be transparent and clearly structured, including challenges associated with the sustainability implementation. This approach improves stakeholder relationships and can attract potential partners and investors. The necessity of sustainability reporting, along with its positive effects and the lack of standardized practices, aligns with previous study. (Varmus et al., 2023) Additionally, companies may improve their ESG rating and strengthen their brand position, through consistent and credible reporting. According to the ESG Rating, a higher risk can lead to a negative reputational impact or regulatory penalties, resulting in additional financial losses. Conversely, organizations with lower risk tend to invest in sustainable practices, which can reduce costs and improve their reputation.

Economically, the comparison between financial performance and stability revealed that the implementation of sustainability affects financial results. However, companies that adapt quickly to sustainability trends tend to achieve higher and more stable profits. This finding underscores the financial benefits of sustainability adaptation. Increased investment in development and innovation is what can accelerate and support adaptation. The research identified gaps in the reporting of financial indicators related to both, direct and indirect investments in sustainability, as well as in reporting the impacts of sustainability implementation on the financial stability of the businesses. Companies should aim to improve transparency in this area and inform stakeholders about their economic situation and investment capacity. Tóth et al. (2022) found that companies often avoid reporting penalties and negative impacts associated with sustainability implementation, a finding that is also confirmed by this study. Based on the results, it is possible to confirm the positive impact of sustainability implementation on financial performance. Therefore, it is recommended that companies increase their investment in innovation, research, and sustainability, as leveraging these trends has a demonstrable effect on return on investment. It is equally important not to avoid communicating negative financial impacts, as doing so helps to build trust with stakeholders, fosters a positive corporate image, and encourages continuous improvement. It aligns with the study of Vijaya et al. (2024) which highlights the need for investments in innovation and green technologies that comply with environmental regulations and thus allow to satisfy the demand for sustainable products.

In the environmental pillar, key issues include reducing emissions, waste chemicals, and greenhouse gases, as well as promoting the circular economy, and utilizing renewable resources. In the context of scandals automotive industry, particularly concerning CO2 emissions, has highlighted the importance of long-term relationships with sustainability partners and transparent communication. However, this aspect may also fall under the social pillar. The data indicates that all companies incorporate elements of environmental sustainability and strive to mitigate the negative environmental impact of their operations while also promoting green transportation practices. However, the two companies fail to meet the required standards set by legislation. It is also possible to demonstrate a correlation between the implementation of sustainability and financial indicators. It is recommended that companies continue advancing efforts to meet the targets set within the environmental pillar of sustainability. The finding supports the previous recommendation related to the economic pillar, particularly the need to increase investment in sustainability. By following this guidance, companies can achieve the mandated targets and standards, avoid potential penalties, and simultaneously contribute to green transportation, environmental improvement, and broader societal goals.

On the social pillar, secondary data from the “Najzamestnávateľ.sk” best employer survey showed that Volkswagen ranked highest. All companies studied aim to provide suitable working conditions, promote diversity and inclusion, support employee education, and foster the health of their employees. They also support and encourage young people to pursue careers in the technical field, and each of the organizations has established a foundation for supporting community development. However, employees generally rate company activities positively in areas such as diversity, inclusion, and employee support, with pay being a key factor in satisfaction. It is recommended that companies prioritize market research in sustainability and engage in active, transparent communication with stakeholders. This approach enables businesses to better understand market trends, stakeholder expectations, and emerging opportunities, thereby supporting strategic decision-making and long-term value creation.

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Previous research has noted that the environmental and social pillars are not the primary focus of attention for company managers and are often not included in reports and disclosures. Furthermore, as profits decline in profits, companies' willingness to engage in social and environmental issues may also diminish. (Doktoralina et al., 2018) In contrast, this research confirmed shortcomings in reporting sustainability elements in the automotive industry; however, companies that are currently failing to increase profits are actively addressing the social and ecological pillars of sustainability.

Conclusions

This study's aim is to identify gaps in the implementation of sustainability in the automotive industry and to provide recommendations for the effective integration of sustainability and the promotion of green transportation. This study reveals opportunities to optimize sustainability implementation, provides recommendations for companies that have not yet adopted sustainability practices, and offers guidance for effective implementation.

The research confirmed that individual automotive companies are integrating sustainability into their practices. It also highlighted gaps in communication and transparency of information, with companies failing to report on sustainability activities or concealing essential indicators. Therefore, the recommendation for companies is to focus on addressing these gaps. Sustainability should be embedded within the company's strategy, with specific, measurable objectives set. It is also essential to keep stakeholders informed through comprehensive annual reports.

Regarding the economic and environmental pillars, the recommendation is to leverage innovations and available technologies, and to invest in development and rapid adaptation to emerging trends, as these measures have a positive impact on the company's financial performance. It has been proven that companies that adapt more quickly to new trends and technologies achieve higher profits and financial stability than companies that are unable to adapt their production to new requirements. In the social pillar, it is crucial to focus on the needs and satisfaction of employees and the community. Employees particularly value initiatives addressing company-wide issues such as diversity, inclusion, and non-financial benefits. The study reveals that social pillar issues are important and a priority even for companies that do not achieve higher economic results.

The research confirmed the significant impact of sustainability on organizational performance in each pillar. However, it also identified gaps in the implementation of sustainability, based on which recommendations for improvement have been provided. By implementing these recommendations organizations can enhance their sustainable management practices and ensure long-term stability.

A limitation of the research was the lack of information obtained from available sources. Nevertheless, the research identified gaps and key areas where recommendations were made. These results provide a solid foundation for future research. Future research should focus on exploring the issue in greater depth, possibly by using qualitative data from interviews with managers.

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RECOVERY AND RESILIENCE PLAN

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SMALL COUNTRIES IN THE CONTEXT OF EU SOCIO-ECONOMIC SECURITY: A CASE OF SELECTED COUNTRIES*

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Abstract. Security is one of the most important and interesting issues in the modern world. The importance of security stems from the many changes that shape the expected, unwavering functioning of states. The definition of socio-economic security in the subjective and objective procedural dimension allows one to reflect the complexity and multi-aspect nature of economic, social and political processes and, through this, visualise changes, predict risks, and build action scenarios. Ensuring socio-economic security is becoming one of the main goals of countries' domestic and foreign policy, and initiatives in this area are taken with full awareness of the changes in the international arena. The lack of a unified toolkit for the assessment of socio-economic security complicates the processes of economic stabilisation and territorial development. The category of economic security is complex, multifaceted and has many features. Therefore, the use of a multi-factor approach to the assessment of economic security is justified. The evaluation of economic security is possible if formal approaches using specific indicators are used. The practical implementation of the analytical and regulatory components of ensuring economic security requires an economic assessment based on and compared to threshold values. It is necessary to continuously study the economic situation according to the selected system of indicators to control the level of economic security and develop expected threat preventive measures. The article aims to create a methodology for assessing socio-economic security and use it to determine the socio-economic security of Latvia in the context of EU countries.

Keywords: socio-economic security; methodology; Latvia; the EU

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JEL Classification Codes: C18, C43, F02, F52, F60

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1. Introduction

The concept of socio-economic security is multifaceted. Dankevych, Stoyanova-Koval, Polova, Los, Burdeina and Kazak (2024) draw attention to state of economic security and directions of restoration socio-economic development and food security in the conditions of war in Ukraine. Tvaronavičienė (2024) discusses security issues related to accessibility of countries to rear Earth elements. Many researchers try to define the concept of socio-economic security, paying more attention to one or another element of the analysis of socio-economic security (object, subject, their relationship). Classical researchers define socio-economic security in different ways, and here are some examples. Bellany (1981) defines socio-economic security as relative freedom from war, coupled with a relatively high expectation that defeat will not be a consequence of any war that should occur. Svirko, Dykyy, Dyka and Trostenyuk (2022) point to importance of budget security as a dynamic determinant of the socio-economic development of Ukraine.

These definitions highlight the object of socio-economic security – the state and political nature, and they emphasise traditional (military) threats to socio-economic security and the importance of force. Of course, it should be noted that critical studies of socio-economic security, constructivism, postmodernism, etc., emphasise the discursive perception of socio-economic security, talk about the importance of identity for socio-economic security, the expansion and deepening of socio-economic security, non-state actors, etc. A significant part of the attempts to expand the boundaries of socio-economic security research in the late twentieth century were based on neorealism and neoliberalism without violating the fundamental principles of positivism. While it was recognised that, in a changing international system, more attention needed to be paid to new, non-military threats and other actors in the global system (not just states), the assumption that there were real, objective sources of threats was maintained. In this sense, traditional studies of socio-economic security and conventional theories of international relations have retained the "objectivist" approach to socio-economic security inherent in neorealism.

Li and Xue (2021), Somych, Opaliuk, Potapiuk, Ovcharuk and Oliinyk (2022) agree that the field of international socio-economic security studies should be substantially broader compared to the field of military security studies. The processes of globalisation, which have created a new type of threat, have required broadening the definition of socio-economic security. Scientists and other stakeholders emphasize importance of the study of international socio-economic security issues related to environmental change and their potential threat to regional development (Chehabeddine et al., 2022). In Europe public concern about the growing number of immigrants and terrorism has increased (Kriviņš et al., 2021). Issues and social security (welfare) and physical security were raised in this regard. All this is summarised by the attitude towards socio-economic security, which we believe is pursuing freedom from threats. Within the context of the international system, this would mean the ability of states and societies to maintain their independent identity and functional integrity. These and other changes in the international system have given new arguments to researchers in international relations and socio-economic security studies who seek to eliminate the monopoly of the military aspect in their research. International Labour Organization (2019) have significantly expanded the concepts of socio-economic security and threat, clearly identifying political, social, economic and environmental threats along with military ones.

Both politicians and scientists emphasise that the nature of the socio-economic security of states and the specifics of threats are changing – we are talking about a decrease in the significance of traditional military threats and an understanding of new types of threats and their appearance in studies of socio-economic security (Sikimić, 2022). The changing international situation and the specifics of socio-economic security also require new methods that allow one to more accurately identify objects of socio-economic security, assess the nature of threats and predict their impact on the socio-economic security of the state. This often influences practical political measures taken to ensure national, regional or global socio-economic security, which has led to numerous theoretical attempts to rethink socio-economic security problems and to search for new models of socio-economic security problems, objects and analysis.

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The European Union's (EU) approach to social and economic security has increasingly adopted multidimensional frameworks that address the complexity and dynamism of contemporary challenges. Researchers have emphasised that economic and social security are intertwined phenomena, requiring integrated methodologies encompassing demographic, environmental, technological, globalisation, and social dimensions (Șerban & Jianu, 2023; Pakhucha et al., 2023). For example, Șerban and Jianu (2023) developed an Economic and Social Security Index. They found that the EU demonstrates comparatively higher performance than other geopolitical groups, validating the necessity of a multidimensional approach to security. This is consistent with broader evaluations highlighting the need for simultaneous monitoring of economic indicators and social quality of life parameters (Bulatova et al., 2021).

In addressing socio-economic security specifically, studies highlight the need for comprehensive strategic initiatives to mitigate risks and enhance resilience amidst technological shifts and evolving threat landscapes (Lyzun & Ozarko, 2023; Tokar, 2024). Lyzun and Ozarko (2023) assert that enhancing technological advantages and forming wide-ranging partnerships are vital in countering contemporary economic threats. Complementing this perspective, Tokar (2024) compares the performance of EU Member States with non-EU nations like Ukraine, recommending targeted policy interventions driven by quantitative assessments. These approaches underscore the importance of harmonised policy frameworks that promote economic competitiveness while securing the socio-economic fabric of member states against internal and external shocks (Cornes & Sandler, 1996; Lyzun & Ozarko, 2023; Tokar, 2024).

The analysis of differing socio-economic conditions among member states reveals significant heterogeneity, posing opportunities and challenges for EU policy. Bağlıtaş and Atik (2023) present statistical evidence indicating that older and newer EU members show distinct profiles in economic security, suggesting that national contexts can influence overall regional performance. Such studies illustrate that an in-depth understanding of regional nuances is indispensable for effective policy formulation and strategic planning (Bağlıtaş & Atik, 2023).

The EU's pursuit of comprehensive security extends into broader strategic partnerships, as Metelenko, Voronkova, Nikitenko and Silina (2025) noted. Their work discusses the formulation of the European Neighbourhood Policy, aimed at stabilising and securing the region through cooperative economic, political, and social initiatives. Bulatova, Osaulenko and Zakharova (2021) proposed that this external security dimension complements internal monitoring systems, categorising member states based on economic, socio-demographic, and environmental security variables. Together, these analyses demonstrate that the EU's security strategy is oriented toward responding to immediate vulnerabilities and establishing long-term resilience through systemic monitoring, intergovernmental cooperation, and proactive policy adjustments (Bulatova et al., 2021; Metelenko et al., 2025).

EU faces multifaceted challenges in ensuring socio-economic security among its member states, particularly concerning smaller countries. Among the most researched issues regarding small countries within the EU is the relationship between small member states and the Union's security and defence policy (Pedi, 2021). Șerban and Jianu (2023) developed an Economic and Social Security Index that integrates several dimensions, such as demographic trends, globalisation, and economic factors, illustrating that high relative performance in socio-economic security is not uniformly distributed across the EU. This evidence emphasises that small states, often coping with limited resources, may be disadvantaged when standard convergence mechanisms are applied uniformly without considering their specific contexts.

Regarding security, small member states face distinct challenges regarding defence and foreign policy integration. Ivančík (2022) analyses how small states perceive and engage in the EU's security and defence integration. Given their typically limited economic and military capacities, these states adopt strategies that often emphasise cooperation and collective security rather than unilateral power projection. Pedi (2020) discusses the unique position of small EU members in the broader context of European security and defence, demonstrating that their integration

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into a collective security framework can strengthen their military posture and contribute indirectly to socio-economic security by reducing overall regional insecurity. Understanding this interplay between defence and socio-economic policies is critical, as a secure environment is essential for sustainable economic development.

The effectiveness of small states in influencing EU decision-making processes is crucial for ensuring that their socio-economic interests are adequately represented. Panke (2015) examines the role of small states in EU decision-making, revealing that while these states may be outnumbered or lack economic clout, strategic alliances and negotiation tactics enable them to exert influence. Such dynamics are significant for socio-economic security, determining how resources, regulatory frameworks, and convergence policies are formulated and implemented across the Union.

The broader context of EU economic security also indicates that vulnerabilities extend beyond military threats or geopolitical instability, including economic disruptions. The integrated index developed by Șerban and Jianu (2023) further illustrate these sensitivities. Small states must navigate a dual challenge: reinforcing their security through active participation in EU defence initiatives while aligning with socio-economic policies that buffer against economic shocks.

The article aims to develop a methodology for assessing socio-economic security and to use it to determine the socio-economic security of Latvia in the context of EU countries. The authors intend to use statistical methods to construct an index of the socio-economic security of EU countries in the period from 2012 to 2022.

2. Methodology

The theoretical basis of this study is systems theory, where a system is most often understood as a set or arrangement of objects that are so relativised or connected that they form a unity or whole, which can also be attributed to the concept of "socio-economic security. The term "system" is also used as a name for two ontologically different categories: things and abstract creations; the basic properties of a system are:

− the behaviour of each element influences the behaviour of the whole, but no element has an exclusive influence on the whole;

− each subset of elements, selected according to some criterion, influences the system's functioning, but none of the subsets has an exclusive influence (therefore, the system is an indivisible whole).

Systems theory (cybernetics) and catastrophe theory can serve as a basis for understanding transdisciplinary phenomena such as socio-economic security: systems theory seeks to explain the functioning and dysfunctions of systems that generate crises and risks, the complexity of which is enhanced by the multiplicity of interactions that unite the various components of a catastrophe; within the framework of "catastrophe theory", there is a catastrophe when a continuous change in causes leads to discontinuous change in consequences, so catastrophes are prepared continuously over a long period before suddenly breaking out. This implies the formalisation of discontinuities in the evolution of systems, which should be analysed and modelled using economic and mathematical methods. The above theories may be applied to certain diffusion phenomena, including socio-economic security (Yunus, 2009; United Nations, 2015).

According to systems theory, socio-economic security is a set of methods (ways) of functioning and performing complex activities, as well as all organisational principles, all norms and rules in force in this field, and an extensive and ordered set of system elements connected by certain logical relationships. The systems analysis procedure imposes certain laws and rigour of behaviour, which include the definition of:

− the accuracy of determining the boundaries and the internal part of the system;

− the constancy of the distinction made between the system and its environment during the study;

− the completeness of system division (into subsystems);

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− the abstractness of the systems (and their subsystems) under consideration;
− the functionality, that is, the division of the system into subsystems according to the type of functions they perform as a whole.

Using the systems approach will allow us to identify the elements of the socio-economic security system at any level, as well as their properties and situations that determine the emergence of threats. It may be stated that a necessary condition for the emergence of threats is the presence of at least two elements:
− the source of the threat;
− the dangerous object.

In other words, according to our proposed approach, a socio-economic threat is a situation in which the potential of threats exceeds or is equal to the potential of socio-economic security. Another condition for the emergence of threats is the existence of connections between these elements, which, interacting with each other, activate the socio-economic security system. This approach allows one to obtain additional elements for describing socio-economic threats, such as:
− the direction and focus of the threat, which allows one to analyse the sum and product of threats, that is, the form of impact of many threat sources on one object;
− the trajectory of threat states allows one to distinguish between threat phases, such as growth, fading or periodic threat.

These are necessary and sufficient conditions for identifying threats to socio-economic security. The systems method allows one to determine how the system of socio-economic security and its individual elements function, what and who makes decisions on this matter and also allows one to:
− identify subsystems of socio-economic security;
− coordinate the control elements of the system of socio-economic security;
− determine the nature of the impact of the areas of socio-economic security on the control elements;
− legal regulations governing the functioning of the system;
− determine the criteria and indicators of the system of socio-economic security;
− the impact of the system on threats from the environment.

With an objective approach, the systems analysis of socio-economic security covers threats that may be national, regional, local or individual; in addition, depending on the goal adopted, the study may cover different types of subjects/entities (state, region, enterprise).

The main task of research within the framework of Catastrophe Theory is to determine the fundamental regularities of the transition of socio-economic structures from the state of normal functioning to an emergency or catastrophic state, as well as the principles of their functioning and cooperation in the process of the changes mentioned above. In addition, catastrophe theory deals with constructing scientific foundations for diagnosing, monitoring, and forecasting threats and methods for preventing threats and disasters and eliminating their consequences. On this basis, quantitative and qualitative parameters of the decisions taken are determined.

We have systematised the main provisions and principles of theoretical concepts of socio-economic security research; the results of this analysis are presented in Figure 1.

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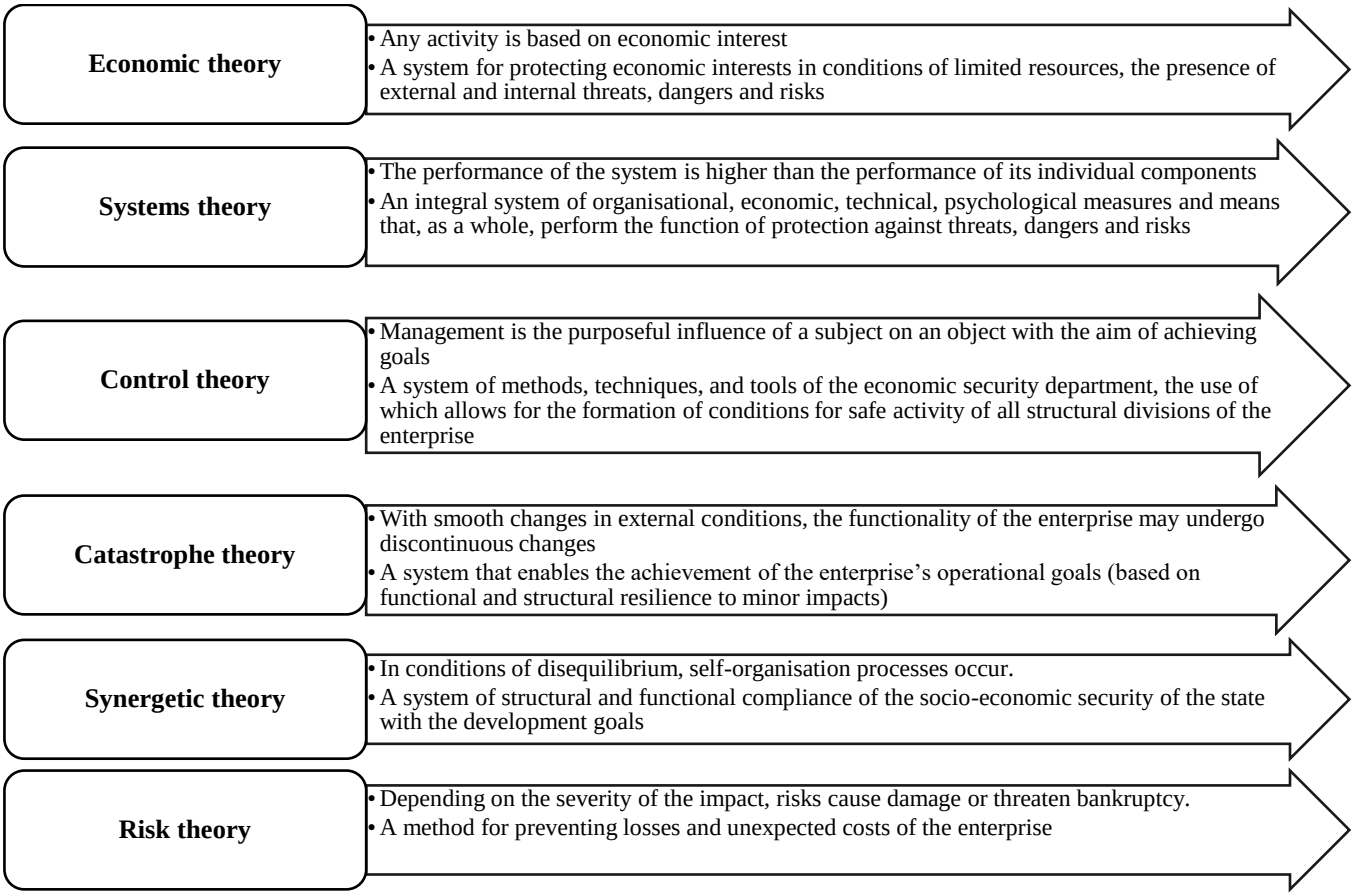


Figure 1. Basic theoretical concepts of socio-economic security research
Source: systematised by the authors based on the European Commission (2023) data

Among the alternative approaches to the strictly economic vision, we can mention the "historical approach", which aims to shift the interpretation of phenomena related to the provision of socio-economic security from disciplinary particularism to a more general point of view, where the effectiveness of a national system is analysed in relation to its future on the physical, economic, social and political territory. Therefore, through the history tool, this approach approaches the subject without missing its geographical aspect, which finds its functional dimension in the "state". At least two points of emphasis help understand the features of this approach compared to those already described. They concern, on the one hand, the role of the state in the methodology of analysis and, on the other hand, the need to integrate socio-economic security into the system of relations and the social, institutional and political spheres surrounding it (Zubko, 2024). In fact, in security studies, the country dimension is considered as one of the places where the problem manifests itself with special characteristics (due to its extent, changes, social weight, etc.). On the other hand, in the historical approach, the state is rather a strategic choice for research purposes, a place and level at which to observe the problems of a crisis, where all factors (economic, social, institutional, political) play their role.

By critically questioning socio-economic security's original motives and goals, the historical approach provides essential information on the context within which this economic category plays a vital role in everyday life. This is important for any intervention policy that views the security issue not as an isolated issue but as part of the system of relations. The comparison between individual cases or, at different times, might be the best method for testing the effectiveness of conventional interpretive schemes of the economic type (which are often deductive). However, the shortcomings of this approach cannot be ignored: the absence (lack) of historical data or even research on the

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economic history of socio-economic security is certainly no more significant than the absence of a reference model for the analysis of systemic linkages, with the latter representing strengths at the conceptual level and weaknesses at the operational level. This characteristic, which does not allow standardisation of the method, risks making the analysis results inaccurate or subjective.

Of particular significance is the identification of types of threats to socio-economic security depending on the area of their occurrence. This is because such an understanding of risks and threats is fundamental and is based on the development of anti-crisis management methods for the state's socio-economic security. At the same time, in addition to socio-economic security, there are social, political, environmental and other threats related to general national security. The practical experience of managing complex economic systems shows that many threats to socio-economic security are generated in areas not directly related to entrepreneurial activity. Moreover, this influence on economic processes may be significant and form long-term negative trends in the country's economic development. Therefore, it is necessary to isolate this type of threat in the system of socio-economic security but to only consider them from the point of view of generating threats to the economic system, and the primary regulatory interaction with such threats should be left in the field of general national security.

Therefore, it may be stated that, as regards the sphere of economic threats to the socio-economic security of the state, they may manifest themselves in structural deformations of industry and production sectors, delays in the development of the country's infrastructure in relation to modern requirements and the general deterioration of its condition; a reduction in the country's overall raw material potential under the condition of an increase in the resource intensity of the industry; destructive trends in the monetary and financial provision of the country, as well as an increase in inflationary trends in the national economy.

Threats generated in the social sphere may manifest themselves as a drop in the incomes of the country's population, a decrease in the level of social guarantees for the population from the state, a general deterioration of the demographic situation, a general increase in the level of intense social tension; an increase in the share of the low-income population in the overall population structure. Information threats may manifest themselves as the development of unstable state policy in the information sphere, associated with an insufficient level of information protection; structural disproportions in the information provision of the country as a whole; the failure to comply with the guarantees of information security of market entities and citizens of the country; a critical increase in the level of dependence of information technologies on foreign rights holders and manufacturers, etc.

Threats to socio-economic security that may arise in the legal sphere manifest as the general imperfection of the country's legislative and regulatory system and its compliance with global democratic standards. In addition, the risks of this plan include the imperfection of the legal mechanism that ensures compliance with the requirements of the law for all subjects of economic relations. Environmental threats may manifest themselves as the widespread use of dirty technologies in production activities, the low level of environmental standards of production, an increase in the number of accidents and disasters caused by human activity in areas of the industrial output that pose an increased risk to the environment; and a general increase in harmful and polluting emissions from industrial enterprises.

Threats related to the military sphere are manifested as the possibility of military aggression from Russia and other authoritarian states characterised by similar moral and cultural degradation of their populations, insufficient funding of the country's armed forces, and a discrepancy between the level of material and technical support of the national armed forces and modern requirements. Therefore, to ensure the effective functioning of the country's national economy, it is necessary to solve several problems that arise in the field of socio-economic security and negatively affect the economic system.

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There is no doubt that there are many approaches to assessing socio-economic security. However, the common feature of their complexity, and therefore effectiveness, is the general degree of coverage of factors influencing the state of socio-economic security and its changes, as well as of indicators proving the emergence of risks and threats to specific areas of economic activity or the national economy of the country as a whole.

To obtain a unified list of indicators of socio-economic security that would give the most effective results in the process of the assessment of its state, it is possible to determine the main criteria, based on which a system of indicators is created that form the basis of the methodology for the assessment of the socio-economic security of the state (Figure 2).

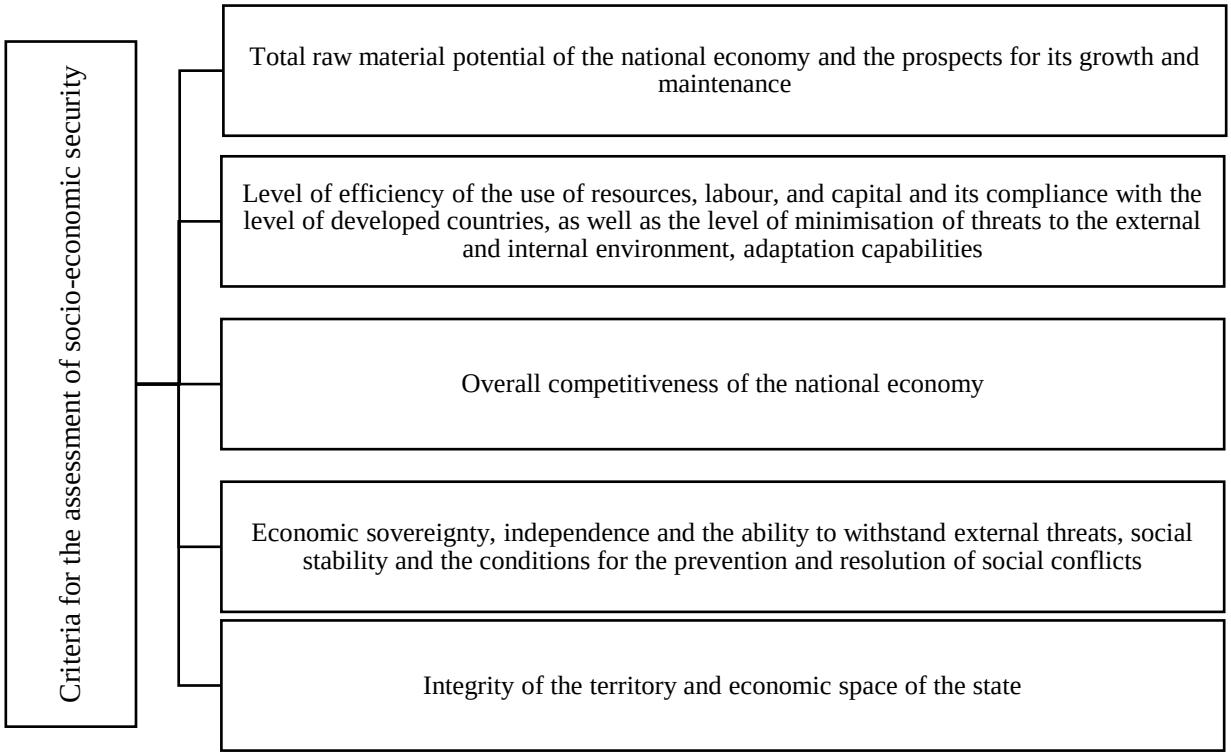


Figure 2. Criteria for the assessment of the state of the socio-economic security of the state
Source: systematised by the authors based on Podgorna et al., 2020; Mavlutova et al., 2021

We believe that the creation of a methodology for the assessment of the state of the socio-economic security of the state should be based on taking into account as many security indicators as possible for a specific period of time and should not lead to the determination of the current state of security in the economic system, but should also focus on making a forecast of future development.

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Taking a significant number of indicators into account may lead to the assessment model becoming too cumbersome for its practical application in implementing state regulatory policy in the security field. The way out of this situation is by using assessment models based on the determination of an integral security indicator that considers a significant number of factors influencing the state of socio-economic security, the influence of which is calculated using a unified methodology (Reshetnyak, 2020). At the same time, the number of factors included in such models may change dynamically depending on the needs in connection with the calculations and the current situation in the national economy. If necessary, specific security indicators may be added to the model, or those whose influence is currently too small to change the value of the integral indicator of the state's socio-economic security may be excluded.

Individual indicators of socio-economic security may have different values. Moreover, since the comprehensive model should be able to take the development of changes in security indicators into account, an objective need arises to formulate their integral index function, which will reflect the mathematical value.

To summarise, multi-aspect indices comprehensively and relatively accurately assess the degree of socio-economic security of a country. A common objection to development indices is that they focus too much on the qualitative elements of socio-economic security, leaving its quantitative measurement in the background. Meanwhile, international statistics on social issues are becoming increasingly detailed. Socio-economic security is no longer determined only by gross domestic product, average annual production, the number of flats built, and the illiteracy rate but also by average daily living expenses per capita or population size.

To construct an appropriate set of variables, the analysis presented here used variables proposed for such studies by international organisations. In this paper, it was assumed that the level of socio-economic security should be identified with a set of "capabilities", the conditions in which an individual functions, the resources available, the environment that determines their condition, and the potentials that may be realised.

They allow economic, social and psychological needs to be met. At the same time, "capabilities" express society's preferences as a consequence of its previous choice. Consequently, the determinants of the level of socio-economic security are the individual elements of states of capabilities that allow individuals to satisfy their needs, which are also an expression of the preferences of these needs and their ordering from the point of view of a team. For this paper and the studies conducted, the following groups of determinants, expressed as states of capabilities, were additionally designated (Figure 3).

Therefore, this method allows for the necessary calculations to be performed relatively quickly and, in general, provides an objective response to changes in the socio-economic security of the state in the past. It allows one to identify the devastating consequences and the impact of risks and threats at the moment. As we can see, a vital element of any system for the assessment of socio-economic security of the state is the criteria for such an assessment, based on which the deviation from standard or calculated values, as well as the presence or absence of threats to the economic system, are determined. The peculiarity of such criteria is their functional ability to reflect the main aspects of the stability of the economic system under which it will function most effectively.

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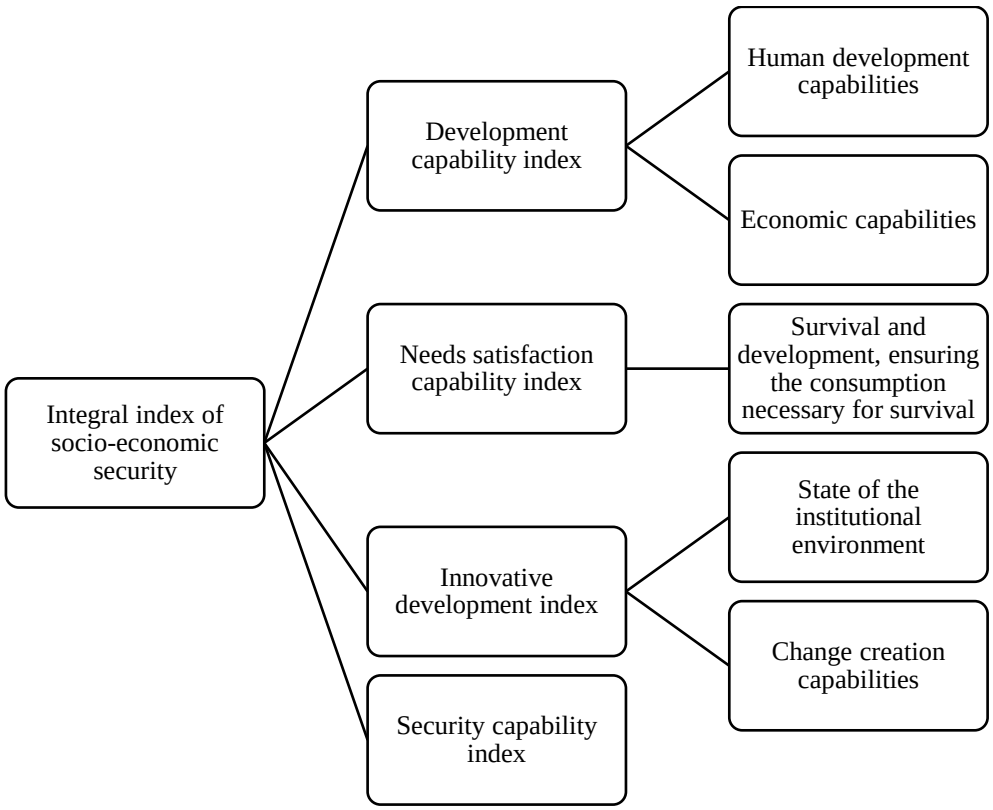


Figure 3. Scheme of the integral indicator of the level of socio-economic security
Source: developed by the authors

1) Needs satisfaction capability index (survival and development, ensuring the consumption necessary for survival);

2) security capability index;

3) development capability index: a) human development capabilities; b) economic capabilities;

4) innovative development index: within the framework of the concept of sustainable development: a) change creation capabilities; b) state of the institutional environment as the possibility of the existence of the current and future generations;

5) integral index of socio-economic security.

The calculation of each index is based on the statistical indicators of the Statistical Office of the European Union. Table 1 presents a complete description of the content of the integral indicator of the level of socio-economic security, and Annex 1 presents a complete list of used indicators and links to statistics with regard to their changes on the website of Eurostat.

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Table 1. Description of the structure of the integral indicator of the level of socio-economic security

Subindex	Indicators
Needs satisfaction capability index (survival and development, ensuring the consumption necessary for survival)	HICP – annual data (average price index and rate of change)
	Own home price index
	Purchasing power parities (PPPs), price level indices and real expenditures for ESA 2010 aggregates
	Euro yield curves – annual data
	Industrial countries' effective exchange rates
	Self-rated health depending on gender, age and degree of urbanisation
	Self-reported unmet need for medical examination by sex, age, stated underlying cause, and degree of urbanisation
	Persons at risk of poverty or social exclusion
	Average and median income
Security Capability Index	Convergence indicators
	Export and import
	Pollution, dirt or other environmental problems
	Employment rates by sex, age, educational attainment level and citizenship
	Unemployment
	Net social security benefits
	Industrial production
Development Capability Index	Government revenue, expenditure and main aggregates
	Government expenditure by function (COFOG)
	Main national accounts tax aggregates
	Annual financial reports for the general government sector
	Government deficit/surplus, debt
	GDP and its main components (output, expenditure and income)
Innovative Development Index	Population by educational attainment level, sex, age and degree of urbanisation (%)
	data on employment in knowledge-intensive activities at the national level
	HRST by category, sex and age
	Graduates by educational attainment level, programme focus
	Training enterprises
	Internet purchases by individuals (until 2019) Financial activities over the Internet (2020 onwards)
	Patent applications to the EPO by country of applicants and inventors
	Applications for European Union trade marks (EUTM)
	Persons with tertiary education (ISCED) and/or employed in science and technology
	Graduates by educational attainment level, programme focus, sex and field of education
	Total high-tech trade in million Euros and as a percentage of total
	GERD by sector of performance
	Share of R&D personnel and researchers in total active population
	Share of GBARD in total general government expenditure

Source: developed by the authors based on Eurostat (2024)

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Since the index structure includes heterogeneous indicators with different units of measurement, we chose the method of bringing them to a common form and shape; for this purpose, the specific weight of each indicator in the total sum of indicators was calculated. Thus, the author's proposed methodology for the calculation of the integral indicator of the level of socio-economic security consists of the following stages:

1. Determination of the main aspects of socio-economic security that are of the highest priority for the current stage of development. Within the context of disclosing the purpose of this study, these are four aspects: the capability of the state to meet the needs of the population (survival and development, ensuring the consumption necessary for survival); the capability of the state to security; the capability of the state to development; the capability of the state to innovative development.

2. Selection of statistical indicators characterising the aspects of the level of socio-economic security determined in the first step, the data on which are available on the official websites of statistical agencies and international organisations.

3. Systematisation of indicators into sub-indices of socio-economic security within the context of the identified aspects of the level of socio-economic security.

4. Conversion into relative indicators (calculation of the total sum of all indicators and the specific weight of each) by calculating the specific weight of each indicator for each country in the total sum within each indicator using the formula:

$$\boldsymbol{I_j = \frac{Xij}{\sum_{i=1}^{n} Xij}} \qquad (1)$$

where Xij is the value of indicator *j* for the i-th country;
$\frac{Xij}{\sum_{i=1}^{n} Xij}$ is the sum of the values of indicator *j* for all countries;
N is the number of countries.

5. Calculation of sub-indices $\boldsymbol{I_i}$ based on the indicators obtained for each country using the formula:

$$\boldsymbol{I_i = \frac{\sum_{j=m}^{M} Xij}{M}} \qquad (2)$$

where $\sum_{j=m}^{M} Xij$ is the sum of the indicators within one sub-index for the i-th country;
M is the number of indicators in the sub-index.

6. Calculation of the integral indicator of the level of socio-economic security for each country $IIseb_i$ using the formula:

$$\boldsymbol{IIseb_i = \frac{\sum(INS_i + ISC_i + IDO_i + IID_i}{4}} \qquad (3)$$

INS_i is the needs satisfaction capability sub-index;
ISC_i is the security capability sub-index;
IDO_i is the development capability sub-index;
IID_i is the innovative development sub-index.

The proposed methodology is a synthesis of several well-known and widespread methods of analysis: ABC analysis, multi-criteria analysis, AHP methodology developed by Thomas Saaty (Saaty, 1990; Sehra et al., 2012). This

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methodology is based on the decomposition of a given decision-making problem into a hierarchical structure that consists of a main goal at the top of the hierarchy, followed by n criteria and/or sub-criteria (Saaty, 1990).

3. Research results

After obtaining the values of each sub-indices, the integral indicator of the level of socio-economic security was calculated, which is the average value of all sub-indices. Figure 4 shows the changes in Latvia's needs satisfaction capability sub-index compared to the EU average and Latvia's ranking among the 27 analysed countries of the European Union.

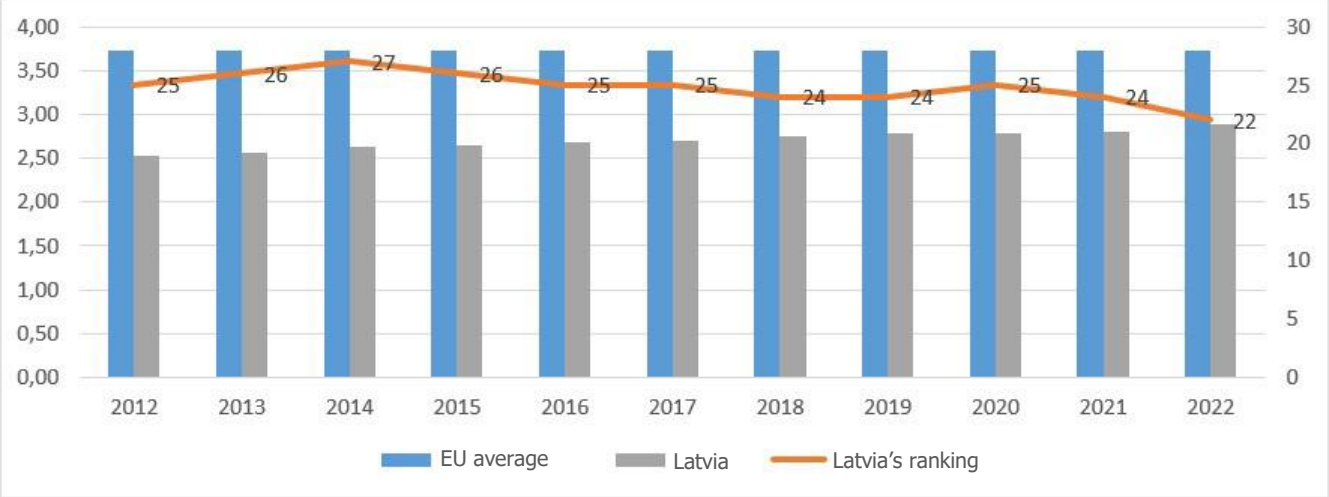
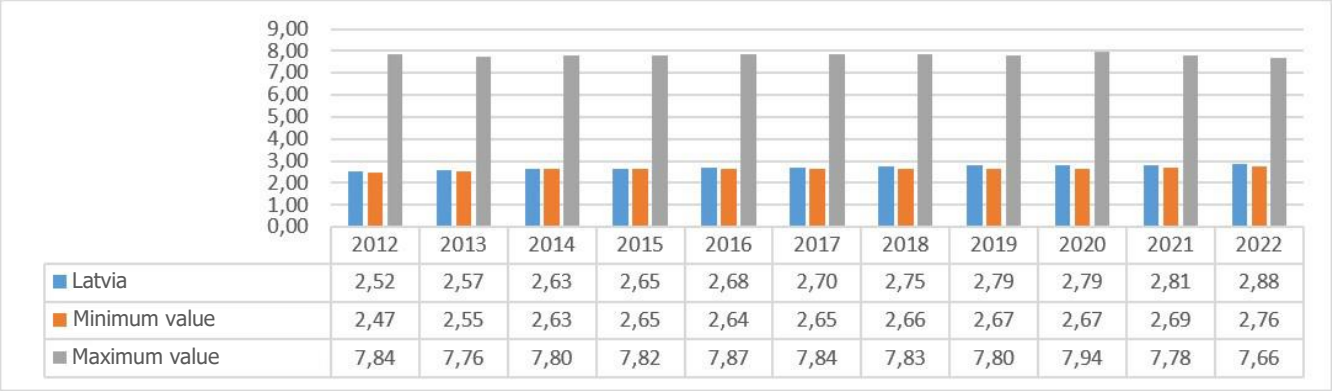


Figure 4. Changes in Latvia's needs satisfaction capability sub-index compared to the EU average, as well as to Latvia's ranking among the 27 analysed countries of the European Union

Note: The value of the needs satisfaction capability sub-index is highlighted in grey (Latvia); the EU average is in blue, and Latvia's ranking is in orange.

As we can see, Latvia's ranking has slightly improved (by 3 positions) during the analysed period from 2012 to 2022, reaching 22nd place. At the same time, the comparison with the average value for all the EU countries shows a fairly large lag, almost 20–32% in different periods. If we analyse each of the indicators included in this sub-index, it is worth noting that Latvia ranks best in the following indicators: HICP – annual data (average price index and rate of change); purchasing power parities (PPPs), price level indices and real expenditures for ESA 2010 aggregates; self-reported need for medical examination by sex, age, stated underlying cause, and degree of urbanisation. The country ranks worst in indicators such as the proportion of people at risk of poverty or social exclusion and average and median income. Let's compare the maximum and minimum values of the sub-index. We can note that the level of Latvia's needs satisfaction capability sub-index is only 37.6% of the maximum value, demonstrating a significant gap between the analysed country and a high level of socio-economic security (Figure 5).

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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Latvia	2,52	2,57	2,63	2,65	2,68	2,70	2,75	2,79	2,79	2,81	2,88
Minimum value	2,47	2,55	2,63	2,65	2,64	2,65	2,66	2,67	2,67	2,69	2,76
Maximum value	7,84	7,76	7,80	7,82	7,87	7,84	7,83	7,80	7,94	7,78	7,66

Figure 5. Changes in Latvia's needs satisfaction capability sub-index compared to the maximum and minimum values in the EU

Latvia has improved its position regarding the needs satisfaction capability sub-index during the analysed period because, since 2014, the minimum value was obtained first by Bulgaria and then, for an extended period, from 2017 to 2022, by Croatia. As for the maximum value, this position was held by Germany throughout the entire period.

Figure 6 shows the changes in Latvia's security capability sub-index compared to the EU average and Latvia's ranking among the 27 analysed countries of the European Union.

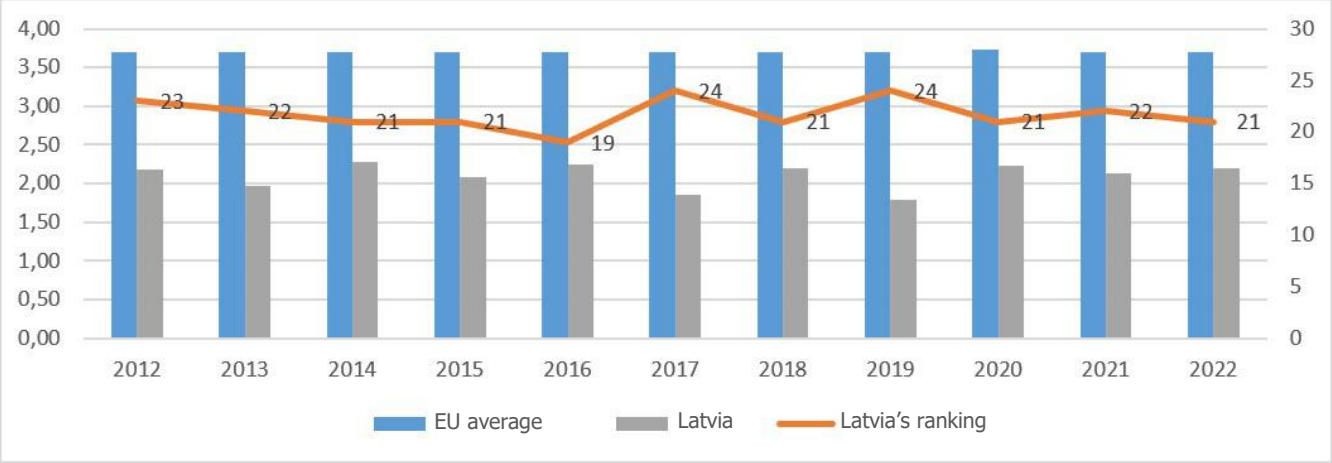


Figure 6. Changes in Latvia's security capability sub-index compared to the EU average, as well as to Latvia's ranking among the 27 analysed countries of the European Union

The data of Figure 6 show us that, during the period from 2012 to 2022, Latvia's ranking in the analysed sub-index improved by 2 positions, and Latvia is in 21st place (in 2012: 23rd). A comparison with the average value of the security capability sub-index across EU countries shows trends similar to the needs satisfaction capability sub-index: we see a significant lag of 40–45% in the sub-index level in different periods. If we analyse each of the indicators included in this sub-index, it is worth noting that Latvia ranks best in the following indicators: Convergence indicator; Pollution, dirt and other environmental problems; Employment rates by sex, age, educational attainment level, citizenship; Unemployment.

The country ranks worst in net social security benefits and industrial production indicators. Let's compare the maximum and minimum values of the sub-index. We can note that the level of Latvia's needs satisfaction capability sub-index is only 14.9% of the maximum value, demonstrating a significant gap between the analysed country and a high level of socio-economic security (Figure 7).

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Figure 7. Changes in Latvia's security capability sub-index compared to the maximum and minimum values for the EU

A lower level of development capability characterises Latvia's security capability sub-index. Due to the international economic situation and the expanding international economic ties, socio-economic security should be considered within the market context. Moreover, only in market relations can the general well-being of individual interest groups be expected. Nevertheless, some security threats are not particularly market-related. Firstly, market relations increase the number of shortcomings that threats may eliminate. Secondly, by their very nature, market relations are associated with a certain insecurity because they are open. No one can be sure of their future in the market, which entirely depends on consumer choice. While this is a paradox: the market contributes to wealth creation and socio-economic security in a social sense, it is an environment not inextricably linked to instability. Therefore, socio-economic security is an important goal but must be addressed in view of other goals. From an economic point of view, it should be borne in mind that any security measure has its price, and it is entirely unacceptable to say that any price can be paid for security (such a policy in itself would be an indicator of economic insecurity). Moreover, as has already been said above, talking about safety in general only makes sense when there is a guarantee of responsible storage. Thus, socio-economic security cannot be sacrificed directly for the sake of security. At the same time, according to researchers, Riga is the only city among the Baltic capitals where the death rate exceeds the birth rate and where more people leave than arrive. The reason for this may be a relatively large number of Riga residents who are unsatisfied with either life in the city or the progress in quality of life over time. The reasons cited for this are poor quality of housing, the improvement of which is hampered by complex building formalities, safety, environmental pollution, and the quality of management (Krasnopjorovs, 2022).

Government measures or private initiatives may check socio-economic security. A particularly significant factor is the activity of private individuals, which is usually neglected when considering measures to check socio-economic security. Although the market, as already mentioned above, is always associated with uncertainty about the future and, therefore, with a certain degree of insecurity, at the same time, it demonstrates a dynamic process in which the most diverse needs of individuals, as well as the need for security, are satisfied. It is related to insurance services, the futures market, savings and other financial instruments. However, indirect impacts are even more necessary as the market creates opportunities for the emergence of products that reduce insecurity: alternative energy sources, better conditions for communication and trade in transport, as well as any other new product increase not only economic well-being but also opportunities, along with socio-economic security. Ultimately, it is about motivating people to engage in activities that help address socio-economic security issues when they become most pressing. In Latvia, this has become especially acute in the conditions of the energy blockade. Therefore, regarding socio-economic security, Latvia's security capability is critical, so state policy must allow it to expand.

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Figure 8 shows the changes in Latvia's development capability sub-index compared to the EU average and Latvia's ranking among the 27 analysed countries of the European Union.

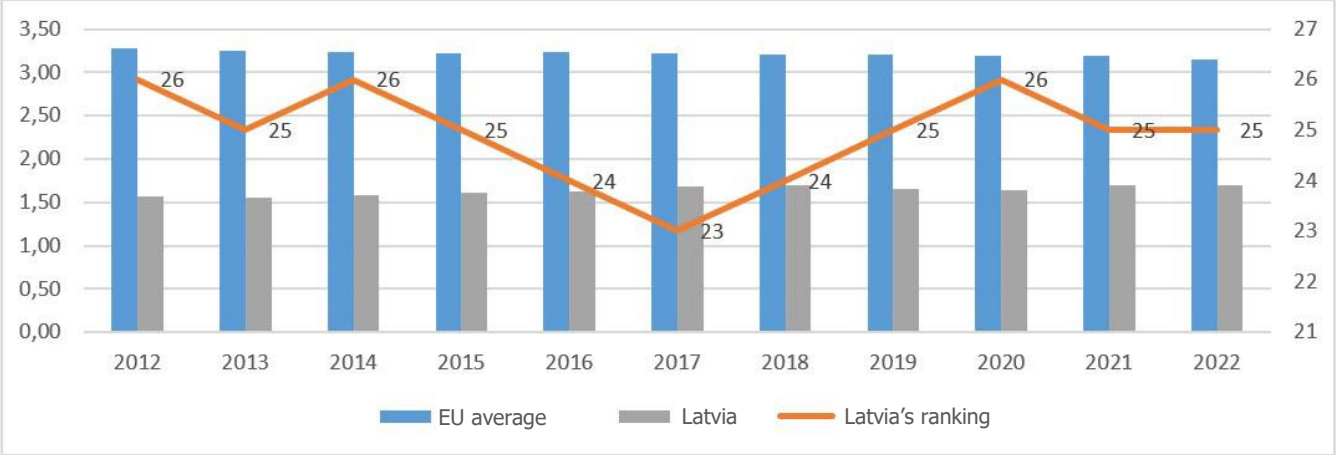


Figure 8. Changes in Latvia's development capability sub-index compared to the EU average, as well as to Latvia's ranking among the 27 analysed countries of the European Union

As we can see, Latvia's ranking, as in the sub-index descriptions above, has slightly improved (by 1 position), reaching 25th place. It can be seen that in 2017, the ranking was even lower, but in 2018 already, this sub-index began to deteriorate again. This is due to the fact that after 2017, assistance to states from EU funds slightly decreased.

The comparison with the average value for all the EU countries shows a large lag, almost 20–32%, in different periods. If we analyse each of the indicators included in this sub-index, it is worth noting that Latvia ranks best in the following indicators: Government revenue, expenditure and main aggregates; Government expenditure by function (COFOG); Annual financial reports for the general government sector. The country ranks worst in indicators such as Main national accounts tax aggregates, Government deficit/surplus, debt, GDP and its main components (output, expenditure and income). Let's compare the maximum and minimum values of the sub-index. We can note that the level of Latvia's needs satisfaction capability sub-index is only 15–18% of the maximum value, demonstrating a significant gap between the analysed country and a high level of socio-economic security (Figure 9).



Figure 9. Changes in Latvia's development capability sub-index compared to the maximum and minimum values in the EU

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It should be noted that Latvia is primarily lagging in two aspects: the amount of financial investments and the fact that the programmes are implemented with interruptions and in a campaign-like manner. At the same time, they are subordinated to the planning periods of the EU funds and are of an intermittent nature (Kubliņš, 2023).

Figure 10 shows the changes in Latvia's innovative development sub-index compared to the EU average and Latvia's ranking among the 27 analysed countries of the European Union.

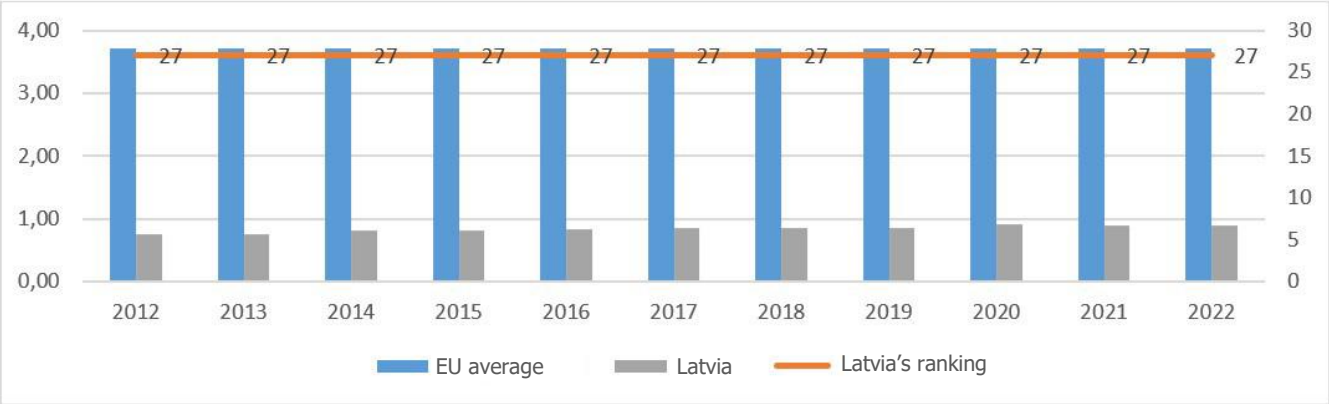


Figure 10. Changes in Latvia's innovative development sub-index compared to the EU average, as well as to Latvia's ranking among the 27 analysed countries of the European Union

Figure 10 shows a very low level of innovative development, which is reflected in the fact that the country ranks last in this sub-index for the period analysed (27). Let's examine each of the indicators included in this sub-index. It is worth noting that Latvia ranks best in the following indicators: Population by educational attainment level, sex, age and degree of urbanisation (%); Internet purchases by individuals; Graduates by educational attainment level, programme focus, sex and field of education.

Figure 11 presents data comparing Latvia and EU averages with regard to the socio-economic security index.

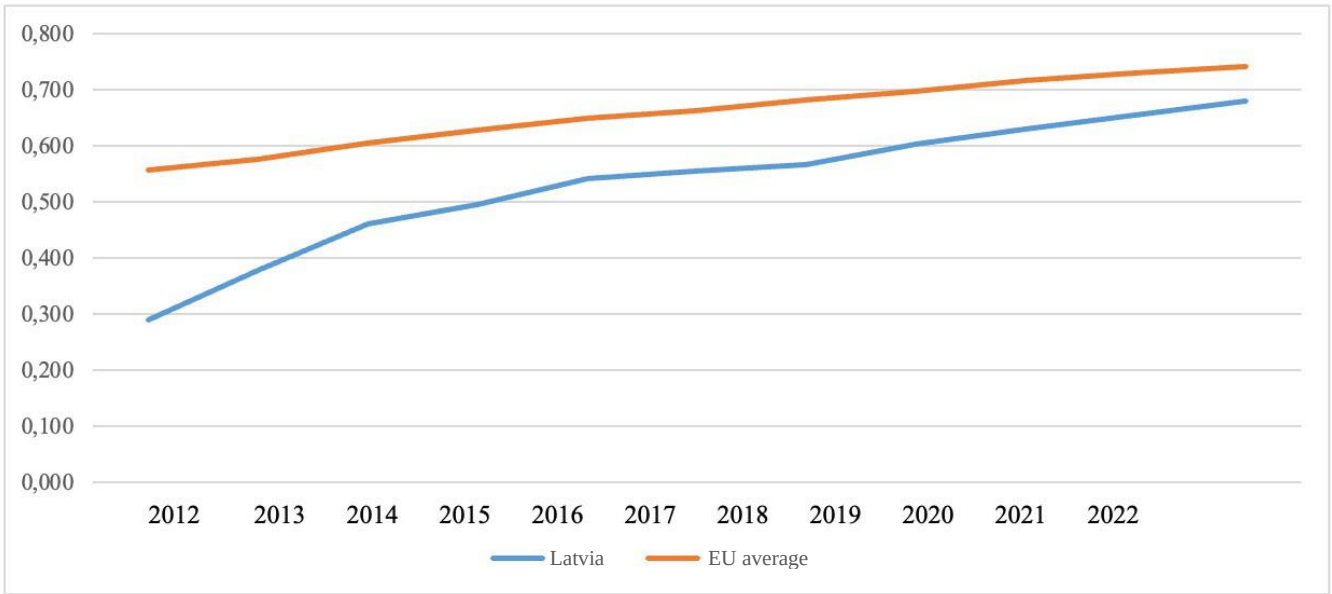


Figure 11. Comparison of Latvia and the EU average based on the Integral Index of Socio-Economic Security

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Let's compare the maximum and minimum values of the sub-index. We can note that the level of Latvia's needs satisfaction capability sub-index is less than 10–15% of the maximum value, which demonstrates a very severe gap between the analysed country and a high level of socio-economic security. This is because Latvia develops fewer new products and prototypes necessary to increase added value and allow us to compete more fully. The fact that funding is provided on a company-by-company basis and is irregular means that, compared to their competitors, Latvian companies cannot plan more than a year, consequently resulting in the impossibility of high innovation activity (Kubliņš, 2023).

Conclusions

The methodology for the assessment of socio-economic security developed by the authors contains four aspects: the capability of the state to meet the needs of the population (survival and development, ensuring the consumption necessary for survival); the capability of the state for security; the ability of the state for development; the capability of the state for innovative development. Each aspect was populated with available statistical indicators and converted into relative values (calculation of the total sum of all indicators and the specific weight of each) by calculating the specific weight of each indicator for each country in the total sum within each indicator.

An important factor in favour of choosing this methodology is that the methods associated with it provide the possibility of using tools that allow the assessment of individual aspects of socio-economic security with different units of measurement. In addition, this method makes the decision-making process more flexible and open to discussion. Also, it increases the potential for responding to changing parameters or criteria (in the case of their replacement). Another advantage of such methods is the possibility of their application to tasks of varying degrees of complexity and at any level of organisation, from the level of departments to the strategic level of the industry and the country.

Just as the assessment of selected areas of socio-economic security may be objective, based on statistical data, it may also be subjective, based on the results of sociological surveys. The proposed system of indicators will provide a comprehensive assessment of key aspects of socio-economic security; such systematisation allows one to assess the level of socio-economic security in the areas most important for its formation. In addition, obtaining statistical data in other aspects is difficult due to their absence or lack of public access; however, this method allows for expanding the analysis in the case of the availability of statistical data.

The presented results of the calculation of the socio-economic security sub-indices allow us to say that, when comparing Latvia with the average European level, the level of this country is significantly lower in terms of all the socio-economic security sub-indices. The worst situation is observed in the field of innovative development; in addition, the country is affected by crisis trends. Thus, harsh financing conditions will continue to put pressure on private investment, while companies will face significant production costs due to energy prices and the gradual substitution of imports of Russian goods. The energy crisis and tighter monetary policy put pressure on regional activity, so Latvia's main economic partners (Lithuania, Estonia, Germany) will experience sluggish growth, preventing strong export recovery. Ultimately, it is public investment that will make the greatest contribution to economic growth through increased social and security spending, as well as investment in energy and transport infrastructure (Coface for Trade, 2024).

An analysis of Latvia and the EU average with regard to the needs satisfaction capability index shows that Latvia lags behind the European average, with a slight increase in the value in 2016. Still, in 2017, this increase was eliminated, and the value decreased. Somewhat different trends may be observed as regards the changes in the comparison of Latvia and the EU in terms of the Security Capability Index: an annual increase in these indicators may be noted, but the level of Latvia's sub-index is lower than the European average, although the gap is narrowing.

It should be noted that the comparison of Latvia's values and the EU average in terms of the Development Capability Index is similar to the situation with the Security Capability Index. At the same time, a comparison using the Innovative Development Index shows that Latvia's value exceeded the EU average in 2021. Similar trends may be observed as regards the Integral Index of Socio-Economic Security.

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Annex 1. Complete list of indicators used and links to statistics regarding their changes on the Eurostat website

No.	Indicator name	Reference
1	**Needs satisfaction capability index (survival and development, ensuring the consumption necessary for survival)**	
1.1	HICP – annual data (average price index and rate of change)	https://ec.europa.eu/eurostat/databrowser/view/trng_cvt_01s$defaultview/default/table
1.2	Own home price index	https://ec.europa.eu/eurostat/databrowser/view/PRC_HPI_OOA/default/table
1.3	Labour cost index	https://ec.europa.eu/eurostat/databrowser/view/lc_lci_r2_a/default/table?lang=en&category=labour.lc.lci
1.4	Industrial countries' effective exchange rates	https://ec.europa.eu/eurostat/databrowser/view/ert_eff_ic_a/default/table?lang=en&category=ert.ert_eff
1.5	Average and median income	https://ec.europa.eu/eurostat/databrowser/view/tepsr_wc310/default/table?lang=en&category=es.tesip.tesov
2	**Security capability index**	
2.1	Convergence indicators	https://ec.europa.eu/eurostat/databrowser/view/nama_10_pc/default/table?lang=en&category=na10.nama10.nama_10_aux
2.2	Export and import	https://ec.europa.eu/eurostat/databrowser/view/nama_10_exi$defaultview/default/table
2.3	Pollution, dirt or other environmental problems	https://ec.europa.eu/eurostat/databrowser/view/cei_pc031/default/table?lang=en&category=cei.cei_pc
2.4	Employment rates by sex, age, educational attainment level and citizenship	https://ec.europa.eu/eurostat/databrowser/view/lfsi_emp_a/default/table?lang=en&category=labour.employ.lfsi.lfsi_emp
2.5	Unemployment	https://ec.europa.eu/eurostat/databrowser/view/une_rt_a/default/table?lang=en&category=labour.employ.lfsi.une
2.6	Net social security benefits	https://ec.europa.eu/eurostat/databrowser/view/spr_net_ben$defaultview/default/table
2.7	Industrial production index	https://ec.europa.eu/eurostat/databrowser/view/sts_inpr_a/default/table?lang=en&category=sts.sts_ind.sts_ind_prod
3	**Development capability index**	
3.1	Government revenue, expenditure and main aggregates	https://ec.europa.eu/eurostat/databrowser/product/view/gov_10a_main?category=gov.gov_gfs10.gov_10a
3.2	Government expenditure by function (COFOG)	https://ec.europa.eu/eurostat/databrowser/view/gov_10a_exp/default/table?lang=en&category=gov.gov_gfs10.gov_10a
3.3	Main national accounts tax aggregates	https://ec.europa.eu/eurostat/databrowser/view/gov_10a_taxag/default/table?lang=en&category=gov.gov_gfs10.gov_10a
3.4	Annual financial reports for the general government sector	https://ec.europa.eu/eurostat/databrowser/view/gov_10a_ggfa/default/table?lang=en&category=gov.gov_gfs10.gov_10a
3.5	Government deficit/surplus, debt	https://ec.europa.eu/eurostat/databrowser/view/gov_10dd_edpt1/default/table?lang=en&category=gov.gov_gfs10.gov_10dd
3.6	GDP and its main components (output, expenditure and income)	https://ec.europa.eu/eurostat/databrowser/view/nama_10_gdp$defaultview/default/table
4	**Innovative development index**	
4.1	Population by educational attainment level, sex, age and degree of urbanisation (%)	https://ec.europa.eu/eurostat/databrowser/view/edat_lfs_9916/default/table?lang=en&category=degurb.degurb_edat
4.2	Data on employment in knowledge-intensive activities at the national level	https://ec.europa.eu/eurostat/databrowser/view/tgs00039/default/table?lang=en&category=t_scitech.t_htec
4.3	HRST by category, sex and age	https://ec.europa.eu/eurostat/databrowser/view/tsc00025/default/table?lang=en&category=t_scitech.t_hrst
4.4	Total high-tech trade	https://ec.europa.eu/eurostat/databrowser/view/htec_trd_tot4$defaultview/default/table
4.5	Patent applications to the EPO by country of applicants and inventors	https://ec.europa.eu/eurostat/databrowser/view/pat_ep_tot$defaultview/default/table
4.6	Internet purchases	https://ec.europa.eu/eurostat/databrowser/view/isoc_ec_ibuy/default/table?lang=en&category=isoc.isoc_i.isoc_iec
4.7	Total high-tech trade in million euro and as a percentage of total	https://ec.europa.eu/eurostat/databrowser/view/htec_trd_tot4$defaultview/default/table

4.8	GERD by sector of performance	https://ec.europa.eu/eurostat/databrowser/view/rd_e_gerdtot$defaultview/default/table
4.9	Share of R&D personnel and researchers in total active population	https://ec.europa.eu/eurostat/databrowser/view/rd_p_perslf/default/table?lang=en&category=scitech.rd.rd_p
4.10	Share of GBARD in total general government expenditure	https://ec.europa.eu/eurostat/databrowser/view/gba_nabste/default/table?lang=en&category=scitech.rd.gba

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CIRCULAR ECONOMY FOR PRODUCTION OF RENEWABLE FUELS AND MATERIALS FROM WASTE-TO-VALUE TECHNOLOGIES

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Abstract. The circular economy offers a sustainable framework to address escalating environmental issues, particularly waste management and resource depletion. This paper investigates the role of emerging waste-to-value technologies in supporting circular economy goals by converting waste into valuable products such as fuels, chemicals, and bioplastics. These waste-to-value technologies are evaluated for their environmental benefits, scalability, and economic viability. The study highlights how integrating such innovations can reduce reliance on virgin resources, minimize landfill use, and lower carbon emissions. Real-world industrial applications are analyzed to illustrate their scalability, economic feasibility, and environmental benefits. Ultimately, waste-to-value innovations are shown to be fundamental to realizing the goals of a circular economy, offering sustainable pathways for resource efficiency. While these technologies show strong potential, further research, policy support, and technological development are needed to overcome challenges related to economic feasibility, regulatory barriers, and large-scale implementation. The transformation of plastic waste into valuable products presents a promising approach for addressing both waste management and sustainable energy production. The waste-to-value technologies, such as pyrolysis, provide viable solutions for reducing plastic pollution and minimizing dependence on fossil fuels. However, additional advancements are necessary in areas like process efficiency, economic feasibility, and environmental impact reduction to enhance the commercial viability and scalability of these technologies. By incorporating these innovations into the larger framework of a circular economy, we can make a substantial contribution to building a more sustainable and resource-efficient future.

Keywords: circular economy; plastic recycling; pyrolysis technology; waste-to-value technologies

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JEL Classifications: R20

Additional disciplines: ecology and environment, environmental engineering, energetics

1. Introduction

Waste-to-value technologies refer to innovative processes and systems designed to convert waste materials into valuable products, such as energy, fuels, chemicals, and raw materials. These technologies aim to minimize waste, reduce environmental impact, and promote sustainability by transforming what would otherwise be discarded into useful resources. Waste-to-value technologies offer several advantages. Firstly, resource recovery helps recover valuable materials and energy from waste, reducing the need for virgin resources. Secondly, environmental impact diverts waste from landfills and reducing greenhouse gas emissions, these technologies contribute to environmental sustainability. Finally, economic opportunities create jobs and stimulate economic growth by developing new industries focused on waste management and resource recovery.

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The concept of a circular economy is revolutionizing how we approach the production of renewable fuels. Instead of the traditional linear model, which often leads to waste and depletion of resources, a circular approach emphasizes sustainability and efficiency. In this framework, resources are used, reused, and recycled, creating a closed-loop system that minimizes environmental impact. Ultimately, the circular economy for renewable fuel production holds immense promise. It encourages innovation, reduces environmental impact, and enhances energy security. By embracing this model, we can pave the way for a sustainable and resilient future where energy production harmonizes with ecological balance.

2. Literature Review

The circular economy model has gained considerable traction as a sustainable solution to the challenges posed by the traditional linear economy. Rather than a "take, make, dispose" approach, the circular economy advocates for designing systems that minimize waste, maximize resource efficiency, and create closed-loop processes where products and materials are reused, recycled, or repurposed. The circular economy concept highlights the significance of sustainability by encouraging the reuse, recycling, and recovery of materials to reduce waste and resource use. The principles of the circular economy have become particularly relevant in addressing the growing issue of plastic waste, which, if managed incorrectly, can lead to severe environmental and ecological consequences in relation to plastic waste. The circular economy provides innovative solutions for transforming plastic into renewable fuels.

Waste-to-value technologies facilitate the recovery of valuable materials and energy from waste, reducing reliance on virgin resources. According to Rezania et al. (2023), this contributes to a circular economy by promoting resource efficiency and sustainability (Kumar et al., 2021). These technologies play a crucial role in mitigating environmental degradation by diverting waste from landfills and reducing greenhouse gas emissions. Zhao et al. (202) emphasize that implementing waste-to-value technologies can significantly lower the carbon footprint associated with waste disposal.

The economic viability of waste-to-value technologies, which convert waste materials into valuable products such as fuels, chemicals, or energy, is critical to their widespread adoption. These technologies, including pyrolysis, gasification, and chemical recycling, hold significant potential for addressing global waste challenges while also creating economic opportunities. However, the success of these technologies depends on a variety of factors, such as investment costs, operational efficiency, market demand for byproducts, and policy incentives. The initial capital required to implement waste-to-value technologies can be high, especially for advanced processes like pyrolysis and gasification. These technologies require specialized equipment, infrastructure, and skilled personnel. According to Awogbemi et al. (2023), while the capital costs for waste-to-value facilities can be substantial, the long-term benefits, including reduced landfill use and the generation of valuable products, may outweigh the upfront investment. Additionally, operational costs must also be considered, including energy consumption, maintenance, and feedstock processing. Pyrolysis, for instance, has relatively high energy requirements, which can affect the economic feasibility of the technology if energy costs are high (Peti et al., 2025).

The revenue potential from byproducts of waste-to-value technologies plays a significant role in determining the economic viability. Pyrolysis, for example, can produce synthesis gas (syngas), oils, and solid residues, all of which can be sold or used to generate energy (Papari et al., 2021). Syngas can be used for electricity generation, while oils can be refined into transportation fuels or chemicals. The demand for these byproducts, especially in regions with limited natural resources, can significantly impact the profitability of waste-to-value processes.

However, market conditions for these byproducts can be volatile. The price of crude oil, for example, can fluctuate, affecting the market for synthetic fuels. In some cases, the revenue from byproducts may not be sufficient to cover operational costs, making the economic viability of the technology more dependent on external factors like subsidies or government support (Bocken et al., 2016).

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Government policies and incentives play a crucial role in determining the economic feasibility of waste-to-value technologies. In many countries, there are growing incentives for renewable energy production, waste reduction, and the development of sustainable technologies. These can include subsidies, tax credits, or carbon pricing schemes. According to Geissdoerfer et al. (2017), policy frameworks that support waste-to-value technologies by promoting green energy, reducing waste to landfills, and encouraging sustainable development are essential to making these technologies more economically attractive.

Furthermore, regulatory standards related to waste management and environmental impact can affect the implementation and success of waste-to-value technologies. Stringent regulations on emissions, for instance, may require additional investments in pollution control equipment (Awogbemi et al., 2023), increasing the cost of implementation but also ensuring the long-term sustainability of these technologies.

The economic viability of waste-to-value technologies also depends on competition from other waste management methods, including traditional recycling, landfilling, or incineration. While WTV technologies can offer significant advantages in terms of resource recovery and waste diversion, they must compete with more established methods that may have lower upfront costs.

However, as waste-to-value technologies mature and scale up, they may benefit from economies of scale, reducing costs and improving profitability. As noted by Chow et al. (2023), advancements in technology and processes may lead to cost reductions over time, making these technologies more economically viable and accessible to a wider range of businesses and municipalities.

Plastic waste arises from the breakdown or disposal of polymer materials. When plastic products deteriorate or are discarded, they contribute to the growing problem of plastic waste. Around 4% of global oil and gas production is dedicated to plastic manufacturing. The generation of plastic waste occurs when plastic materials become outdated or unusable (Pharande & Bagwan, 2023). The widespread production and consumption of plastics play a major role in the accumulation of plastic waste. Due to their versatility and low cost, plastics are extensively used across various industries. While solar panels are pivotal in advancing renewable energy, they contribute to plastic waste due to their construction materials and challenges in recycling. Solar panels, particularly those using crystalline silicon technology, consist of various materials (Figure 1). The plastic components, especially the backsheet made of polyethylene terephthalate (PET) and polyvinyl fluoride (PVF), are essential for weatherproofing but complicate recycling efforts. These materials are not easily separable and can degrade over time, leading to environmental concerns (Xu et al., 2018).

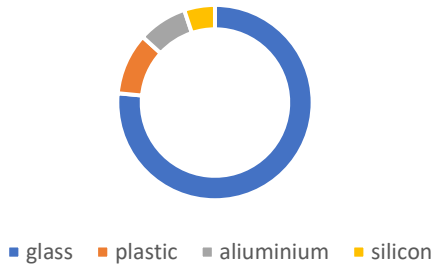


Figure 1. Solar panel composition
Source: Xu et al. (2018)

Recycling solar panels is complex due to the difficulty in separating and processing the various materials. While glass and aluminum are relatively straightforward to recycle, plastics and metals like silicon and silver require more advanced techniques. While solar panels are a cleaner energy source, their plastic components and the challenges in recycling them contribute to plastic waste. Addressing these issues requires advancements in recycling technologies and materials to ensure that the growth of renewable energy does not lead to new environmental problems (Tvaronavičienė, 2024). Various plastic manufacturing processes also lead to the creation of plastic waste (Valizadeh et al., 2024). With industrial growth and an expanding global population, the use of plastics has increased dramatically (Chang, 2023). Plastic waste is a complex mixture of different plastic polymers.Plastics are synthetic materials made from polymers, which are long chains of repeating units.

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Various types of plastics exist (Figure 2), each distinguished by its distinct chemical structure and properties. Projections indicate that by 2050, global plastic waste could reach 12 billion tons (Chen et al., 2023). Pyrolysis provides a technique to convert plastic waste into oil (Papari et al., 2021).

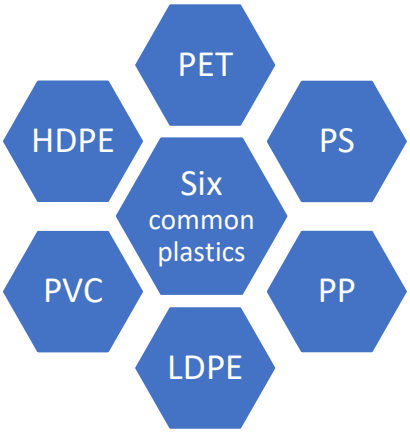


Figure 2. Six common types of plastics
Source: Chang (2023)

The prospects of using pyrolysis to convert plastic waste into liquid oil have been extensively analyzed in recent studies due to the growing concerns over plastic waste and the increasing demand for sustainable waste management solutions. Pyrolysis is a promising technology for converting plastic waste into valuable liquid fuel, addressing both the environmental issue of plastic pollution and the energy demands associated with fossil fuels.

Pyrolysis involves the thermal decomposition of plastic waste in the absence of oxygen at high temperatures (typically between 300°C and 900°C). This process breaks down complex polymer chains into smaller molecules, resulting in the production of liquid oil, gases, and solid residue (char). The liquid oil produced is rich in hydrocarbons and can be further refined to be used as a substitute for fossil fuels in engines or industrial processes (Chang, 2023).

The economic feasibility of using pyrolysis on a large scale depends on factors like the cost of setting up pyrolysis plants, the efficiency of the process, and the value of the end products. Pyrolysis can be economically viable if the liquid oil produced is of high quality and can be sold at a competitive price, making it an attractive option for industries looking to capitalize on waste-to-energy solutions (Chang, 2023).

Despite its promise, the widespread adoption of pyrolysis to convert plastic waste into liquid oil faces challenges such as the need for consistent feedstock quality, economic costs, and technical limitations regarding scalability. Nevertheless, projections suggest that as technology advances and the need for sustainable waste management increases, pyrolysis could play a significant role in managing plastic waste and providing alternative energy sources (Faisan et al., 2023).

Waste-to-value technologies focus on transforming plastic waste into valuable products, thus contributing to sustainable development by reducing waste, conserving resources, and promoting a circular economy. These technologies aim to close the loop of plastic consumption by reusing or recycling plastic waste into new, useful products, including fuels, chemicals, and materials. The main waste-to-value technologies for plastic are shown in figure3.

Mechanical recycling involves physically processing plastic waste through shredding, cleaning, and re-melting to create new products. This method is effective for thermoplastics like polyethylene (PE), polypropylene (PP), and polyethylene terephthalate (PET). However, it is limited by the quality degradation of plastics after multiple recycling cycles and challenges in processing contaminated materials recycling of a broader range of plastics, including those that are difficult to process mechanically.

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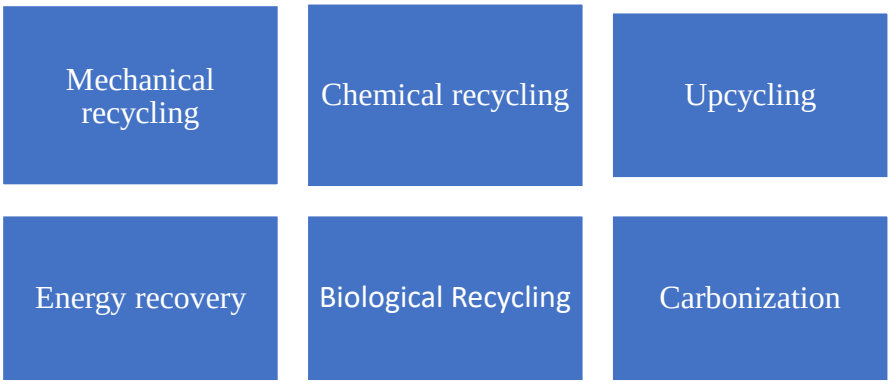


Figure 3. Waste-to-Value Technologies for Plastic
Source: Chang (2023)

Upcycling involves converting plastic waste into higher-value products. Energy recovery technologies, such as pyrolysis and gasification, convert plastic waste into energy (heat, electricity, or fuel) by thermally decomposing the plastics. These methods reduce the volume of plastic waste and generate energy, though they may emit greenhouse gases if not properly managed. Emerging biological recycling methods utilize enzymes or microorganisms to break down plastics into simpler, reusable components. While still in developmental stages, these methods offer a promising avenue for recycling complex plastics under mild conditions. Plastic carbonization involves converting plastic waste into carbon-rich materials like activated carbon, which can be used in energy storage, environmental remediation, and organic synthesis applications.
Energy recovery technologies: pyrolysis and gasification for plastic waste.

Managing energy consumption and minimizing emissions is essential for environmental sustainability throughout the waste-to-fuel process. Heat generated during pyrolysis can be recovered and reused to power the process or produce electricity. A life cycle assessment should be performed to assess the environmental benefits of the plastic waste-to-fuel process, which includes estimating the overall reduction in greenhouse gas emissions compared to the disposal of plastics in landfills or incineration, analyzing the net energy produced from the process versus the energy consumed during conversion; evaluating how much plastic waste is diverted from landfills and the circular economy benefits from recycling plastic into fuels (Alhazmi et al., 2021; Javed et al., 2025; Vlasopoulos et al., 2023).

This study explores the feasibility and potential advantages of converting waste plastics into fuel through pyrolysis within the framework of circular economy principles. By analyzing the technical, environmental, and economic dimensions of the pyrolysis process, the research evaluates its viability as both a waste management solution and an energy recovery method. The primary objectives of the study are:

- to reserach the application of plastic waste pyrolysis technologies within the circular economy framework, assessing its potential as a sustainable and resource-efficient technology for plastic waste management and the recovery of valuable materials.
- to assess the environmental, economic, and technical feasibility of implementing pyrolysis within circular waste management frameworks.

Through these objectives, the study aims to support the development of sustainable plastic waste management strategies and promote the use of waste to get valuable fuels.

3. Methodology of Research

The heat transfer is significant in the reactor for better breaking down of the plastics and for the height yield of the plastic oil from the plastic vapour forming inside the reactor. The heating of the reactor can be done in multiple ways (Fig. 2). The heating of the burner can be given through a burner where we can use gases like LPG, CNG, biogases, and sometimes solid fuels like wood and coal are also being used mostly in the fixed bed reactors. The reactor can also be made for electricity as a heating medium using windings created around it, and

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the electricity is passed to heat it. Sometimes, solar energy can also be used to heat. The main disadvantage of this type of reactor using electricity as a medium is that it won't get the efficiency to produce enough temperature supply for producing gases from plastics. The microwave reactor is also used sometimes, but not very commonly, to produce it. Its main disadvantages are longer heating times, loss of energy, and the need for unique materials to create the special reactor. These classifications can be further broken down (see Figure 2).

The steps to investigate the conversion of plastic waste into valuable products within the context of a circular economy are investigated. The research will assess the feasibility, environmental impacts, and economic viability of various waste-to-value technologies, including mechanical recycling, chemical recycling, pyrolysis, gasification, and other advanced methods. This research was to determine how pyrolysis technologies can contribute to a sustainable, circular economy by recovering resources, reducing waste, and creating valuable materials and energy.

Economic feasibility and market considerations: an economic analysis is crucial to determine the feasibility of plastic waste-to-fuel technologies. This analysis should include capital and operational costs, which estimate the investment required for setting up the technology and maintaining operations; revenue generation, which is evaluating the revenue potential from selling the produced fuel and any co-products (e.g., chemicals, carbon black); and finally return on investment, which is analyzing the time it takes to recover the initial investment and the long-term profitability of the process.

SOLOIDWORKS was a simulation platform for designing and analyzing complex processes, including chemical reactions, heat transfer, and fluid dynamics. It simulates reactor designs requiring detailed thermodynamic, fluid dynamics, and reaction kinetics information, such as pyrolysis. The main parameter simulated is temperature. Three different temperatures were simulated for the reactor (450C, 500C, 600C), as shown in Figure 4.

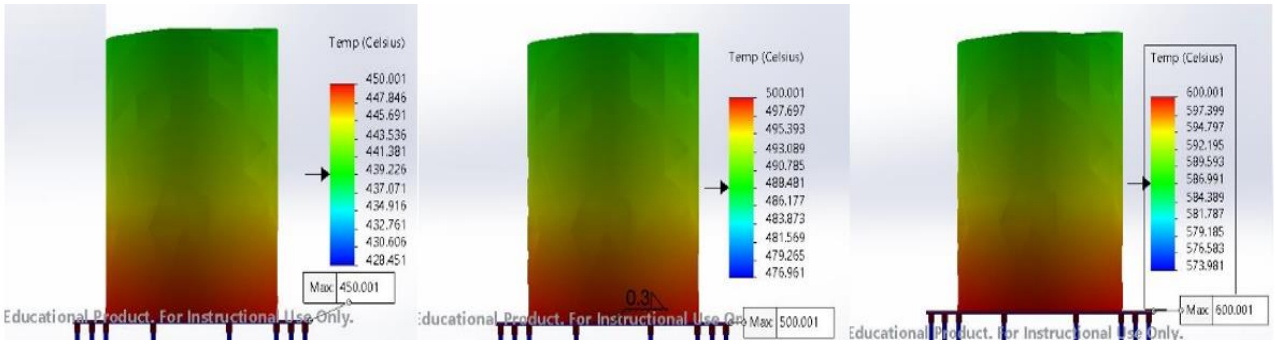


Figure 4. Heat distribution in a reactor with different heated temperatures
Source: own processing

Energy recovery technologies, including pyrolysis and gasification, are methods used to convert plastic waste into energy, such as heat, electricity, or fuel, by thermally decomposing plastics in controlled environments. These technologies are considered crucial in addressing the global plastic waste crisis, as they offer a way to reduce the volume of waste while simultaneously generating energy.

Pyrolysis is a thermal decomposition process that takes place in the absence of oxygen. When plastic waste is heated to high temperatures (usually between 350°C and 800°C), it breaks down into simpler chemical compounds. The products of pyrolysis include liquid oils, gases, and solid char. The liquid oil can be refined into valuable fuels such as diesel, gasoline, and other petrochemical products, while the gases can be used for power generation. For the simulation was used mixed plastic waste, including polyethylene (PE), polypropylene (PP), polystyrene (PS), and polyethylene terephthalate (PET). The chosen temperature was between 450°C and 600°C, with the exact temperature depending on the type of plastic.

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4. Experimental results and discussion

Following the completion of the reactor design and its analysis in SolidWorks, the system is assumed to operate under ideal conditions with no heat loss. This assumption allows for an accurate estimation of the internal temperature retention. When the reactor is loaded with LDPE plastic waste, it reaches a thermal load of approximately 450°C. At around 400°C, the onset of pyrolysis occurs, initiating the production of pyrolytic vapours.

Table 1 above defines the plastic types used: LDPE (Low-Density Polyethylene), HDPE (High-Density Polyethylene), and PP (Polypropylene). A base plate temperature of 450°C is applied in the reactor model design. To enhance thermal retention, the base plate is strategically positioned beneath the reactor body, which helps maintain consistent heat distribution. This configuration effectively promotes gas production while minimizing wax formation during pyrolysis (Rasul et al., 2022).

The complete plastic pyrolysis system designed for converting LDPE into pyro-oil has been successfully validated through design and simulation in SolidWorks. Data obtained from simulations, along with supporting research literature, confirm that this reactor model is suitable for laboratory-scale experiments and can serve as a reliable prototype for future experimental studies.

Table 1. The parameters used for simulation with different types of plastics

Samples	a)	b)	c)
Temperature, C	450	500	600
Melting temperature, C	110	140	Depends on mixed plastics
Material (plastic)	LDPE	HDPE and PP	Mixture
Temperature of pyrolysis, C	250-380	390-500	380-550

The pyrolysis of plastic waste is a thermochemical process that breaks down polymers into smaller molecules in the absence of oxygen, converting plastic into valuable products such as liquid fuels, gases, and char. Below (Table 2) are the key aspects of plastic waste pyrolysis, categorized into technical, environmental, economic, and operational dimensions:

Table 2. The aspects of plastic waste pyrolysis process (Antelava *et al., 2021)*

Aspect	Description
Technical	Pyrolysis can be categorized into: • slow pyrolysis (operates at lower heating rates; higher char yield); • fast pyrolysis (rapid heating; maximizes liquid oil production); • catalytic pyrolysis (uses catalysts to enhance yield and quality of pyro-oil and reduce reaction temperature). Typically includes thermoplastics such as: low-density polyethylene (LDPE), high-density polyethylene (HDPE), polypropylene (PP), polystyrene (PS), mixed plastics (with pre-treatment to remove PVC/PET due to harmful emissions or low oil yield). Heat transfer efficiency and residence time are critical factors in determining output quality.
Environmental	Emission Reduction: reduces plastic accumulation in landfills and oceans and can lower CO_2 emissions compared to incineration or landfilling. The pyrolysis process creates byproducts such as gas fraction (used to fuel the process itself, reducing external energy needs) and solid residue (char), which may be used as a filler or adsorbent.
Economic	Pyrolysis oil can be refined into diesel, gasoline, or chemicals. Gaseous byproducts may be reused for energy input. There are several cost considerations of pyrolysis, such as capital investment for reactor setup and control systems; operational costs including energy, labor, and feedstock preparation, and profitability depends on oil prices, plastic waste availability, and subsidies.
Operation	Feedstock reparation consists of cleaning, drying, and shredding, which are essential for efficient pyrolysis. Also, mixed plastic streams may need sorting or dechlorination (PVC removal). Process efficiency depends on consistent heating, feed rate, and oxygen exclusion. Meanwhile, energy recovery from gas fraction improves net energy balance.

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The table above demonstrates how plastic waste-to-value technology (pyrolysis) is integral to the circular economy, promoting sustainability, reducing waste, and creating economic opportunities. Technologies that convert plastic waste to value (e.g., through recycling, upcycling, or energy recovery) can play a key role in a circular economy by extending the lifecycle of materials and reducing resource consumption. These technologies align with circular economy principles such as closing the material loop. In a circular economy, materials are used for as long as possible. Plastic-to-value technologies such as mechanical recycling (melting and remoulding plastics), chemical recycling (breaking polymers down into monomers or fuels,) or upcycling (converting waste into higher-value products) allow plastic waste to re-enter the economy instead of being landfilled. This reduces the need for natural mineral resources.

For instance, Sundaram et al. (2023) conducted a life cycle analysis indicating that synthetic fuels derived from plastic waste, especially when produced using renewable energy inputs, could result in 30–50% lower carbon emissions than fossil fuels. These benefits are compounded by the potential to integrate plastic-to-fuel technologies into circular economy systems, where materials are continuously reused, reducing reliance on virgin resources. The researchers emphasized the role of plastic-to-fuel conversion in promoting circularity by returning discarded plastics back into the energy cycle, thus minimizing both raw material demand and carbon emissions (Moroliya et al., 2023).

Further supporting these findings, Geyer et al. (2020) reported that approximately 8 million tons of plastic enter the oceans every year, contributing to severe marine pollution. Recycling technologies such as pyrolysis offer a promising means of reducing this flow by thermochemically breaking down plastics into usable fuels. Additionally, another group of researchers noted that the heterogeneity and contamination often present in plastic waste streams can lower the quality and yield of the resulting synthetic fuels, potentially increasing overall emissions and complicating downstream fuel purification (Hasan et al., 2025).

However, challenges remain. While plastic waste-to-fuel conversion can reduce emissions, the processes are not entirely emission-free. Abnisa et al. (2019) found that pyrolysis, a primary technology in this space, has a carbon intensity of approximately 500–700 g CO_2 /kWh. Although this is lower than many fossil fuel-based energy systems, further improvements are needed to reduce emissions from energy input and process inefficiencies. Moreover, converting plastic waste to synthetic fuels can reduce the carbon footprint of waste treatment processes by as much as 30% compared to traditional methods like incineration or landfilling (Liu et al., 2019). This reduction arises from avoided emissions associated with both plastic disposal and the extraction and refining of fossil fuels. Finally, the researchers' group estimated that converting one ton of plastic waste into synthetic fuel could offset up to 2.3 tons of CO_2 emissions that would otherwise be generated through conventional oil refining and use (Kevorkijan et al., 2023) .

The plastic waste-to-value technologies for synthetic fuels present a valuable opportunity to simultaneously address two pressing environmental issues: plastic pollution and dependence on fossil fuels. This approach supports a more sustainable and circular model for both energy production and plastic waste management by transforming post-consumer plastic waste into usable energy products, particularly synthetic fuels. Each year, millions of tons of plastic end up in landfills or the natural environment, posing significant ecological risks. Converting this waste into fuel not only diverts plastic from these harmful endpoints but also offsets greenhouse gas emissions associated with conventional plastic disposal and fossil fuel use.

Waste is the primary driver behind advancing waste-to-energy technologies within the circular economy framework. Utilizing waste directly addresses sustainability challenges by ensuring a consistent and reliable year-round supply of raw materials for energy recovery. Future research should prioritize the development and optimization of valorization strategies, including improved methods for waste collection, segregation, storage, and enhancement of final product quality.

To strengthen the economic viability of waste-to-energy systems, it is essential to consider the utilization and commercialization of byproducts. However, the roles and interactions among key stakeholders remain insufficiently defined, highlighting the need for comprehensive and inclusive research. Additionally, effective policy mechanisms and incentive structures must be aligned with the latest scientific advancements to foster the

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practical adoption of these technologies. Sustainability assessment models should be grounded in empirical data to minimize assumptions and uncertainties, enabling more accurate and objective evaluations of waste-to-energy systems.

Conclusions

Waste-to-value technologies represent a promising approach to addressing waste management challenges while creating valuable products and promoting sustainability. The literature indicates that while these technologies offer significant benefits, including resource recovery and reduced environmental impact, they also face challenges related to economic viability, regulatory frameworks, and public acceptance. Continued research and development and supportive policies are essential for advancing waste-to-value technologies and realizing their full potential in a circular economy.

Pyrolysis has shown to be a viable waste-to-energy technology that can not only reduce plastic waste in landfills but also provide valuable products that can displace fossil fuels, contributing to the reduction of carbon emissions. The process aligns with the principles of the circular economy, where the goal is to close the loop of product life cycles through recycling and reuse.

The adoption of plastic waste-to-value technologies faces several technical, economic, and regulatory challenges. However, with ongoing research, technological advancements, and supportive policy frameworks, these barriers can be overcomed. The integration of waste-to-value technologies into the circular economy offers a sustainable path forward for managing plastic waste, reducing fossil fuel dependence, and mitigating environmental pollution.

The conversion of plastic waste to valuable products represents a promising strategy for both waste management and sustainable energy production. Technologies like pyrolysis, gasification, and chemical recycling offer solutions to reduce plastic pollution and reliance on fossil fuels. However, further advancements in process efficiency, economic feasibility, and environmental impact mitigation are needed to make these technologies commercially viable and scalable. Integrating these technologies into the broader circular economy can significantly contribute to a more sustainable and resource-efficient future.

Scientific novelty and practical value of the findings

The novelty of research into plastic waste-to-value technologies using pyrolysis lies in recent innovations that enhance efficiency, selectivity, sustainability, and integration into the circular economy. Environmental and economic performance shows high energy input and questionable environmental gains. Life cycle assessments present that carbon savings are up to half as much as landfills or incineration. Pyrolysis technologies for plastic waste are becoming for real-world circular economy integration, especially in regions lacking advanced recycling infrastructure.

Converting waste plastics into pyrolysis oil is an emerging waste-to-value approach that addresses both the growing plastic pollution crisis and the demand for alternative energy and feedstock sources. This process holds significant environmental and economic benefits by transforming low-value or non-recyclable plastic waste into a valuable liquid fuel or chemical feedstock. However, to minimize the overall carbon footprint, it is essential to carefully consider the energy sources used, enhance technological efficiency, and implement effective waste management strategies. With continued advancements in the broader adoption of renewable energy sources, pyrolysis-based plastic valorization is poised to become a more sustainable and economically attractive pathway within the circular economy framework.

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ASSESSMENT OF THE APPLICATION OF ENVIRONMENTALLY FRIENDLY TECHNOLOGIES TO INCREASE BUSINESS COMPETITIVENESS*

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Abstract. The paper analyses the impact of the application of environmentally friendly technologies on business competitiveness, taking into account the principles of sustainability and the aspects of business competitiveness. The growing awareness of environmental issues encourages companies to introduce innovative, environmentally friendly technologies, which reduce the negative impact on the environment and create the prerequisites for the formation of business competitive advantages. The paper presents a theoretical concept of environmental innovations and an analysis of their benefits for business. It also discusses the key factors influencing the uptake of these technologies, ranging from regulatory policy and financial incentives to consumer expectations and companies' strategic objectives. The empirical part of the study includes an analysis of three production sectors' performance results to assess how environmentally friendly technologies contribute to competitive advantage, digitalisation and sustainability. Following three stages of methodology, the study applies COPRAS method and grouping of countries based on the performance of production sectors (in particular, food, rubber, and furniture). The results reveal that most companies surveyed see the introduction of technology as an investment in long-term business success. The paper provides recommendations for companies seeking to strengthen their market position through sustainable technologies. The results are relevant for both business practice and public policy to create a sustainable and competitive production environment.

Keywords: environmentally friendly technologies; business competitiveness; environmental issues; sustainability; production

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1. Introduction

This paper aims to examine the impact of advanced technological solutions and green technologies on company competitiveness and environmental sustainability. The aim is to assess how companies adopt sustainable practices, particularly in the food, rubber, and furniture manufacturing industries, while meeting global demands for resource efficiency, reducing environmental impact, and aligning with sustainable development goals (SDGs) such as the United Nations SDGs. The paper aims to identify gaps in integrating green transformation by analysing country-specific practices and providing insights for improving corporate sustainability. Advanced technological solutions have a significant impact on business. This is becoming very important because of the

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growing global demand for efficient business, sustainability, and environmental awareness. The study offers wide-ranging potential outcomes: increased green practices and reduced business technology drive competitiveness and stand out as a new approach in this area.

The EU, the United Nations, and the G20 countries have increasingly implemented policies and actions to promote sustainability (García-Gallo et al., 2020). Policies promoting sustainability can be divided into environmental, socio-economic, and technological. Sustainable policies include climate, air quality, environmental ethics, and others. Therefore, companies need to identify environmental sustainability as an objective rather than using it as a marketing tool. Advanced technological solutions significantly influence business operations, addressing the growing global demand for sustainability, efficiency, and environmental awareness. The integration of green technologies enhances environmental practices and strengthens business competitiveness, positioning sustainability as a strategic necessity rather than an option. The research provides novel multi-criteria assessment approaches by combining environmental, socio-economic, and technological indicators to evaluate the dynamics of corporate competitiveness. Focusing on three key manufacturing industries, food, rubber, and furniture, the paper identifies specific differences in adopting sustainable practices across countries. It reveals neglected aspects such as energy inefficiency and e-waste management. In addition, the study highlights less-researched challenges, such as the impact of environmental noise on corporate performance, and adds new perspectives to sustainable development research. Organisations like the European Union (EU), the United Nations, and G20 countries are increasingly implementing policies and initiatives to foster sustainable development. These policies span environmental, social, economic, and technological dimensions, emphasising critical aspects like climate ethics, air quality, and resource conservation. Companies are now expected to prioritise environmental preservation as a core goal instead of merely utilising it as a marketing tool.

Despite advancements, global circularity has declined to just 7% in 2023. Studies highlight the potential of improving heat energy efficiency in manufacturing to reduce operational costs and environmental harm significantly. It is estimated that up to 50% of energy in the manufacturing sector is wasted due to inefficiencies, emphasising the urgent need for sustainable practices. Addressing these inefficiencies mitigates environmental damage and enhances competitiveness by reducing costs. Environmental noise is a less recognised but impactful pollutant affecting public health and business performance. Long-term noise exposure can lead to health issues such as cardiovascular diseases, sleep disturbances, and psychological stress, which reduce workforce productivity. Studies reveal that addressing noise pollution is critical for community well-being and ensuring industrial competitiveness. For businesses located in urban areas, minimising noise is increasingly important as it influences residential and commercial preferences, thereby affecting market positioning. This research underscores the transformative potential of sustainable practices and green technologies in modern business.
The European Commission focuses on implementing the Green Deal to achieve a lower environmental impact. Technology plays an important role in the European green transformation, aiming to promote sustainability and strengthen the competitiveness of European businesses. Limited and fragmented application of modern environmentally friendly technologies is noticeable at the European Union (EU) level. The results of a bibliometric literature analysis show that the number of articles on green transition is five times lower than on digital transformation (Burinskiene & Nalivaike, 2024). The European Commission's Green Deal highlights the importance of minimising environmental impacts through technological innovation. However, the adoption of environmentally friendly technologies remains fragmented across the EU.

The European Union (EU) political agenda focuses on the priority implementation of the green transformation. Successfully implementing the green transition is essential for achieving the United Nations (UN) declared Sustainable Development (SD) goals.

Recent scientific research highlights the importance of environmentally friendly technologies for this transformation, especially in addressing the challenges of sustainable development in business. It is noted that, despite the increased attention paid to the topic of the green transition, scientific research on the application of environmentally friendly technologies to increase business competitiveness is fragmented, and there is a noticeable lack of knowledge in this research area.

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This study aims to make a substantial contribution to the literature on the role of technological solutions in influencing business competitiveness and in helping to find solutions and take initiatives to increase operational efficiency and reduce environmental impacts. This study will contribute to a better understanding of the impact of technological solutions on business competitiveness by addressing existing research gaps. The objectives of the study include:
1. to investigate the need for environmentally friendly innovations, their classification and their impact on business competitiveness.
2. to investigate the determinants of market uptake of environmentally friendly technologies, the main ones being government regulatory policies, financial incentive mechanisms, consumer expectations and firms' strategic objectives.
3. to examine the impact of integrating sustainable solutions into business and eco-innovation on a company's competitive advantage, operational efficiency and corporate reputation.
The paper consists of such sections: theoretical background presented in Section 2; COPRAS analysis results are presented in Section 3; Conclusions section is presented at the end of the paper.

2. Theoretical background

The EU, the UN, and the G20 actively support the implementation of policies and actions to promote sustainable development and the transition to a circular economy (European Commission, 2025). Policies to promote sustainable development include environmental, socio-economic and technological aspects. Sustainable policies focus on reducing climate change, improving air quality, environmental values, etc. Companies should, therefore, pursue environmental protection as an objective in its own right rather than treating it as a marketing tool. The UN Sustainable Development goals have led to the emergence of environmental sustainability and green business management principles, which place increasing demands on companies in the area of environmental corporate social responsibility (ECSR). Chuang & Huang (2018) investigated the influence of ECSR on green IT capital and its impact on environmental performance and business competitiveness. Rath et al. (2021) analysed the criteria that are decisive for technologies that help to manage environmental factors, taking into account their mode of operation, their ability to reduce the carbon footprint, their ability to combat air pollutants, their cost-effectiveness or economic dimension and future considerations in line with the sustainable development goals.

Companies are now being encouraged to put environmental protection at the heart of their business and not just as a marketing tool (Msosa et al., 2024). The European Commission's Green Deal highlights the importance of technological innovation in reducing environmental impacts. However, the uptake of green technologies in the EU remains fragmented. The non-metallic minerals industry is the third most energy-intensive industry. The high energy intensity of the production process contributes around 7% of the world's carbon dioxide emissions to the atmosphere. Although the energy efficiency of this sector in the EU has improved significantly since 1995, its energy intensity remains high. To meet the objectives of the Paris Agreement, further action is needed to reduce carbon dioxide (CO2) emissions from this sector (Korczak et al., 2022). Despite a strong focus on recycling, the global circularity rate has decreased from 9-8% to 7% between 2021 and 2023. Recycling rates for materials such as paper and plastics are still only around 50% in Europe, indicating that resources are not being used to their maximum efficiency. Recycled raw materials account for only 1.9% of new production in Europe, reflecting the very low level of integration of secondary raw materials in production. Despite technological advances or due to accelerated cycles of technological innovation, product life cycles are getting shorter. This trend is contrary to sustainability principles as it leads to a faster depletion of resources. The 2023 Turnover Gap Report shows that deteriorating turnover is exacerbated by the prevailing trends towards unsustainable consumption and production patterns. The report highlights that high material resource extraction, persistent stockpiling and low efficiency of end-use processes significantly contribute to the current turnover gap, hindering the transition towards a more sustainable and circular economy (Sakao et al., 2024).

The European Commission (2025) also stresses the need to reduce environmental impacts through technological innovation. Research shows that technology application practices affect business competitiveness. Chikan et al. (2022) define business competitiveness as the ability of a company to fulfil its primary objectives sustainably, i.e. satisfy customer requirements and generate profits. A Harvard Business School study empirically identified

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a promising triple-bottom-line strategy, which, if successfully implemented, can achieve better business results and increase business competitiveness (Lee et al., 2022). A study by Untari et al. (2021) assessed the impact of new technology applications on business performance. The results revealed that new technologies and innovations affect business competitiveness (Bhawsar, 2023).

Global challenges: global warming, pollution levels, and climate change have become serious threats in recent years and have caused a number of environmental problems that have affected human, animal, and plant health. As a result, regulation, which is important for business competitiveness, has forced various organisations to come together to find solutions and take various initiatives to increase efficiency and reduce environmental impact. The environmental problems of energy consumption, use of natural resources, pollution and waste management are not only constraining but also opening up new competitive opportunities that are changing the competitive landscape for many industries. These environmental challenges and the need to ensure cost-effective operations force companies to rethink their business models. However, sustainability principles are still not sufficiently applied, increasing long-term risks for the environment, the economy and society. Technological solutions are increasingly shaping how we do business as the demand for sustainable, efficient and environmentally friendly solutions grows (Chen et al., 2023). The introduction of green technologies contributes to environmental improvements and strengthens companies' competitive position, making sustainability a necessary strategic orientation rather than an option.

Achieving sustainable development objectives has become crucial for saving and maintaining the environment, and various green technologies are being used to address the problem. Companies that manage environmental factors effectively can achieve a competitive advantage in the market. Processes evolve through life-cycle stages, starting with research, moving on to process engineering, plant operation and finally decommissioning. Most technologies that reduce environmental impacts are applied early in the life cycle. The number of technologies decreases sharply thereafter. Therefore, addressing environmental concerns early in the life cycle is advisable. As the process becomes more mature, the cost of addressing environmental issues increases exponentially as the scale of the equipment increases. The long-term environmental objective is to develop lean processes with 100% material recovery. The short-term emission control strategy is implementing pollution prevention programmes by introducing cost-effective technologies to control general air pollution, effluents and waste generation.

However, the uptake of environmentally friendly technologies across the EU remains insufficient. Despite progress, global circularity has fallen to just 7% by 2023. Studies show that improving thermal energy efficiency in manufacturing can significantly reduce operating costs and environmental damage. Multi-criteria evaluation methods are used to assess progress (Raudeliuniene et al., 2025). This paper aims to investigate the impact of advanced technological solutions and green technologies on the competitiveness and environmental sustainability of companies in different countries.

Environmentally friendly technologies are defined as innovative solutions that reduce negative environmental impacts and promote more efficient use of resources (Javaid et al., 2022; Fernando et al., 2019; Jin et al., 2019). In the scientific literature, ATT is often associated with eco-innovations, which include changes in processes, products or business models that contribute to the implementation of sustainability goals (Passaro et al., 2023; Vence & Pereira, 2019; Pichlak & Szromek, 2021). They can be divided into several groups: waste reduction technologies, energy efficiency solutions, integration of renewable energy sources and the use of sustainable raw materials. Many studies show that applying environmentally friendly technologies can increase a company's competitiveness through several aspects: lower production costs, better reputation, greater customer loyalty and easier access to investment (Shrivastava, 2018; Li et al., 2019). However, it is emphasised that the implementation of technologies is associated with risks and investments, whose payback depends on various internal and external factors - legal regulation, consumer behaviour and technological infrastructure.

Javaid et al. (2022) described the use of artificial intelligence (AI), the Internet of Things (IoT), big data, machine learning (ML), and other advanced technologies to implement Industry 4.0 and how they contribute to creating a sustainable environment. The authors identified twenty key applications of Industry 4.0 in creating a sustainable environment. These technologies are environmentally sustainable, produce goods more efficiently,

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and reduce resource consumption. Fernando et al. (2019) analysed the research gap on eco-innovation and its impact, especially the mediation effect of service innovation on business sustainability. The authors found that eco-innovation and service innovation capabilities are significant intangible resources and enable an organisation to achieve long-term goals, competitive advantage and business sustainability. Jin et al. (2019) calculated the green common factor efficiency of industrial water resources. They analysed the effects of technological innovation, the degree of environmental regulation, and the variability and control of the interaction between these two factors. The authors found that the impact of technological innovation and environmental regulation on industrial water resources has regional, economic, and industrial structure differences, so it is relevant to formulate a differentiated technological innovation system and environmental protection policy, improve the green investment in Research and Development (R&D) of industrial enterprises, and form a green development model.

Passaro et al. (2023) analysing the factors determining SMEs' eco-innovation and their interrelationships, found that it is important for SMEs to follow a sustainability direction and invest in eco-innovations that would reduce the social and environmental impact of production activities. Vence et al. (2019) highlighted the importance of eco-innovation, including organisational, social and systemic innovations, in reducing environmental impacts. The authors noted that business models based on eco-innovation ensure the transition to a circular economy. Integrating eco-innovation into business models influences the ecological and social value of the value proposition and changes the practices of producers and consumers. Pichlak & Szromek (2021), analysing the environmental aspects of innovative activities carried out by companies and the tendency of sustainable business leaders to create eco-innovations, found that the greenest companies are those that develop technologies for biodiversity protection and that the adoption of open innovation strategy strengthens the tendency to create eco-innovations.

Li et al. (2019) conducted a hierarchical regression analysis of the impact of energy saving and environmental data on the competitiveness of green technological innovations. The authors found that a firm's green technological innovation capability has a significant positive impact on the firm's competitiveness, provided a new analytical framework to understand the mechanism underlying the impact of a firm's green technological innovation capability on the firm's competitiveness, and provided useful insights into the development of green technological innovation competitiveness and the impact of new government policies on the regulatory framework of green development. Abad-Segura et al. (2025) examined the dynamic relationship between sustainable technological innovation (STI) and business competitiveness, noting that incorporating technology into business strategies will positively impact society and the environment. The authors also described the emergence of technology integration in finance, which promotes the emergence of technology-oriented investment platforms aligned with sustainability criteria and focused on attracting investors who value social and environmental responsibility. Hamdouna & Khmelyarchuk (2025) also studied technological innovations as key factors of sustainable competitiveness of economic entities, increasing their resilience to various challenges and threats, and identified three main scientific approaches: the resource-based approach system, where technological resources enable companies to make efficiency-enhancing decisions, taking into account sustainability aspects. The dynamic capabilities theory extends the resource-based approach system, where companies adapt and reconfigure their resources and capabilities in response to a rapidly changing environment. The triple bottom line system, which focuses only on the company's financial performance, is based on the balance of three main elements - economic, environmental and social goals.

In the literature, different authors have applied the COPRAS approach; for example, Raudeliuniene et al. (2025), to investigate sustainable construction practices in the European region, chose the COPRAS approach for their study, which allowed them to assess the environmental impact of the methods and materials used while optimising the resource allocation. This method helps to ensure the cost-effectiveness and environmental sustainability of building projects. Mishra et al. (2021) examined a two-step hybrid approach to assess sustainable bioenergy production technologies. The authors used the SWARA model to determine the subjective weights of the criteria. In a second step, they ranked bioenergy production technologies using intuitionistic fuzzy sets based on the COPRAS method. The authors evaluated six bioenergy production technologies based on four sustainability dimensions and eleven sub-criteria. Hezam et al. (2023) proposed a hybrid single-valued neutrosophic-informed decision-making approach that combines MASWIP integrating MEREC, an integrative

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objective weighting model, which combines integrated objective and subjective weighting models to calculate criterion weights in a single-valued neutrosophic environment, and a complex-proportional assessment using the COPRAS approach to prioritise bioenergy production technologies from a single-valued neutrosophic viewpoint. Ramana et al. (2022) defined the ranking algorithm, the Complex Proportional Assessment - COPRAS approach, as a new integrated approach with non-linear fuzzy data that better represents uncertainty and has an impact on sustainable performance.

The authors noted that the variance method proposed for the weighting of criteria overcomes hesitations and takes into account reliability. Amudha et al. (2021) defined the COPRAS method as a multi-criteria decision-making tool that is used to increase or decrease index values, as well as to reduce attribute indices when evaluating results. It is an ambiguous hierarchical process is an analytical hierarchical process method developed using the theory of ambiguous logic. Badrinath et al. (2022) applied the fuzzy COPRAS method to examine which factors in the shipping industry hinder the sustainability of a shipping port. In their study, the authors proposed an 8-dimensional problem-solving strategy as the optimal strategy for the identified sustainability-influencing criteria, such as loading and unloading of petroleum products, unexpected accidents, high energy consumption, structural failures, and dust generation. Demirci (2021), examining the concept of sustainability, through the interrelated aspects of economic, social and environmental protection, which is a component of the supply chain, emphasised the importance of integrating components of the sustainable supply chain process when selecting suppliers oriented towards green practices. The authors applied multi-criteria decision-making methods that provide the most important decision support opportunity, rationally and conveniently for decision-makers in selecting green suppliers for which criteria were set. Applying the multi-criteria COPRAS decision-making method, green suppliers were selected, as a result of which the most suitable one was determined from 7 alternatives. Kusakci et al (2022) also highlighted the importance of integrating sustainability principles into urban planning at the local level. The authors used fifty-three indicators of economic, social, environmental and institutional dimensions to assess the sustainability indicators of thirty Turkish cities to create a sustainable cities index. For this purpose, the authors applied a new three-stage methodology that hybridised Interval Type-2 Fuzzy Analytical Hierarchy Process (IT2F-AHP) and Complex Proportional Assessment of Alternatives (COPRAS), taking into account the high uncertainty due to the subjective weighting assigned by experts, and calculated the total scores of the 30 cities. Więckowski et al. (2024) conducted a comparative analysis of three selected multi-criteria decision analysis (MCDA) methods to find a solution to a practical decision problem and investigate the results' reliability.

The authors used the COPRAS method for complex proportional assessment, the PROMEHTEE method for preference ranking organisation to enrich the assessments, and the EDAS method for distance-from-average assessment and RANCOM method for ranking comparison to determine the weights of the criteria. The application was directed to the management of sustainable development in selected European countries, taking into account different energy sources according to the share of consumption per capita.

3. COPRAS analysis

In this paper, a multi-criteria assessment approach COPRAS method was used to analyse three main manufacturing sectors – food, rubber and furniture – in different countries. The methodology of the analysis is based on such three stages:

1) Analysis of the indicators representing the application of environmentally friendly technologies to increase production sectors competitiveness.
2) Multi-criteria COPRAS method application for the analysis, including indicators reflecting the application of ICT in three main production sectors' competitiveness.
3) Comparison of three main production sectors' results and groupping similar performance particular production sectors by countries.

Research methods used during the analysis: 1) indicator analysis, 2) multi-criteria assessment, 3) comparative analysis and grouping.

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Indicators of the EU, Norway and Serbia three production sectors (food, rubber and furniture) were retrieved on technology application published by the Eurostat (2023) database and were used during the research.

Five key criteria of corporate behaviour were assessed: (1) companies applying some measures affecting the paper or energy consumption of ICT equipment; (2) companies taking into account their environmental impact before choosing ICT services or ICT equipment; (3) companies handing over ICT equipment at the end of its useful life to e-waste collection and/or recycling companies; (4) companies with a high digital intensity index that consider their environmental impact before choosing ICT services or ICT equipment; (5) companies with a low digital intensity index that apply some measures that affect the paper or energy consumption of ICT equipment) related to companies' environmental and IT behaviours.

The study examines the classification of green technologies to assess their impact on environmental sustainability and business competitiveness. The focus is on evaluating the application of these technologies to improve business performance using an industry competitiveness approach. To this end, a multi-criteria approach was developed that integrates indicators that reflect the dynamic changes in corporate competitiveness. The study uses a variety of research methods, including literature source analysis, comparative analysis, and multi-criteria evaluation, to ensure a comprehensive study of the topic.

The manufacturing sector covers 3 industries (food, rubber, and furniture). In the food industry, the most common measure applied in the countries is that when the ICT equipment of the enterprise is no longer used, it is not sold, returned to a leasing enterprise, or donated (from 63.9% in Slovenia to 89.5% in Ireland). The lowest rate of implementation of the measure was reported by companies with a very high Digital Intensity Index, which have assessed the environmental impact of ICT services or equipment before choosing them and which apply measures that affect the paper or energy consumption of ICT equipment from 0,2% in Romania to 13.4% in Ireland. The Czech Republic and Denmark have similar measures in place, especially affecting the amount of paper used for printing and copying (60.8% and 61.1%, respectively); Estonia and Sweden have measures that reduce/increase the energy consumption of ICT equipment (69.9% and 71% respectively). Meanwhile, in Poland and Romania, ICT equipment no longer in use is mostly neither sold, returned to the leasing company, nor donated (83.0% and 83.6%, respectively).

Interestingly, Norway and Slovenia have the same proportion (88.8% and 85.2%) of measures, which are handed over for collecting and recycling electronic waste at the end of the useful life of the company's equipment. In the food industry, the criterion "When the ICT equipment of the company is no longer used, it is not sold, returned to the leasing company or donated" has the highest minimum and maximum, which means that in countries such as Ireland, Norway, Slovenia it is acceptable to discard the equipment. The results of the assessment are presented below in Table 1.

Table 1. Food, rubber, and furniture manufacturing sectors: COPRAS analysis results with country production sector ranks

Food manufacture		**Rubber manufacture**		**Furniture manufacture**	
Country	**Rank**	**Country**	**Rank**	**Country**	**Rank**
Serbia	1	Hungary	1	Greece	1
Bulgaria	3	Romania	1	Hungary	1
France	3	Slovenia	1	Romania	1
Romania	3	Norway	1	Slovenia	1
Slovenia	3	Serbia	1	Slovakia	1
Slovakia	3	Bulgaria	2	Norway	1
Sweden	3	Croatia	2	Serbia	1
Norway	3	Sweden	2	Latvia	2
Croatia	4	Greece	3	Poland	2
Poland	4	Cyprus	3	Croatia	3
Netherlands	5	Poland	3	Lithuania	4
Portugal	5	Slovakia	3	Bulgaria	5
Greece	6	Latvia	5	France	6
Latvia	6	Malta	5	Ireland	7

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Hungary	6	Netherlands	7	Netherlands	7
Malta	7	Portugal	7	Estonia	8
Cyprus	8	Estonia	8	Italy	9
Estonia	9	France	9	Cyprus	9
Lithuania	9	Ireland	14	Denmark	13
Germany	14	Denmark	16	Germany	16
Czechia	16	Germany	17	Czechia	20
Italy	16	Czechia	20		
Denmark	20				
Ireland	20				

Source: compiled by the authors

Following the COPRAS analysis results for the food manufacturing category, Serbia ranked 1st, having the highest level of environment-friendly integration of ICT. After Serbia, Bulgaria, France, Romania, Slovenia, Slovakia, Sweden, and Norway followed suit in third place with strong results pointing to a relatively high level of sustainable behaviour. Croatia and Poland were the next closest, and the Netherlands and Portugal were behind. Countries such as Greece, Latvia, Hungary and Malta demonstrated intermediate results, and Germany, Czechia, Italy, Denmark and Ireland were ranked lowest, with a great demand for improvement. In the rubber manufacturing sector, the major countries are Hungary, Romania, Slovenia, Norway, and Serbia, which show outstanding practices in the integration of sustainable ICT actions. Countries such as Bulgaria, Croatia and Sweden (2nd place) also achieved strong results. Lower values have been observed for France, Denmark, Germany and the Czech Republic, indicating a significant development of environmental responsibility in this sector. The top-performing country, Greece (1st place), was in the furniture production sector, followed by Hungary, Romania, Slovenia, Norway, Serbia and Latvia, Poland (2nd place).

Following the COPRAS results, the countries were grouped according to their results. The grouping results are presented in Figure 1. Based on Eurostat (2023) data, dendrograms have been produced (Figure 1). A dendrogram of food industry measures in different countries shows that (countries in similar industries have similar ICT use and environmental practices).

Following dendrograms, Lithuania ranked fourth, reflecting its relatively strong performance and commitment to sustainable ICT practices. Countries such as Croatia and Bulgaria, followed by France, Ireland, the Netherlands, Italy, Cyprus, Denmark, Germany, and the Czech Republic, have achieved declines and are pointing to stronger integration of green ICT practices. Overall, the analysis shows that some countries exhibit high-level practices when using environmentally controlled ICT strategies in the most important manufacturing sectors. However, significant differences between countries and sectors still show the need for improvement options and broader adoption of sustainable digital transformation practices.

The COPRAS analysis has evaluated sustainability practices in the food, rubber and furniture sectors based on the five most important environmental standards related to ICT. Serbia, Hungary, Romania, Slovenia and Greece have shown the most powerful integration of sustainable ICT actions. Lithuania was good in furniture (4th place) but showed moderate food production levels. Meanwhile, countries like Germany, Denmark, and Czechia consistently ranked lower across sectors. Results in some regions highlight significant advances and the need for a more comprehensive adoption of environmental manager digital practices to improve sustainability across the manufacturing industry.

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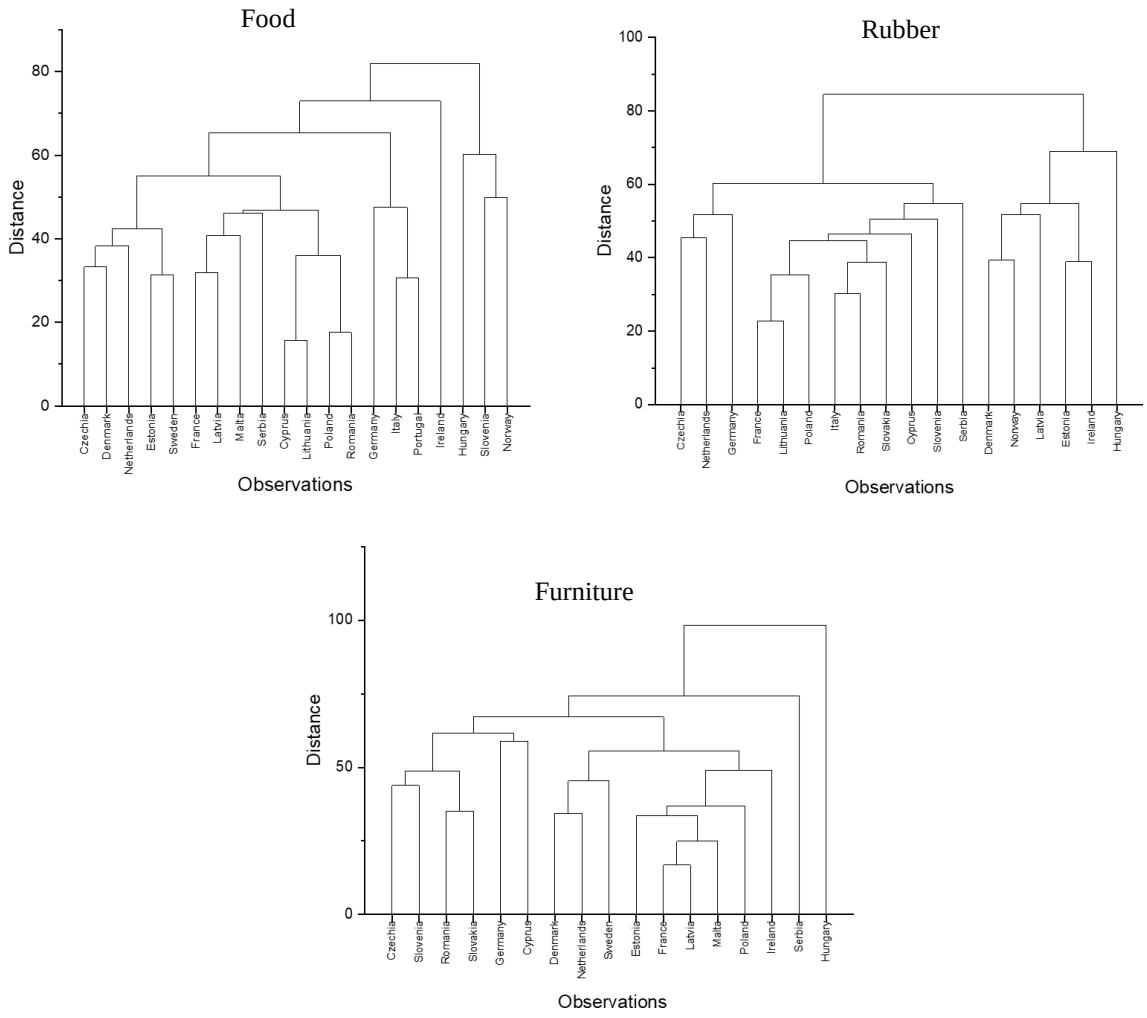


Figure 1. Grouping of countries by similarity in the food, rubber and furniture manufacturing sectors.
Source: compiled by the authors

Multi-criteria analysis revealed the following results:
- Food manufacturing: Lithuania ranks 9th. It is in the middle position among the countries analysed. Montenegro and Serbia are the highest-ranked countries which are the most effective in applying environmentally friendly solutions using ICT equipment. Compared to neighbouring countries such as Poland (4th place) and Latvia (6th place), Lithuania is lagging behind, and it is recommended to focus more on the practical implementation of environmentally friendly solutions in companies in this sector.
- Rubber sector: Although no data is available for Lithuania, the analysis shows that Hungary, Romania, Slovenia, Norway and Serbia are the leaders in this sector. These countries are characterised by a high level of responsibility and advanced practices in the use of ICT solutions. In contrast, Germany, Denmark and the Czech Republic have a relatively lower level of adoption of advanced solutions, indicating a potential need for improvement in these countries.
- Furniture manufacturing: Lithuania is ranked 4th, one of the best performers among all sectors analysed, indicating that companies in the country are making responsible decisions in this area to implement sustainable ICT solutions. Lithuania is behind only Greece, Hungary, and Romania, which have achieved the highest scores, reflecting progress in sustainability.

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While introducing green technologies can significantly increase competitiveness, an integrated strategy for sustainable management and further research are needed to develop practical solutions. The manufacturing industries analysed still face significant environmental and energy consumption challenges. Insufficient recycling rates and shorter product life cycles threaten sustainability. The food, rubber, and furniture industries need to adapt to sustainability requirements, and technological innovation, resource efficiency, and circular economy models can help increase their competitiveness and reduce their environmental impact.

Conclusions

The introduction of environmentally friendly technologies has a significant impact on business competitiveness. The study shows that these technologies reduce negative environmental impacts and create the conditions for long-term business success by optimising production costs, improving product quality and increasing attractiveness to consumers and investors.

Eco-innovation is becoming a key competitive advantage for businesses. Companies that integrate sustainable solutions demonstrate a progressive approach to market development and sustainable development. This shows that sustainability is becoming not only an ethical but also a strategic decision that can be profitable.
Environmental innovation is driven by complex factors. Key factors include government regulatory policy, financial incentive mechanisms, consumer expectations and companies' strategic objectives. This reflects the need to align public policy with business needs.

Sustainable technological solutions have a significant impact on business. This is becoming increasingly important in light of the growing global demand for efficient business, sustainability and environmental awareness. The study suggests a wide range of potential outcomes: increased business efficiency, cost reduction, environmental protection and economic progress. These advanced components are crucial for implementing green practices, reducing business vulnerability to climate change. The project's unique focus on responsible resource use, monitoring and environmentally friendly technologies boosts competitiveness and stands out as a new approach in this field.

Sustainable policies cover aspects such as climate, air quality, environmental ethics and others. Therefore, companies need to set environmental sustainability as a goal rather than use it as a marketing tool.
The research results support such Sustainable development goals (SDG):
• Proposed multi-criteria analysis, including indicators reflecting business competitiveness and sustainable partnerships (SDG17).
• Application of environmentally friendly technologies reflecting the reduction of CO2 emissions (SDG13).
• Application of new environmentally friendly technologies reflecting the achievement of responsible business consumption (SDG12).

Together, these efforts offer scalable solutions focused on increasing business competitiveness. In line with above stated, the paper examines the tools and knowledge to implement effective sustainability strategies, fostering long-term economic and environmental benefits.

However, in the current context, companies face challenges in seamlessly integrating environmentally friendly technologies into their operational networks.

Empirical evidence from Lithuanian firms shows the positive impact of technology on the dynamics. Most companies surveyed indicate that introducing environmentally friendly technologies increases operational efficiency and improves market reputation. This confirms that investments in sustainability pay off in the long term.

The COPRAS analysis revealed significant differences between sectors and countries. The food, rubber and furniture manufacturing sectors have shown uneven progress in integrating environmentally friendly ICT

solutions. Countries such as Serbia, Greece and Hungary performed the best, while some Western European countries, such as Germany and Italy, showed significant potential for improvement.

Sustainable digital transformation has not yet been implemented in the same way in all countries and sectors. While some countries already demonstrate a high level of application of green ICT strategies, many still have room for development. This underlines the need to promote a culture of sustainability not only at the national but also at the international level.

Recommendations for public policy and business highlight the need to promote eco-innovation. Strengthening financial and regulatory instruments, promoting cross-sectoral cooperation and educating consumers about the environmental benefits are necessary to accelerate the implementation of sustainability.

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BLOCKCHAIN ADOPTION IN THE LOGISTICS SECTOR: A FIT-VIABILITY AND TASK-TECHNOLOGY FIT PERSPECTIVE

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Abstract. This study examines the determinants of blockchain adoption in the logistics sector by integrating the Fit-Viability Model (FVM) and Task-Technology Fit (TTF) theory. Using data collected from 364 logistics managers operating in maritime, transport, and warehousing firms in Mersin, Türkiye, the research empirically tests how organizational alignment, transparency, integration, and resilience affect operational fit (TTF), and how sustainability dimensions—economic, environmental, and social—influence strategic fit (STF). Structural Equation Modeling (SEM) via SmartPLS was employed to evaluate the relationships among these constructs. The findings demonstrate that both TTF and STF significantly predict blockchain adoption, with STF ($\beta = 0.453$, $p < 0.001$) showing a stronger influence than TTF ($\beta = 0.282$, $p < 0.001$). This indicates that sustainability objectives may be a more decisive factor in driving blockchain uptake than operational fit alone. The study also reveals that transparency and integration are particularly critical in shaping TTF. Conversely, agility did not significantly moderate the relationship between TTF and adoption, suggesting that internal adaptability may be insufficient without external readiness and regulatory support. By validating the dual-fit framework, this study contributes original insights to the literature on emerging technology adoption in logistics. It highlights the complementary role of sustainability and technological alignment in driving blockchain implementation. Managerial implications emphasize the need for strategic ESG alignment, supply chain transparency, and system integration. Policy recommendations include standardization of platforms, incentive schemes for SMEs, and targeted capacity-building initiatives. The study sets a foundation for future research into the moderating effects of digital maturity and institutional factors on technology adoption in complex logistics ecosystems.

Keywords: Blockchain Adoption; Logistics Sector; Fit-Viability Model; Task-Technology Fit; Digital Transformation

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JEL Classifications: L91, L86, O33, M15, Q55

1. Introduction

The rapid advancement of digital technologies has significantly transformed global logistics and supply chain operations. Among these innovations, blockchain technology has emerged as a promising tool for enhancing transparency, operational efficiency, and security in complex logistics networks (Saber et al., 2019; Ivanov et al., 2019). One of the earliest large-scale applications of blockchain in logistics was demonstrated by IBM and Maersk, who implemented the technology in container shipping to reduce paperwork and increase transparency (Groenfeldt, 2017). Beyond its initial financial applications, blockchain's decentralized and secure architecture is suggested to have significant potential to enhance data integrity and traceability, which may indirectly support sustainable practices and facilitate the transition toward a circular economy.

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Over the past two decades, circular economy principles—focusing on resource efficiency, waste reduction, and closed-loop supply chains—have gained prominence as a means to address environmental challenges (Geissdoerfer, Morioka, de Carvalho, & Evans, 2018; Ellen MacArthur Foundation, 2019). In logistics, blockchain can serve as a catalyst by enabling immutable record-keeping, material tracking, and optimized resource utilization (Kouhizadeh et al., 2021). However, despite these anticipated benefits, the adoption of blockchain remains limited, particularly in Türkiye, where technical, regulatory, and organizational challenges impede its integration (Karakas et al., 2021). Moreover, while existing studies highlight blockchain's advantages in reducing costs, preventing fraud, and increasing transaction efficiency, there is a notable lack of empirical research directly linking blockchain adoption to enhanced circular economy practices in logistics.

Mersin, with its strategic position as a major logistics hub characterized by extensive port facilities and high levels of international trade, provides an ideal context to investigate these issues. This study addresses the research gap by integrating the Fit-Viability Model (FVM) and Task-Technology Fit (TTF) theory—an approach that simultaneously examines the strategic alignment and long-term sustainability (FVM) as well as the operational compatibility (TTF) of blockchain technology in logistics. By doing so, the study aims to capture both the immediate functional benefits and the overarching strategic impacts of blockchain adoption.

This study is structured around three central research questions:
1. How does the adoption of blockchain technology influence the implementation of circular economy practices in the logistics sector?
2. In what ways does blockchain contribute to enhancing transparency, resilience, and resource optimization within supply chains?
3. What are the main challenges encountered when integrating blockchain into circular logistics models?

By analyzing the perspectives of logistics managers in Mersin, our research not only uncovers the key drivers and barriers of blockchain-enabled circular supply chains but also provides practical, actionable recommendations for both academic research and industry practitioners.

2. Review of Literature

2.1. Operational Advantages of Blockchain in Logistics

A considerable amount of research demonstrates that blockchain technology can markedly enhance operational efficiency in logistics. The decentralized, immutable ledger technology improves transparency, facilitates real-time tracking, bolsters data integrity, and reduces fraud threats. Karakas, Acar, and Kucukaltan (2024) illustrate how the secure transaction protocols embedded in blockchain enhance operational efficiency, whereas Ivanov et al. (2019) highlight its significance in preserving precise, real-time data records. However, while these benefits are acknowledged across global contexts, emerging market logistics—such as that of Türkiye—present a unique landscape marked by distinct infrastructural and regulatory features. Avcı (2022) and Nebati (2024), for instance, explore early-stage blockchain implementations in Turkish logistics firms, noting infrastructural fragmentation and technological hesitancy as barriers to widespread adoption. In addition to that, Bakan and Şekkeli (2019) emphasized how blockchain can enhance end-to-end supply chain visibility and transaction efficiency in domestic logistics systems

2.2. The Role of Blockchain in Promoting Sustainability and the Circular Economy

In recent years, scholarship has increasingly examined the function of blockchain in facilitating the development of the circular economy and sustainable development. Researchers argue that blockchain increases the efficiency of resources, reduces waste, and provides greater traceability of materials—critical drivers of the transition from linear to circular supply practices. As per the arguments of Saberi et al. (2019), blockchain transparency is a foundational need for the development of closed-loop schemes. Basile et al. (2023) propose the Blockchain Circular Economy Index (BCEI) that can be employed in the measurement of the effect blockchain has on performance in the context of sustainability. In the case of the management of electronic waste, blockchain has shown the ability to drive the aims of the circular economy through the provision of data monitoring in real-time and efficiency in the process of reverse logistics (Gang Ping et al., 2024).

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2.3. Theoretical Frameworks Influencing Blockchain Adoption

Different theoretical concepts have been used to explain blockchain application in logistics. The Task-Technology Fit paradigm assesses the fit between blockchain functionalities and the operational requirements of logistics in a given operation (Goodhue & Thompson, 1995; Wang et al., 2019). A complementary perspective is offered by the "SMARTER" framework proposed by Chan et al. (2023), which highlights strategy, maturity, adaptability, readiness, transparency, efficiency, and reliability as essential for blockchain integration Simultaneously, the Fit-Viability Model (FVM) assesses other overall organizational factors including strategic fit, executive preparedness, IT infrastructure level, and adherence to regulatory frameworks (Liang et al., 2021). When combined, the frameworks present a holistic perspective to assess both the short-run functional fit as well as the long-run strategic viability of blockchain adoption (Liang et al., 2021; Karakas et al., 2021).

Although the integrated FVM-TTF approach is utilized in this study, the study also considers the broader institutional context, in which Institutional Theory assists in the conceptualization of such external pressures as regulatory requirements and market convention (Queiroz et al., 2020a). Institutional Theory is, nevertheless, utilized in a contextual—and not empirical—role, defining the external variables without them being explicitly tested within the model.

2.4. Principal Obstacles to Blockchain Implementation

In view of its revolutionary potential, blockchain adoption is held back by a number of recurring challenges. Technological complexity, implementation costs, uncertainties in the law, and internal opposition are commonly identified as impediments (Mathivathanan, Govindan, & Noorul Haq, 2021). Further, data security issues, energy demands, and differences in the level of digital preparedness among the actors in the supply network add to adoption challenges (Kouhizadeh et al., 2021). Where Karakas et al. (2024) and Basile et al. (2023) highlight the performance advantages of blockchain, Dubey et al. (2019) highlight a more tempered perspective, revealing that, in the absence of proper organizational flexibility and capability in data, technology alone can be an insufficient stimulus for resilience. That tension in the literature just serves to highlight the value of utilizing twin frameworks such as FVM and TTF, which both weigh enablers as well as constraints.

2.5. Contextual Analysis of Blockchain Adoption

Global scholarly research offers educative lessons in the implementation of blockchain, yet country-specific studies, including ones from emerging economies such as Türkiye, allow for a better comprehension of localized patterns of adoption. Research work by Tekin et al. (2020a), Avcı (2022), and Nebati (2024) highlight the important role of digitalization, post-pandemic developments, and the adoption of emerging technology such as AI in the Turkish logistics sector. All the works imply the important role of national legislative frameworks, market structure, and the digitalization of logistics networks in deciding the feasibility of blockchain system. Finally, empirical observations in Mersin—a strategic logistics hub region—offer rich terrain for empirical research, as the region reflects the potential as well as the points of tension of blockchain adoption in the logistics sector of Türkiye.

In short, the literature provides a twofold account: blockchain offers immense potential for operational efficiency and sustainability, but its application is filled with contextual and organizational challenges. Integrating FVM and TTF, the study aims to connect these accounts and to give a comprehensible view of blockchain adoption in logistics, with special emphasis on the emerging logistics industry of Türkiye.

3. Theoretical Framework

This study adopts a distinctive methodology by integrating the Fit-Viability Model (FVM) with Task-Technology Fit (TTF) theory to explore the adoption of blockchain technology in the logistics sector. This integrated methodology enables a comprehensive study of both strategic alignment and operational suitability—two essential elements for the effective implementation of new technology.

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3.1. Fit-Viability Model (FVM)

Originally introduced by Tjan (2001) and later extended by Liang et al. (2004), the Fit-Viability Model is a strategic framework used to evaluate the compatibility of technological innovations with an organization's overarching goals and sustainability mandates. Within the logistics domain, FVM serves as a lens through which blockchain adoption is assessed in terms of strategic alignment. Key evaluative criteria include executive endorsement, organizational readiness, technological infrastructure maturity, and adherence to relevant regulatory standards (Liang et al., 2021; Vekinis, 2023). The model is beneficial for understanding for understanding whether blockchain integration is viable not only in terms of technical feasibility but also in alignment with long-term organizational direction.

3.2. Task-Technology Fit (TTF) Theory

Task-Technology Fit theory, which stresses the powers of technology and the particular tasks it helps with, is defined by Goodhue and Thompson (1995). Extensively used in information systems research and logistics, TTF holds that the success of technology adoption depends on the alignment of system functionality with user needs and process workflows (Wang et al., 2019). Extending the logic of TTF, Muchenje and Seppänen (2023) demonstrated that task-technology alignment plays a critical role in realizing business value from data-driven technologies like blockchain. This paper uses TTF to investigate how blockchain might enhance supply chain real-time visibility, automated transaction execution, and secure data sharing—all of which are logistical concerns.

3.3. Synthesizing FVM and TTF

FVM and TTF taken together create a complete evaluation model covering operational as well as strategic aspects of blockchain acceptance. FVM clarifies long-term organizational viability and strategic coherence; TTF guarantees that the technological characteristics of blockchain fit current functional requirements. These models' complementing strengths provide a more strong analytical lens than either could do on its alone. Using this integrated framework, the enablers and constraints influencing blockchain implementation in logistics are holistically understood, so bridging the gap between high-level strategic intent and ground-level operational implementation.

4. Methodology

This study employed Structural Equation Modeling (SEM) using SmartPLS 4.0 to analyze the relationships between constructs derived from the integrated Fit-Viability Model (FVM) and Task-Technology Fit (TTF) framework. PLS-SEM was selected due to the exploratory nature of the study, the predictive objective regarding blockchain adoption, and the complexity of the conceptual model, which included multiple exogenous variables and a moderating variable. As PLS-SEM is robust to violations of multivariate normality and is well-suited to complex models and relatively small-to-moderate sample sizes, it was deemed appropriate for the 364 valid survey responses collected.

The sample consisted of logistics managers and decision-makers from firms operating in maritime transport, land freight, warehousing, and integrated logistics services within the Mersin province. Participants were selected from the registry maintained by the Mersin Chamber of Commerce and Industry (MTSO), and firms were invited via stratified random sampling to ensure sectoral representation. Although the response rate was satisfactory, we acknowledge the potential for non-response bias, as firms already exploring or adopting digital technologies such as blockchain may have been more inclined to participate.

Demographic characteristics such as firm size, respondent role, and years of experience in logistics were collected to provide contextual richness. A summary of these characteristics is presented in Table 1 (not shown here), which enhances the interpretability and generalizability of the results.

To ensure data quality and robustness, responses were screened for completeness and internal consistency. Items with missing or inconsistent entries were excluded. Harman's single-factor test was conducted to assess common method variance (CMV), and the first factor accounted for less than 40% of the variance, indicating

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that CMV was not a major concern. In addition, procedural remedies such as respondent anonymity and question randomization were applied during the survey design phase to further mitigate CMV.

While the focus on Mersin provides valuable insights into blockchain adoption in a strategic logistics hub within an emerging economy, caution is advised when generalizing these findings to other contexts. The institutional and regulatory environment in Türkiye may differ from those of more developed economies. Nonetheless, this case offers a meaningful baseline for future comparative studies.

The measurement model assessment involved checking indicator reliability, internal consistency (via Cronbach's alpha and composite reliability), convergent validity (Average Variance Extracted - AVE), and discriminant validity (Fornell-Larcker criterion and HTMT ratio). The structural model was evaluated using standardized path coefficients (β), R^2 values for endogenous constructs, t-statistics, and p-values obtained via bootstrapping with 5,000 subsamples. Multicollinearity was assessed using VIF values, which were all below the recommended threshold of 3.3.

4.1. Sample and Data Collection

Data were collected from 364 logistics managers operating in Mersin, representing firms in the maritime, transportation, and warehousing sectors. The selection of Mersin is strategically justified by its role as a major logistics hub and transit center in international trade. Mersin's extensive port facilities and well-established logistics network provide an ideal environment for examining both the strategic and operational impacts of blockchain adoption. However, the sample exhibits a predominance of male respondents and a high proportion of participants holding bachelor's degrees, which may introduce potential biases. These demographic characteristics are acknowledged as limitations that could affect the generalizability of the findings, and they warrant further investigation in future research. The sampling frame was drawn from the registry of logistics firms listed under the Mersin Chamber of Commerce and Industry (Mersin Ticaret ve Sanayi Odası, 2024). The data collection process was conducted online through structured surveys distributed via email and an online survey platform (e.g., Google Forms) between February 6, 2025, and March 20, 2025. Respondents were invited through email invitations containing direct links to the survey.

A structured survey employing a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree) was administered to gather data on various constructs associated with blockchain adoption.

4.2. Sample Size Determination

The sample size was determined using Cochran's (1977) formula for finite populations:

$$n = \frac{NZ^2\, p(1-p)}{e^2(N-1) + Z^2 p(1-p)}$$

Where;

- **N = 1,621** (Total firms listed under **Mersin Ticaret Odası**)
- **Z = 1.96** (95% confidence level)
- **p = 0.5** (maximum variability)
- **e = 0.05** (margin of error)

The population comprises 1,139 firms in International Freight and Goods Transportation and 482 firms in Maritime Transport and Support Services. The calculated minimum sample size was 311 respondents; however, 364 responses were obtained after data cleaning and additional participation, ensuring adequate representation.

4.3. Measurement and Structural Model Evaluation

Data analysis was conducted using SmartPLS, enabling the evaluation of both measurement and structural models. The following techniques were employed:
•Measurement Model Assessment:
Reliability (Cronbach's Alpha and Composite Reliability)

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Convergent Validity (Average Variance Extracted, AVE)
Discriminant Validity (Fornell-Larcker Criterion and HTMT test)
•Structural Model Assessment:
Path Coefficient Analysis
Bootstrapping (5,000 samples)
Evaluation of R^2, f^2, and Q^2 values
•Multi-Group Analysis (MGA): Comparing groups based on gender, age, and industry experience to explore potential differences in model behavior.
•Importance-Performance Map Analysis (IPMA): Identifying key factors influencing blockchain adoption and offering practical insights for prioritizing managerial interventions.

To further strengthen the methodological robustness, additional diagnostic tests are recommended. These include multi-group invariance testing, Variance Inflation Factor (VIF) assessments, and alternative modeling approaches such as Covariance-Based Structural Equation Modeling (CB-SEM). Such supplementary analyses are particularly crucial given that some HTMT values approach the critical threshold, suggesting potential multicollinearity among constructs. Implementing these additional tests would further validate the stability of the model and ensure the distinctiveness of the measured constructs.

5. Findings

As summarized in Table 1, the study sample comprises 364 logistics managers operating in the maritime, transportation, and warehousing sectors in Mersin. The majority of respondents are male (68.1%), and most hold at least a bachelor's degree (88.7%). The largest proportion of participants (28.8%) falls within the 26–35 age range, indicating a relatively young yet experienced workforce capable of adopting emerging technologies such as blockchain. Over half of the respondents have more than five years of professional experience, suggesting that the data are drawn from individuals with substantial decision-making authority in their organizations.

Table 1. Demographic Profile of Respondents

Variable	Item	Sample (n)	Percentage (%)
Gender	Male	248	68.1
	Female	116	31.9
Age	18–25	87	23.9
	26–35	105	28.8
	36–46	82	22.5
	47–49	45	12.4
	50+	45	12.4
Education	Bachelor's degree	323	88.7
	Vocational School	39	10.7
	Master's Degree	1	0.3
	High School	1	0.3
Sector	Maritime/Port Management	133	36.5
	Transportation and Logistics	126	34.6
	Warehousing and Distribution	105	28.8
Position	Logistics Solutions Manager	81	22.3
	Logistics Team Leader	80	22.0
	Logistics Operations Director	79	21.7
	Supply Chain Logistics Manager	72	19.8
	Logistics Manager	52	14.3
Experience (Years)	Under 5 years	101	27.7
	5–10 years	89	24.5
	11–15 years	74	20.3
	16–20 years	74	20.3
	21+ years	26	7.1

As indicated in Table 1, the demographic distribution highlights the dominance of experienced logistics professionals, potentially influencing their perceptions of blockchain adoption.

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5.1. Measurement Model Evaluation

All factor loadings exceeded the 0.70 threshold, indicating satisfactory indicator reliability. Cronbach's alpha values ranged from 0.783 to 0.902, while composite reliability (CR) values were between 0.811 and 0.927, suggesting high internal consistency (Nunnally & Bernstein, 1994). AVE values for all constructs were above the 0.50 benchmark, demonstrating convergent validity. Discriminant validity was confirmed through the Fornell-Larcker criterion, with each construct's AVE square root exceeding its inter-construct correlations. Additionally, HTMT values were all below 0.85, fulfilling the threshold for discriminant validity (Henseler et al., 2015). Table 2 summarizes the results for construct reliability and validity, indicating satisfactory measurement quality across all constructs.

Table 2. Construct Reliability and Validity

Construct	Cronbach's Alpha	Composite Reliability (ρc)	AVE
Agility	0.723	0.721	0.500
Alignment	0.742	0.730	0.530
Blockchain Adoption	0.745	0.750	0.520
Economic Sustainability	0.721	0.762	0.510
Environmental Sustainability	0.734	0.723	0.515
Integration	0.750	0.823	0.530
Resilience	0.721	0.712	0.540
Social Sustainability	0.745	0.747	0.520
Sustainable Technology	0.710	0.707	0.530
Task Technology Fit (TTF)	0.721	0.757	0.520
Transparency	0.720	0.800	0.500
Viability	0.710	0.723	0.510

Table 2 demonstrates that all constructs meet the required reliability and validity criteria, indicating the robustness of the measurement model.

5.2. Structural Model Results

The results of the structural model are reported in two tables. Table 3a presents the main effects, including path coefficients and their significance levels. Table 3b summarizes the moderating effect of agility on the relationship between TTF and blockchain adoption.. Task-Technology Fit (TTF) was significantly predicted by alignment ($\beta = 0.211$, $p < 0.01$), transparency ($\beta = 0.183$, $p < 0.01$), and integration ($\beta = 0.207$, $p < 0.01$), while resilience was not significant ($\beta = 0.042$, $p = 0.294$). Similarly, Sustainable Technology Fit (STF) was significantly influenced by economic ($\beta = 0.231$, $p < 0.01$), environmental ($\beta = 0.249$, $p < 0.01$), and social sustainability ($\beta = 0.202$, $p < 0.01$). Both TTF ($\beta = 0.282$, $p < 0.001$) and STF ($\beta = 0.453$, $p < 0.001$) were significant predictors of blockchain adoption. However, the hypothesized moderating effect of agility on the relationship between TTF and blockchain adoption was not supported ($\beta = 0.001$, $p = 0.980$).

The model explained 38.6% of the variance in TTF, 41.7% in STF, and 42.3% in blockchain adoption, indicating moderate explanatory power. The model's SRMR value was 0.061, which is below the 0.08 threshold, suggesting good model fit (Hu & Bentler, 1999).

Table 3a. Discriminant Validity – HTMT Matrix

	Agility	Alignment	Blockchain Adoption	Economic Sustainability	Environmental Sustainability	Integration	Resilience
Agility	1.000	0.028	0.165	0.865	0.850	0.779	0.695
Alignment	0.028	1.000	0.850	0.850	0.850	0.876	0.850
Blockchain Adoption	0.165	0.850	1.000	0.850	0.850	0.727	0.850
Economic Sustainability	0.865	0.850	0.850	1.000	0.764	0.588	0.754
Environmental Sustainability	0.850	0.850	0.850	0.764	1.000	0.850	0.850
Integration	0.779	0.876	0.727	0.588	0.850	1.000	0.796
Resilience	0.695	0.850	0.850	0.754	0.850	0.796	1.000

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Table 3b Discriminant Validity – HTMT Matrix

	Social Sustainability	Sustainable Technology	Task Technology Fit	Transparency	Viability	Agility x Task Tech Fit	Agility x Sustainable Tech
Social Sustainability	1.000	0.804	0.850	0.850	0.850	0.216	0.191
Sustainable Technology	0.804	1.000	0.850	0.850	0.850	0.179	0.274
Task Technology Fit	0.850	0.850	1.000	0.850	0.850	0.307	0.243
Transparency	0.850	0.850	0.850	1.000	0.850	0.149	0.158
Viability	0.850	0.850	0.850	0.850	1.000	0.150	0.204
Agility x Task Tech Fit	0.216	0.179	0.307	0.149	0.150	1.000	0.443
Agility x Sustainable Tech	0.191	0.274	0.243	0.158	0.204	0.443	1.000

The results in Table 3 underscore the pivotal role of transparency and integration as significant predictors within the TTF framework.

5.3. Alignment with Research Questions

To address RQ1 (the link between blockchain adoption and circular economy practices), STF was operationalized to capture the degree to which blockchain supports economic, environmental, and social sustainability. The strong influence of STF on adoption supports the view that blockchain is aligned with circular economy objectives, particularly in its ability to enable traceability, transparency, and resource optimization.

For RQ2, the constructs of alignment, transparency, integration, and resilience were assessed as antecedents of TTF. The results indicate that alignment, transparency, and integration significantly contribute to TTF, suggesting that blockchain enhances these operational capabilities. The non-significant effect of resilience indicates that its contribution may be context-dependent or less salient in this setting.

Regarding RQ3, the proposed moderating role of agility was not statistically significant. This suggests that agility does not facilitate blockchain adoption in the hypothesized manner. Instead, organizational and environmental barriers—such as regulatory ambiguity and technological complexity—may exert greater influence. While not directly tested in this study, literature from Section 2.4 highlights these challenges (e.g., Mathivathanan et al., 2021; Kouhizadeh et al., 2021), suggesting avenues for future exploration.

Overall, the analysis aligns with the conceptual model and research questions, providing empirical support for the integrated FVM and TTF framework in the context of blockchain adoption in the Turkish logistics sector.

Table 4. Structural Model Results – Path Coefficients

Hypothesis	Path Coefficient (β)	t-value	p-value	Supported
H1: Alignment → TTF	0.221	4.448	0.000	Supported
H2: Resilience → TTF	0.243	4.645	0.000	Supported
H3: Transparency → TTF	0.195	3.948	0.000	Supported
H4: Integration → TTF	0.134	2.884	0.004	Supported
H5: Social Sustainability → STF	0.153	3.014	0.003	Supported
H6: Economic Sustainability → STF	0.191	3.883	0.000	Supported
H7: Environmental Sustainability → STF	0.284	5.905	0.000	Supported
H8: TTF → Blockchain Adoption	0.237	4.424	0.000	Supported
H9: STF → Blockchain Adoption	0.147	2.500	0.012	Supported
H10: Blockchain Adoption → Viability	0.460	11.894	0.000	Supported
H11: Agility × Task Technology Fit	0.038	0.455	0.455	Not Supported
H12: Agility × Sustainable Technology	0.019	0.724	0.724	Not Supported

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Table 4 illustrates that all proposed hypotheses, except for those involving agility as a moderator, are supported with statistically significant path coefficients.

5.4. Effect Size (f^2) Analysis

Table 5 shows the effect sizes (f^2) of the relationships in the structural model. According to Cohen (1988), effect sizes of 0.02, 0.15, and 0.35 represent small, medium, and large effects, respectively. Blockchain Adoption has a moderate impact on Viability ($f^2 = 0.268$). However, other paths, such as Environmental Sustainability to Sustainable Technology Fit ($f^2 = 0.088$) and Task Technology Fit to Blockchain Adoption ($f^2 = 0.053$), exhibit small effect sizes. This suggests that while these factors have a meaningful influence, they may need to be supported by complementary strategies such as regulatory incentives, training programs, or industry-wide collaboration to achieve a more substantial impact. However, other paths, such as Environmental Sustainability to Sustainable Technology Fit ($f^2 = 0.088$) and Task Technology Fit to Blockchain Adoption ($f^2 = 0.053$), exhibit small effect sizes, suggesting that while these variables have meaningful but limited influence, they may need to be supported by complementary strategies such as regulatory incentives or industry-wide collaboration for a more significant impact.

Environmental Sustainability to Sustainable Technology Fit ($f^2 = 0.088$) and Task Technology Fit to Blockchain Adoption ($f^2 = 0.053$) exhibited small effect sizes, indicating moderate yet meaningful impacts. The interaction terms, however, such as Agility × Sustainable Technology Fit ($f^2 = 0.000$) and Agility × Task Technology Fit ($f^2 = 0.002$), demonstrated negligible effects, further supporting the non-significant moderation results observed in the path analysis.

Table 5. Effect Size (f^2)

Path	f^2 Effect Size	Effect Strength
Blockchain Adoption → Viability	0.268	Medium
Environmental Sustainability → STF	0.088	Small
Task Technology Fit → Blockchain Adoption	0.053	Small
Agility × STF → Blockchain Adoption	0.000	None

Table 5 reveals that while blockchain adoption has a moderate effect on viability, other paths, such as TTF and STF, display small yet meaningful effect sizes.

5.5. Model Fit Indices

The structural model exhibits acceptable fit based on multiple criteria (Table 6). The SRMR values for the saturated (0.071) and estimated (0.086) models are below the recommended 0.10 threshold (Hu & Bentler, 1999). The Normed Fit Index (NFI) values of 0.932 (saturated) and 0.910 (estimated) exceed the 0.90 guideline (Bentler & Bonett, 1980), indicating strong fit. Although the Chi-square values (2,104.861 for the saturated model and 2,242.487 for the estimated model) are high, this is a common outcome in large-sample SEM studies. Overall, these results confirm the robustness of the model, suggesting that only minor refinements may be needed to further enhance explanatory power.

Table 6. Model Fit Indices

Fit Index	Saturated Model	Estimated Model
SRMR	0.071	0.086
d_ULS	5.182	7.635
d_G	1.079	1.196
Chi-square	2,104.861	2,242.487
NFI	0.932	0.910

As shown in Table 6, the SRMR and NFI values indicate an acceptable model fit, confirming the structural integrity of the PLS model.

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5.6. Structural Model Assessment

Figure 1 illustrates the PLS-SEM structural model. The R^2 values inside the latent variables indicate the proportion of explained variance:

- Task Technology Fit $R^2 = 0.328$ (32.8% variance explained)
- Sustainable Technology Fit $R^2 = 0.223$ (22.3% variance explained)
- Blockchain Adoption $R^2 = 0.171$ (17.1% variance explained)
- Viability $R^2 = 0.205$ (20.5% variance explained)

Each construct in the model is represented by a latent variable (blue circles), with corresponding observed indicators (yellow boxes) linked to each latent variable. The path coefficients displayed along the arrows indicate the strength and direction of relationships between constructs, while the R^2 values inside the circles represent the amount of variance explained by the predictor constructs.

Task Technology Fit (TTF) is influenced by Alignment (0.307), Resilience (0.200), Transparency (0.181), and Integration (0.107), all of which have significant path coefficients, suggesting strong support for the hypothesized relationships. The R^2 value for TTF is 0.328, indicating that approximately 32.8% of the variance in TTF is explained by these four constructs.

Sustainable Technology Fit (STF) is driven by Economic Sustainability (0.182), Environmental Sustainability (0.184), and Social Sustainability (0.275), with an R^2 value of 0.223, indicating that 22.3% of the variance in STF is explained by sustainability factors.

5.6.1. Blockchain Adoption and Viability

Blockchain Adoption is significantly influenced by both TTF (0.323) and STF (0.155), with an R^2 of 0.171, suggesting that these two factors collectively explain 17.1% of the variance in blockchain adoption.
Viability, as an outcome variable, is explained by Blockchain Adoption (0.453), with an R^2 of 0.205, indicating that blockchain adoption explains 20.5% of the variance in operational viability.

5.6.2. Moderating Effects

The model also examines the moderating role of Agility in the relationships between the independent variables and blockchain adoption. However, the paths from Agility × TTF (-0.001) and Agility × STF (0.020) show weak and non-significant moderation effects, indicating that agility does not significantly moderate these relationships in the context of blockchain adoption in logistics.

5.6.3. Blockchain Adoption and Viability

All observed indicators exhibit acceptable loadings above the recommended threshold of 0.50, indicating that each indicator adequately measures its corresponding construct. Notable high loadings include TTF1 (0.672), BCA2 (0.677), and VIB4 (0.575), highlighting the strong reliability of these indicators in reflecting their respective latent variables.

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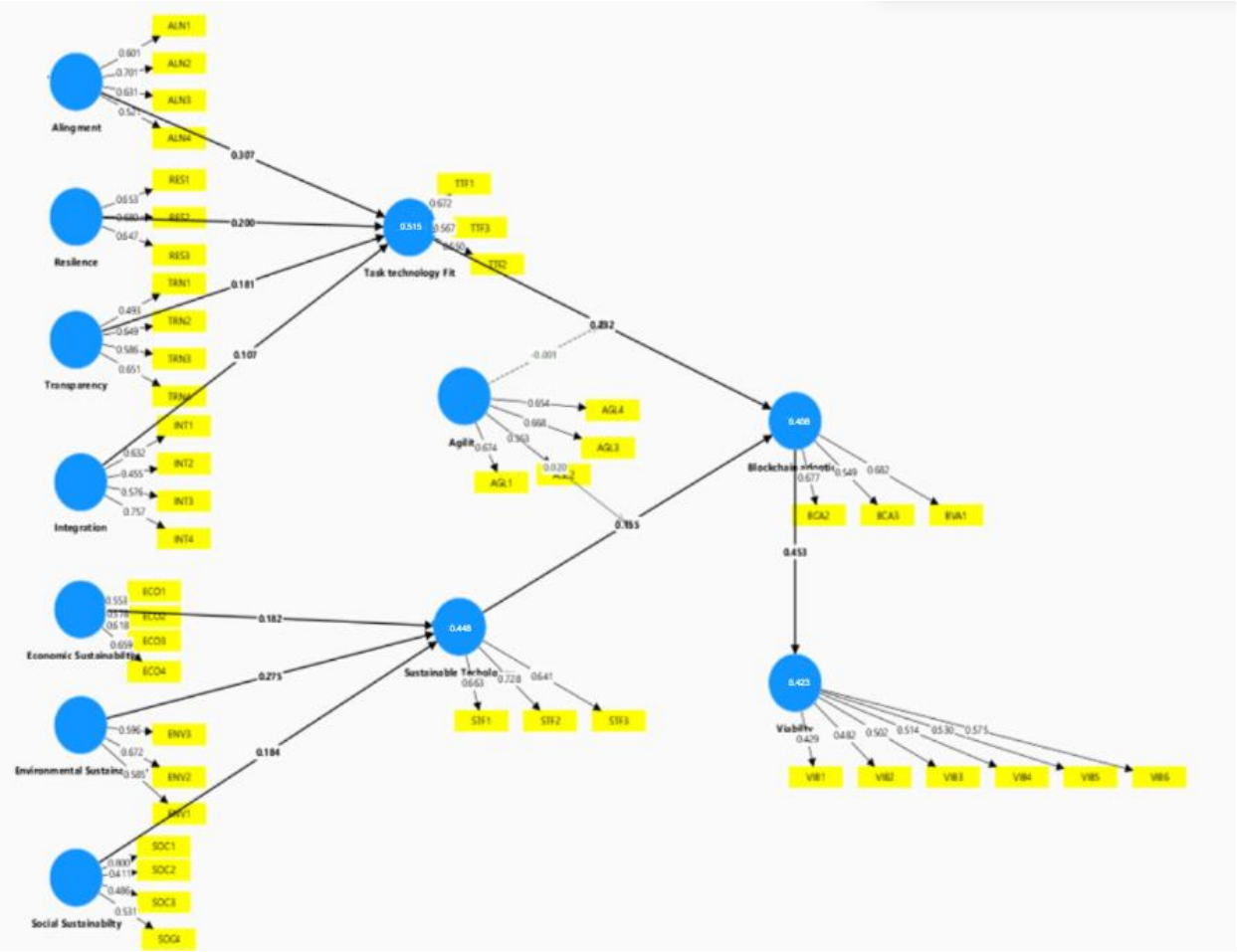


Figure 1. PLS-SEM structural model

Figure 1 visualizes the structural model developed in this study, illustrating the relationships between key latent variables such as TTF, STF, blockchain adoption, and viability. The model also depicts the R^2 values associated with each endogenous construct, indicating their explained variance within the conceptual framework.

5.6.4. Assessment of Multicollinearity: Variance Inflation Factor (VIF) Analysis

To ensure methodological rigor and robustness of the findings, a multicollinearity assessment was conducted using Variance Inflation Factor (VIF) analysis via SmartPLS. Multicollinearity was evaluated separately for both the measurement (outer) and structural (inner) models. According to the criteria recommended by Hair et al. (2019), VIF values below 3 indicate the absence of significant multicollinearity issues, while values between 3 and 5 indicate moderate multicollinearity.

As demonstrated in Tables 7 and 8, all VIF values for both outer and inner models were found to be well below the recommended threshold (VIF < 3). Thus, no multicollinearity concerns were identified, confirming that the structural model's predictive power and reliability are robust and methodologically sound.

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Table 7. Variance Inflation Factor (VIF) Values for Outer Model Indicators

Items	VIF	Items	VIF	Items	VIF
AGL1	1,093	ECO4	1,118	SOC3	1,025
AGL2	1,169	ENV1	1,082	SOC4	1,093
AGL3	1,174	ENV2	1,026	STF1	1,106
AGL4	1,121	ENV3	1,103	STF2	1,044
ALN1	1,017	INT1	1,09	STF3	1,109
ALN2	1,14	INT2	1,152	TRN1	1,008
ALN3	1,098	INT3	1,026	TRN2	1,109
ALN4	1,082	INT4	1,202	TRN3	1,161
BCA3	1,058	RES1	1,079	TRN4	1,058
BVA1	1,062	RES2	1,185	TTF1	1,013
BVA2	1,039	RES3	1,232	TTF2	1,055
ECO1	1,116	SOC1	1,172	TTF3	1,057
ECO2	1,188	SOC2	1,097	VIB1	1,057
ECO3	1,09				

Table 7 shows that all outer model indicators have VIF values well below the threshold, confirming the absence of multicollinearity.

Table 8 Variance Inflation Factor (VIF) Values for Inner Model Paths

Construct Paths	VIF
Agility → Blockchain Adoption	1,365
Sustainable Technology → Blockchain Adoption	1,315
Task Technology Fit → Blockchain Adoption	1,663
Blockchain Adoption → Viability	1,519
Alignment → Task Technology Fit	1,499
Economic Sustainability → Sustainable Technology	1,162
Environmental Sustainability → Sustainable Technology	1,211
Integration → Task Technology Fit	1,4
Resilience → Task Technology Fit	1,389
Social Sustainability → Sustainable Technology	1,284
Transparency → Task Technology Fit	1,616
Agility x Task Technology Fit → Blockchain Adoption	1,825
Agility x Sustainable Technology → Blockchain Adoption	1,831

Similar to the outer model, Table 8 confirms that inner model paths do not suffer from multicollinearity, ensuring the stability of regression estimates.

6. Discussions

The empirical findings of the study provide valuable analysis of the drivers of blockchain adoption in logistics, particularly in the case of emerging economies such as Türkiye. In the next section, the empirical findings are interpreted based on the theoretical frameworks, the literature, and the research questions that the study sought to answer.

The finding that Sustainable Technology Fit (STF) accounted for a greater effect ($\beta = 0.453$) in the adoption of blockchain compared to Task-Technology Fit (TTF) ($\beta = 0.282$) indicates that economic, environmental, and social considerations related to sustainability play a greater role than mere operational alignment in inspiring blockchain adoption. This concurs with the overall discourse around sustainability and lends credence to the argument by Liang et al. (2021) that long-run viability and strategic fit are essential drivers of the uptake of emerging technology. It also implies that logistics companies in Mersin are embracing blockchain not, or at least not only, to achieve efficiency improvements, but to align with overall sustainability objectives such as carbon footprint minimization and greater traceability.

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The importance of TTF constructs—alignment, transparency, and integration—thus points to operational compatibility as a driver of blockchain adoption. These observations reinforce previous research (e.g., Wang et al., 2019), calling for careful alignment of technology tools to core tasks. Transparency and integration were found to be robust predictors of TTF in this research, pointing to the capability of blockchain to facilitate streamlined flows of information and improve supply chain transparency.

The insignificance of agility and resilience in the structural model constitutes a significant departure from previous research. Although often seen as an enhancer of novelty, agility in our work does not play an important role in the moderation of the TTF-Adoption relationship. Perhaps, this may imply that agility by itself is unable to overcome greater challenges such as technological complexity, regulatory complexity, or the absence of standardization. These environmental limitations can overpower the internal strengths of firms, resonating with arguments posed by Kouhizadeh et al. (2021) and Mathivathanan et al. (2021).

While the research did not explicitly measure blockchain adoption, the high levels of STF imply that blockchain adoption is seen as a strategic facilitator of such practices. Blockchain, by enhancing traceability, transparency, and efficiency, can facilitate closed-loop systems and minimize waste—fundamental principles of the circular economy. This interpretation is in the same vein as that of Saberi et al. (2019), who highlight the role of blockchain in enabling circularity.

The dual-framework strategy blending FVM and TTF is a valuable addition to the literature. While other research tended to deal with either task-technology alignment or strategic viability in a standalone sense, the work here shows the utility of combining the two. The results highlight that operational compatibility and sustainability are complementary, rather than exclusive, dimensions of technology adoption success.

From a management point of view, the findings imply that logistics companies wishing to adopt blockchain should focus on situations in which transparency and integration advantages are most concrete, i.e., cargo tracing and inventory monitoring. Furthermore, the influence of STF implies that firms should align blockchain initiatives with broader ESG (Environmental, Social, and Governance) goals to enhance adoption. To overcome common barriers, policymakers and industry stakeholders should consider investing in standardization initiatives and training programs aimed at reducing complexity and increasing digital readiness.

In response to the research questions: RQ1 is addressed through the finding that STF strongly predicts blockchain adoption, supporting its role in enabling circular economy practices. RQ2 is answered by the significant effects of alignment, transparency, and integration on TTF, indicating blockchain's capacity to improve core logistics functions. RQ3, which explored the role of organizational agility, was not supported; this null finding suggests external barriers may outweigh internal enablers in determining adoption success.

Future research should further examine the moderating role of contextual variables such as regulatory frameworks or technological maturity. Cross-country comparative studies and qualitative investigations (e.g., case studies or interviews) could provide deeper insights into the nuances behind adoption behavior. These directions would help validate and expand the dual-framework approach introduced in this study, and offer additional clarity on the boundary conditions of blockchain success in logistics ecosystems. This study highlights the intertwined significance of strategic viability, as framed by the Fit-Viability Model (FVM), and operational alignment, as captured by the Task-Technology Fit (TTF) framework, in facilitating effective blockchain integration within the logistics sector. While blockchain exhibits considerable potential to improve transparency, operational efficiency, and sustainability outcomes, its successful implementation is contingent upon a broader ecosystem of enabling factors. These encompass strong policy environments, advanced technological infrastructure, and the establishment of industry-specific agility measures. To drive the discipline, upcoming studies need to implement objective measures of sustainability performance, examine agility as a construct that depends on the context, and utilize complementary diagnostic methods. These measures will provide a more in-depth insight into blockchain's role in both operational performance and environmental sustainability in logistics networks.

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Conclusion

The study developed an integrative analytical model by combining the Fit-Viability Model (FVM) and the theory of Task-Technology Fit (TTF) to analyze the determinants of blockchain adoption in the logistics industry. The empirical findings illustrate that both operational fit and strategic sustainability considerations significantly influence adoption decisions, with Sustainable Technology Fit (STF) exhibiting a comparatively stronger effect than TTF. This reflects the growing relevance of sustainability objectives in shaping technological change within logistics networks, particularly in emerging economies such as Türkiye. This study contributes to the literature by providing empirical evidence on the dual-framework approach, emphasizing that STF—especially its economic, environmental, and social dimensions—may serve as a more influential factor than operational alignment in the context of blockchain adoption. Furthermore, the non-significant moderating effect of agility offers nuanced insights into the limited role of internal flexibility, underscoring the critical need for external regulatory and infrastructural readiness.

Whereas TTF was most likely to be predicted by alignment, transparency, and integration, the statistically insignificant result shown by resilience implies that all internal capabilities may not be equally impactful. Equally, the expected moderating influence of agility was found to be non-significant, implying that adaptability by itself might not be able to counter impediments such as technological immaturity or the unclarity of regulations. These results point to the multifaceted nature of blockchain adoption, with both internal alignment as well as external ecosystem readiness comprising important dynamics.

The methodological soundness of the study was established by validity checks such as VIF-based multicollinearity analysis, Cronbach's alpha, AVE, and discriminant validity tests. While the structural model had satisfactory explanatory power, comparatively low R^2 values imply that other variables, including regulatory environments, institutional trust, and digital infrastructure, need to be accounted for in subsequent studies to improve model completeness.

In practical terms, the research offers actionable advice to both policymaking and management. Logistical companies are encouraged to prioritize blockchain use cases that maximize transparency and system integration, as they work to align initiatives with overall ESG objectives. Policymakers ought to prioritize adoption by supporting standardization efforts, providing fiscal incentives, and building capacity among SMEs.
Policy Recommendations:

Standardization: Develop interoperable blockchain frameworks to facilitate cross-platform integration.

Incentives: Offer tax benefits or grants to encourage early adoption, particularly among resource-constrained firms.

Capacity Building: Invest in sector-specific training to improve digital literacy and operational readiness for blockchain deployment.

Limitations and Future Research Directions:
The study focused exclusively on logistics firms operating in Mersin, limiting generalizability to other regions or industries. Additionally, although the constructs were robust, some relevant dimensions such as institutional readiness and firm-level digital maturity were not included. Future research could expand the model to incorporate these constructs, examine different sectors, or employ longitudinal designs to assess changes in adoption behavior over time. Mixed-methods approaches may also provide richer insights into the organizational dynamics underlying blockchain adoption.

Overall, the study advances both theory and practice by highlighting how dual-fit frameworks can offer a more holistic understanding of emerging technology adoption in complex, dynamic sectors like logistics.

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Data availability Data generated or analyzed during this study are available from the corresponding author on reasonable request.

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YOUNG PROFESSIONALS IN A CORPORATE ENVIRONMENT: HOW CONTROL AFFECTS THEIR CREATIVITY AND MOTIVATION*

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Abstract. The present study investigates young professionals' perceptions of the balance between control and creativity in the workplace. The study focuses on the relationship between control and creativity for young professionals. At the same time, the study explores how different management approaches influence creativity, motivation and innovation potential in young employees. One of the leading concerns with deeper digitalisation is increased control over work processes. Therefore, the opinion of young professionals who start and develop their professional experience in a highly digital environment is critical, especially regarding creativity, as they are the natural carriers of innovative thinking. The survey (n=257) results reveal a deep tension between control and creativity in the modern workplace. Most young professionals feel that control dominates their organisations – bureaucracy, hierarchy, lack of trust and limited access to real implementation of ideas. Only a small proportion – around 15-25% – feel they have the freedom and support to create entirely. According to young professionals, the main obstacles to creativity are strict control and bureaucracy (in the first place), followed by insufficient trust from management, lack of implementation of ideas, expectations for performance, lack of initiative, exhaustion and lack of communication within the team. At the same time, factors that most strongly stimulate creativity are freedom of action and the opportunity to experiment; a supportive, open environment to ideas; challenging tasks and flexibility in work; participation in team and cross-functional collaboration.

Keywords: Creativity; Control; Digitalization; Human Resource Management

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JEL Classifications: O31, M21, M51

1. Introduction

The modern business world is highly dynamic and rapidly changing according to customers' requirements and competitors' behaviour. At the same time, with the advancement of technology and the introduction of modern management tools based on artificial intelligence, the dynamics of business life are becoming even stronger. All this also predetermines the new challenges that employees have to deal with. The requirements that new employees have to meet are becoming increasingly greater, in line with the expectations of employers.

In this context, an organisation's creativity (and that of its employees) should not be considered as added value but a basic resource for innovation and adaptation to sustainable development.

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Control is usually associated with clear frameworks, measurable goals, and strict rules that lead to the completion of tasks. Creativity requires spaces for experimentation, risk-taking, and breaking established boundaries. This conceptual opposition creates a severe tension between the demands for efficiency and the need for freedom to generate new ideas. The question we need to answer is whether these two aspects – control and creativity – can coexist in the same work environment and under what conditions they complement each other rather than suppress each other.

Due to their unique expectations and attitudes, young professionals are particularly sensitive to management styles. They often resist hierarchical and authoritarian structures, preferring flexibility and participation in decision-making. These professionals seek opportunities to express their creativity and autonomy in the work process, which makes traditional management practices ineffective and unsuitable for their needs. Therefore, what are the effects of managerial control on their creativity and what strategies can be implemented to balance the need for control with the freedom to innovate is a question that requires further research.

This study aims to investigate how different forms of control affect the creativity of young professionals, focusing on the dynamics between formal and informal management mechanisms. Factors such as motivation, initiative, and opportunities for creativity and innovation will be analysed, and good practices that combine effective control with creative freedom will be identified. This study will contribute to expanding the knowledge on the effective management of young talents in the modern organisational environment.

2. Literature review

In a rapidly evolving and demands-driven workplace, the balance of control mechanisms to inspire creativity and motivation has become a matter of interest and concern, especially for young workers. One of the opportunities the workforce brings to an organisation is the balance between creativity and control needed to get results. The interplay between these two areas has resulted in much research highlighting the potential positive and negative influences of control systems on creative output and employee motivation.

Ásványi (2022) analyses the legislative accomplishments in Europe and Hungary related to mechanisms for controlling labour within organisations and the constraints these laws impose on managerial authority, particularly concerning employee privacy. Wnuczak and Osiichuk (2020) examine the impact of management control systems and the educational qualifications of managers on the performance of public cultural institutions in economies that have undergone a transition. Coelho et al. (2021) simultaneously studied the influence of various control mechanisms and management strategies on service employees' creativity, employing symmetric and asymmetric modelling techniques. Phan, Baird, Bhuyan and Tung (2024) explore the connections among management control systems, organisational capabilities, and performance, emphasising the significance of job autonomy in influencing employee results. Tang et al. (2017) investigate the impact of high-performance work systems on employee creativity, highlighting the intermediary functions of perceived organisational support and decentralised management. Their research aligns with findings made by Cai et al. (2024), who explore the impact of employee creativity on leader-empowering behaviours, taking into account the moderating role of supervisor-subordinate relationships and their similarities. Volery and Tarabashkina (2021) study the influence of organisational support and employee creativity on innovative work behaviour, emphasising the impact of work centrality. Almost the same idea is shared by Alharbi, Jamil, Mahmood and Shaharoun (2019). They analyse the relationship between organisational culture and management control systems and their combined effect on promoting innovation within the organisation.

On the other hand, Biswas and Akroyd (2022) investigate the design and application of management control systems in the context of strategic change processes, specifically focusing on the shift from closed to open innovation. Kaveski and Beuren (2020) also studied managerial control systems, but their research reveals how these systems impact job performance, with individual creativity as a mediating factor. Barros and Ferreira (2023) contribute to this topic, further developing the relationship between MCS and innovation in enterprises.

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A study developed by Klementová & Stroková (2020) explores the psychological influences and emotions experienced by employees when controlling practices are introduced in organisations. They pinpoint obstacles and suggest approaches to improve acceptance. Miao, Fayzullaev and Dedahanov (2020) examine the influence of management traits on employee creativity, emphasising the mediating effect of job satisfaction. Bollinger (2020) also analysed the managers and their control. Still, the scholar focuses on the impact of various managerial control methods and practices on creativity during innovation processes. Wang, Yang & Zhang (2021) also explore the relationship between control and innovation. They study the influence of diverse organisational control mechanisms on different types of innovation, highlighting the need for a balance between exploration and exploitation.

The findings of the study by Du, Li and Zhang (2018) indicate a positive association between job control and employee creativity, which, according to the authors, is mediated by creative self-efficacy. Furthermore, a promotion focus influences the indirect effect of job control on employee creativity through creative self-efficacy; specifically, the link between job control and creative self-efficacy is more pronounced for employees with a high promotion focus (ibid). Su, Baird and Tung (2022) focus on the relationship between creativity and collegiality. Their research investigates the impact of management control systems on employee creativity and collaboration and how these behaviours mediate the connection between control mechanisms and organisational performance. Almost in the same line comes the research of Fraihat et al. (2023), who pay attention to the moderating role of communication in employee individual creativity and organisational structure. Egwakhe, Omonijo, Akande and Umukoro (2022) highlight the role of organisational culture and its influences on the relationship between corporate entrepreneurship and organisational performance. They report a moderating effect of this impact.

Interesting research in a more recent context is proposed by Juan, Li, Zhang and Gong (2024), who analyse the circumstances that influence how electronic monitoring impacts employee creativity, emphasising the importance of autonomous and controlled motivation. Kivrak, Arslan and Yorno (2025) examine how job autonomy fosters creativity through perceived support from supervisors. They also investigate the moderating effect of job difficulty on the connection between job autonomy and employee creativity. After comprehensive research, Chan and Chu (2024) admit that high-performance work systems at the organisational level boost employee creative engagement by enhancing their overall well-being. Concurrently, scholars conclude that employee mindfulness contributes to heightened creative engagement by improving their work well-being. Marler (2024) describes the challenges and opportunities of using artificial intelligence and algorithms in management and decision-making processes in a more sustainable organisational manner. Aguinis, Beltran and Cope (2024) add to this discussion further development by exploring the idea of using generative AI as an HRM assistant.

Kostev and Anguelov (2024) present a thought-provoking study devoted to employees' perception of the level of digitalisation of Bulgarian conditions. Stoyanova and Stoyanov (2024) comprehensively explore the digitalisation of Higher Education Institutions to secure their competitiveness and increase the quality of the educational process through innovative and creative digital tools. Dimcheva and Stoyanov (2023) examine in depth the introduction of AI in the decision-making process of companies, including and for HRM purposes. Temelkova (2018) explores, analyses, and integrates the competencies required for effective digital leadership to manage collaborative network teams' interconnected, advanced technological landscape. Krumova, Dimitrov and Dimitrova (2023) focus on the relationship between recruitment strategies and employee performance as a specific aspect of the ICT sector. On the other hand, Anguelov (2023) considers the tools and applications provided by different digital tools as an entirely new level of human resource management development, with all accompanying challenges, opportunities and limits.

3. Methodology of the research

The present study investigates young professionals' perceptions of the balance between control and creativity in the workplace. The study focuses on the relationship between control and creativity for young professionals. At the same time, the study explores how different management approaches influence creativity, motivation and innovation potential in young employees. The study comes as a logical step in implementing the uni-

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versity-funded project, devoted to developing new strategies for further digitalisation of Human Resource Management. One of the leading concerns with deeper digitalisation is increased control over work processes. Therefore, the opinion of young professionals who start and develop their professional experience in a highly digital environment is critical, especially regarding creativity, as they are the natural carriers of innovative thinking.

In pursuit of the main objective of this study, the following two hypotheses were defined:
***Hypothesis 1*:** Excessive control negatively impacts the creativity of young employees despite their need for mentorship and intensive collaboration with their immediate supervisors.
Hypothesis 2: The creativity of young employees is positively influenced by the perceived support they receive from their managers.

The survey was developed through a cascade approach, combining a theoretical review of the existing literature on organisational behaviour, creativity and leadership and qualitative interviews with eight young professionals from different sectors (technology, marketing, education, finance). The interviews helped to identify key themes and common challenges, which were subsequently formulated as survey questions.
The final survey contained 20 questions, structured in three main sections:

- I section: Demographic and Professional Profile
- II section: Perceptions of control and creativity in the workplace;
- III section: Preferences regarding organisational climate and culture.

The questionnaire includes predominantly closed formats – with multiple-choice answers and Likert scales, allowing for both quantitative. The very last question is open and requires qualitative analysis.

The survey was conducted between June and September 2024 in electronic format via the Google Forms and Teams platform. Its distribution was carried out through university and youth communities, internal networks of organisations that voluntarily participated in the study, and individual efforts of the project team. The sample includes 257 respondents, 97% of which meet the criterion of "young professionals" – i.e. individuals between the ages of 18 and 35, with at least 1 year of work experience. 3% of responders are 36+ age. The sample is not strictly representative, but it offers good diversification by sectors, including IT, marketing, administration, education, finance, and design. Participation in the survey was voluntary and anonymous. Respondents were informed about the purpose of the study and the confidentiality of the information provided. The collected data were processed using Excel. Descriptive statistics (frequencies, percentages, averages) were used for the quantitative and open-ended questions – qualitative analysis through thematic coding.

4. Analysis and discussion of the collected data

Demographic and professional profiles of respondents

The largest share of respondents work in the technology and software sector – 29%, followed by marketing and advertising – 21% and art and design – 14%. Combined, 64% of respondents are in fields that require a high degree of creativity and innovation. Finance (9%) and healthcare (7%), which are traditionally associated with stricter regulation and control, are less represented. The received questionnaires suggest that most participants work in industries where creativity is essential, but there is also pressure for structure and results. This makes the question of the balance between control and creativity particularly relevant. Basic data forming demographic and professional profiles of our responders are presented in Table 1.

The leading age group is 25–30 years old (47%), followed by 31–35 years old – 28%, with the age group of 18–24 years in third place – 22%. Only 3% of respondents are over 36 years old. Based on the data obtained, it can be concluded that the sample is indeed focused on young professionals in an active phase of career development. They probably have strong aspirations for expression, innovation, and personal value but are still adapting to organisational norms and control.

Regarding professional experience, 34% have between 1–3 years of experience, and 37% of respondents indicate experience between 4–6 years. Only 8% are new to the profession, and 21% have over 6 years of experi-

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ence. Based on these data, it can be commented that most respondents are professionally mature but not for too long in high management roles. They have enough experience to compare different work models and feel control's effect on their productivity and personal creativity.

Table 1. Demographic and professional profile of respondents.

Industry sector		**Age**		**Professional experience**	
Technologies and software	29%	18-24	22%	Less than 1 year	8%
Marketing and Advertising	21%	25-30	47%	1-3 years	34%
Arts and Design	14%	31-35	28%	4-6 years	37%
Education	11%	36+	3%	Over 6 years	21%
Accounting and Finance	9%				
Healthcare	7%				
Other	9%				
Work position/ Hierarchy level		**Work style**			
Internship position\ Start position	14%	Individually		9%	
Specialist	52%	Mainly Individually		18%	
Team leader/ manager	18%	Hybrid (Individually and in teams)		42%	
Middle-level manager	11%	Mainly in teams		22%	
Other	5%	Entirely in teams		9%	

Source: own research; n=257, results in %

Regarding job positions, most respondents (52%) indicate they are in a "specialist" position – an executive profile with some self-management, while 18% state they are team leaders. 11% of respondents are in managerial positions, and only 14% are trainees or newly hired. Most respondents are not senior management but are often subject to management control. This makes them ideal for assessing how control affects their motivation and creative potential "from within".

Regarding individual and teamwork, the representatives of the largest group here, 42%, state that they work in a mixed model, while 22% – mainly in a team, and 18% – mainly independently. Only 9% work entirely in a team or entirely independently. These data allow us to conclude that a hybrid work style prevails, which requires a balance between personal autonomy and collective responsibility. This places additional demands on how control is exercised – it must be flexible and adaptable to the environment. A summary of key characteristics of the demographic and professional profile of respondents is presented in Table 2.

Table 2. The main profile of responders

Factor	**The main profile of respondents**
Industry	Creative and innovative sectors (Technologies, Marketing, Arts)
Age	Young professionals (25-35 years old)
Experience	1-6 years, developing professionals
Job Position	Mainly specialists and team leaders
Working style	Hybrid (Individual + teamwork)

Source: own research

Control and creativity for young professionals

The next part of the questionnaire is dedicated to the relationship between control and creativity, according to the judgment and personal opinion of the young specialists. The first question in this part of the questionnaire is: Do you think a high level of control at work limits creativity? Respondents could choose from pre-set answers using a five-point Likert scale of agreement or disagreement. Results are presented in Figure 1.

The data clearly shows that a large part - 69% of the respondents agree that control limits creativity, and 17% are neutral. Only 14% disagree with this statement. In this sense, the feeling that control in the work environment does not support but instead blocks creative thinking prevails. At the same time, control may be perceived as a form of micromanagement or a lack of trust, suppressing initiative among young specialists. Neutral and disagreeing respondents probably work in better-structured environments, where control is perceived as a framework rather than a limitation. This should also not be underestimated, as it plays a significant role in forming work skills, especially in the first years of professional development.

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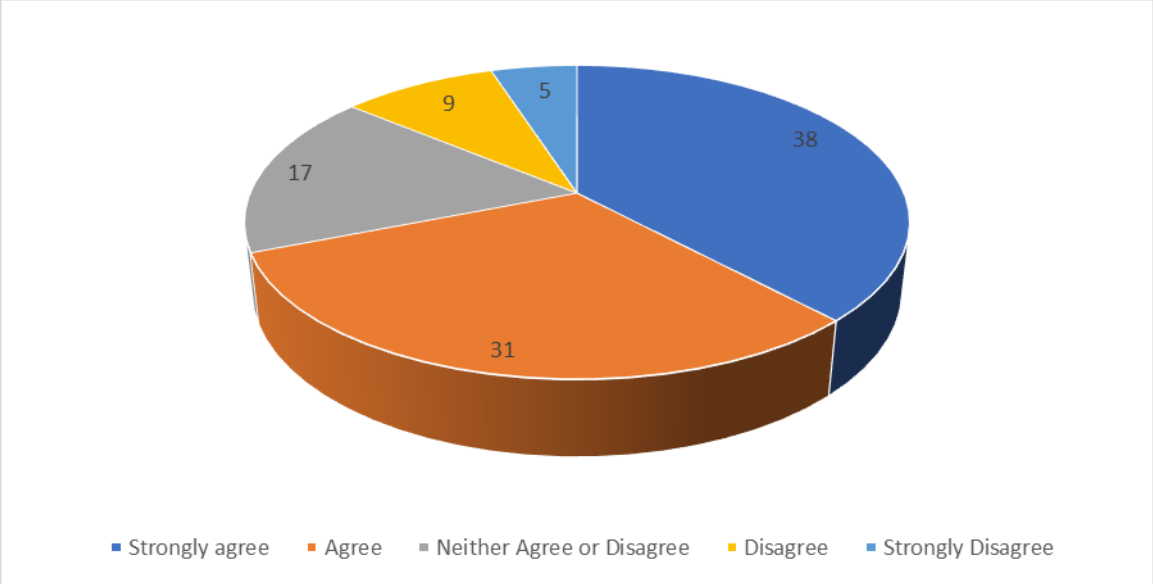


Figure 1. Responds collected to the question: Do you think a high level of control at work limits creativity? (in %, the total number of 257 answers)

The next question is, "How would you rate the level of control in your job?" And the responders are requested to assess from 1 to 5, where (1 = no control, 5 = extremely strict control). Results are visualised in Figure 2.

Most responses here are concentrated at scores 3 (33%) and 4 (29%), indicating a moderate to high level of control. A total of 44% are between 4 and 5 – claiming to feel a significant amount of control. Only 5% of respondents think almost complete freedom (score 1). Although most respondents are in creative industries, control is present and tangible, according to their assessment. High levels of control can be organisational (procedures, deadlines) and socio-psychological (expectations, reports, approvals). The results of this question support the data accumulated from the previous question: perceived control is considered a direct limiter of creativity.

The next question is, "How would you rate the opportunity to express creativity in your work?" respondents are again asked to rate on a scale of 1 to 5, where 1 = no opportunity and 5 = complete freedom (Figure 3).

Like the previous question, the most frequently given ratings are 3 (36%) and 4 (28%). At the same time, 43% claim they have high or complete freedom (rating 4 and 5), while 21% answer with 1 or 2 – they feel limited creative freedom. Although there is no drastic shortage of creative freedom, it is lower than expected for industries with high innovation. At the same time, it should be noted that our respondents are young professionals, and these data can be interpreted in several directions – first, the level of sensitivity and assessment of young professionals may be excessively high, leading to a discrepancy between personal and real organisational freedom in creativity. On the other hand, it is also possible that, given their less life and professional experience, young professionals are sometimes subjected to higher levels of control, which is not necessarily always perceived negatively. A significant proportion of respondents stated that they felt medium or limited freedom, corresponding with the previous answers about strong control. These results show that the balance between control and freedom is not optimal for a significant proportion of respondents.

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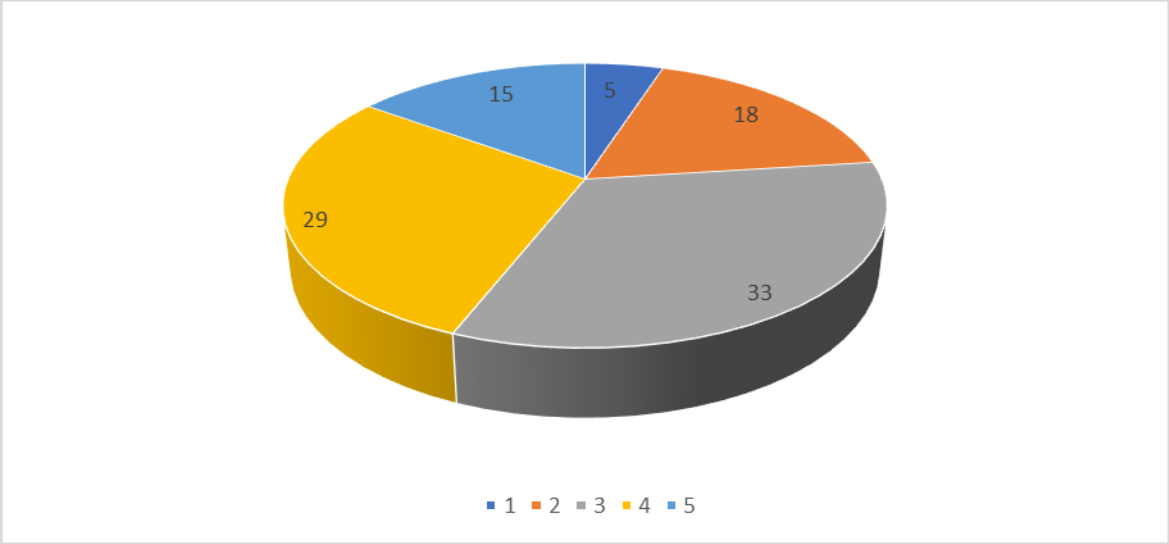


Figure 2. Responds collected to the question: How would you rate the level of control in your job? (in %, the total number of 257 answers)

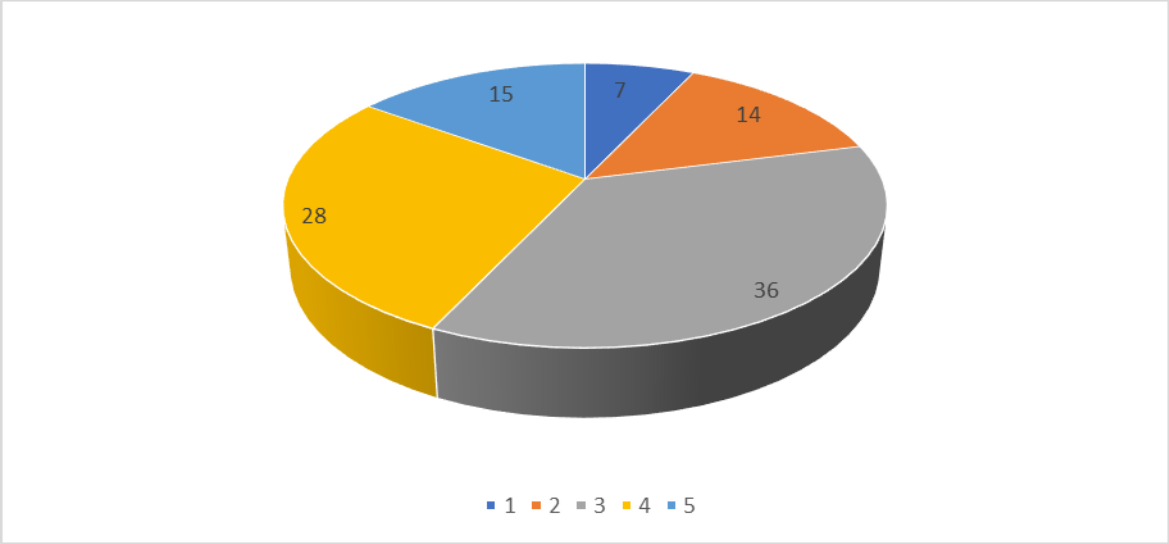


Figure 3. Responds collected: How would you rate the opportunity to express creativity in your work? (in %, the total number of 257 answers)

"Which forms of control do you feel most strongly in your daily work?" is the question in the questionnaire, with respondents being asked to select the top three answers according to their impressions of their work (Figure 4).

Strict deadlines are among the most common forms of control – they are mentioned by 72%. In second place are mandatory procedures but with a significantly smaller share – 46%. Next in importance are micromanagement – 39%; Constant supervision – 32% and lack of choice – 31%.

One of the direct conclusions that emerges from the answers to this question is that control is not only formal but multifaceted and complex. Its formality is cut through deadlines and procedures. At the same time, however, control is also personal – it is expressed through micromanagement and lack of choice. The least frequently mentioned answer is "No such control" – only 9% of respondents. This means that almost everyone

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feels some form of pressure or supervision. The feeling of lack of choice and freedom is particularly worrying, as this is a direct barrier to creative behaviour and creative expression.

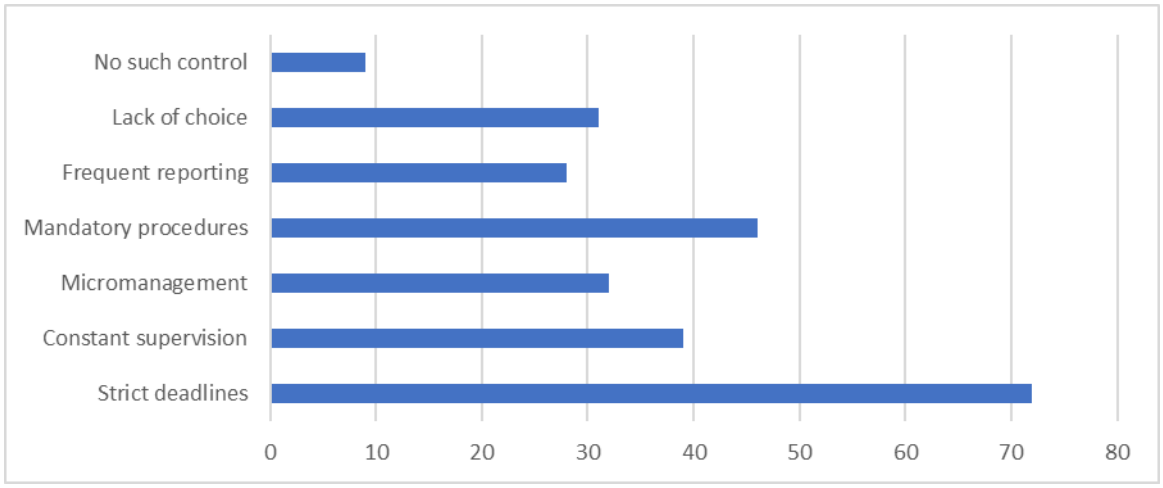


Figure 4. Responds collected to the question: Which forms of control do you feel most strongly in your daily work? (in %, the total number of 257 answers)

The purpose of the next question is to understand the environment that is most conducive to creativity. It reads as follows: In what environment are you most creative? (Figure 5). The results of this question are not surprising (at least about the first choice), although their proportionality could have been more expressive. The leading choice is Complete Freedom, which is indicated by 33% of respondents, followed by Moderate Control – 28% and Clear Rules and Goals – 21%. Only 7% of respondents state that they are most creative "under pressure". Interesting results were obtained regarding team creativity - only 8% of respondents say they are most creative in a team, and another 3% – state that they are most creative independently. Based on these results, we can make several interesting observations. Most participants feel most creative with complete freedom, but nearly 50% indicate options with clear but not intrusive frameworks. This suggests that young professionals do not entirely reject structure but prefer it to be flexible and inspiring, not restrictive. Creative potential depends on autonomy, even when goals and expectations exist. At the same time, the levels of team and individual creativity are surprisingly low, especially considering the professional and demographic profiles of the respondents. The other answers were preferred due to their greater clarity and specificity.

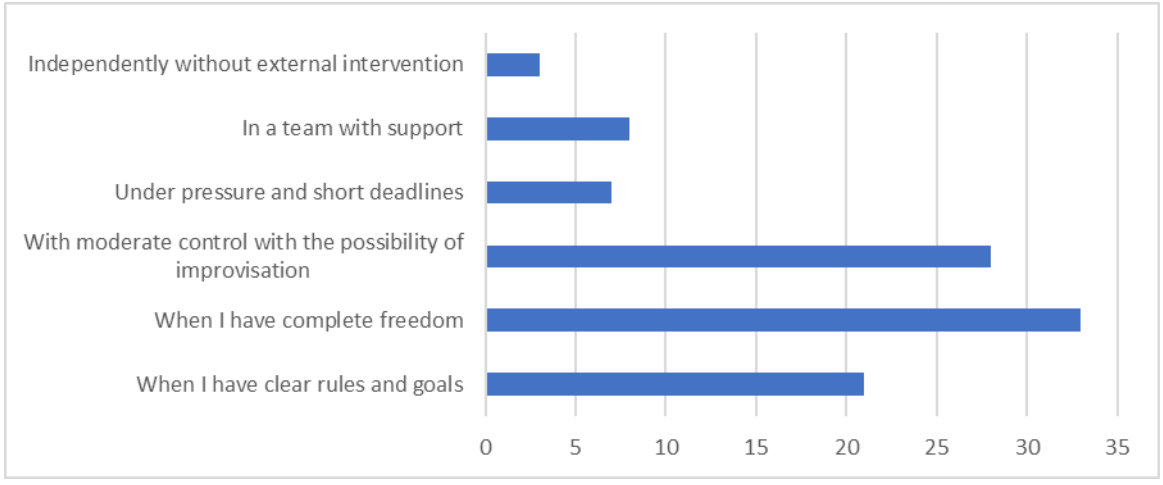


Figure 5. Responds collected to the question: In what environment are you most creative? (in %, the total number of 257 answers)

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The following question is, "What level of control is best for your creativity?" (Figure 6). The overall percentage of responses in favour of low and very low levels of control reaches 54%, clearly showing a preference for a more autonomous environment, especially for tasks requiring creativity. Only 5% of respondents find high control favourable – an indicator that the directive style does not support the creative process in young professionals. The share of those who answered "It depends on the task" (22%) is interesting, which speaks of contextual thinking. Some participants realise the need for different levels of structure depending on the nature of the task (e.g., creative vs. executive).

The conclusion that can be drawn based on the results of this question is that freedom – but in limitations – turns out to be a key element for creativity, while firm control is rather demotivating. In this line of consideration, management should adapt to the situation and the nature of the team rather than being based on a universal approach.

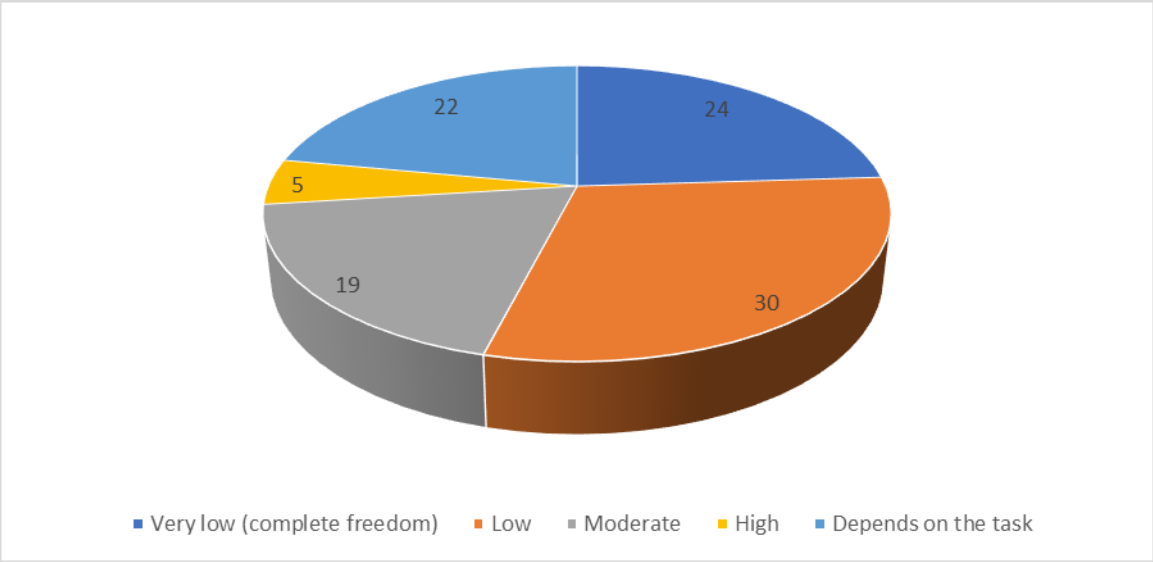


Figure 6. Responds collected to the question: What level of control is best for your creativity?
(in %, the total number of 257 answers)

“Do you feel that your ideas are taken seriously by management?” is the following question (Figure 7). Only 34% of respondents (those who chose answers always + often) feel that their ideas are a priority for management. This is a worryingly low share, given that creativity depends on the perception of one's value within the organisation.

The "sometimes" group (which accumulates the most significant percentage of preferences on this question) shows uncertainty and hesitation – that is, ideas are heard but not always considered. This creates a feeling of inconsistent support and can result in distrust of one's abilities, especially when you are a young specialist still seeking your development.

In total, 30% feel ignored or undervalued – this can lead to discreet withdrawal from participation in innovation processes. This high percentage can directly lead to the overall dissatisfaction of young people with their current job and their looking for another, more favourable job. Here, we can conclude that when young people do not see a real effect from their suggestions, their motivation to share and think creatively drops sharply. In this sense, leaders must not only listen but also validate the contribution, either through feedback or visible implementation.

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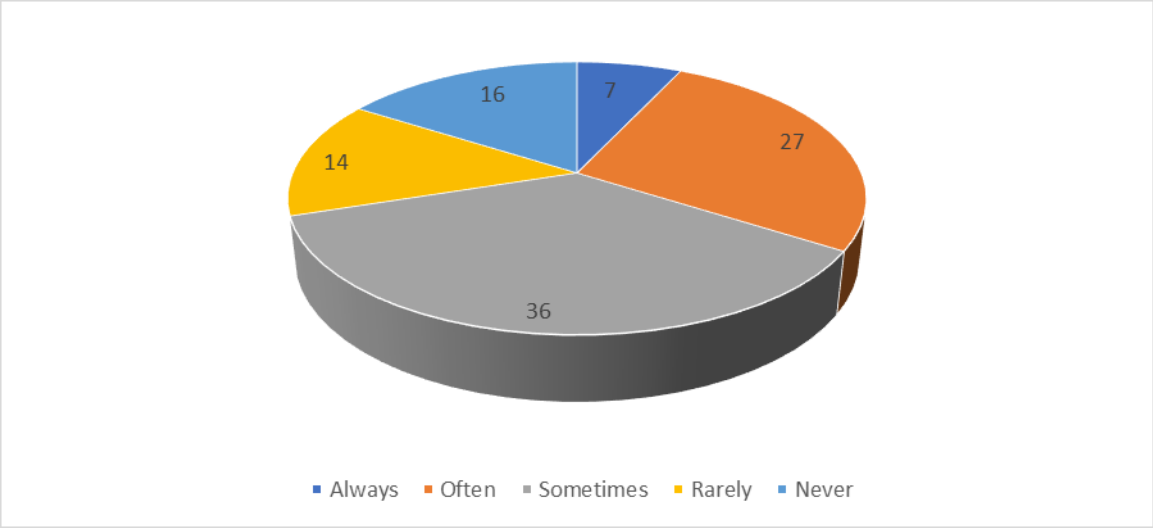


Figure 7. Responds collected to the question: Do you feel that management takes your ideas seriously? (in %, the total number of 257 answers)

To what extent do managers in your organisation encourage creativity? is the following question (Figure 8). Here we have again a 5-point Likert scale (1 = not at all, 5 = completely). The average score here is around 3.1, which indicates moderate support but with significant deviations. Almost 32% (the share of people who chose scores 1 and 2) believe that there is no or little encouragement – this is a serious signal that some managers do not understand or do not value creativity as a priority. Only 11% gave the maximum score – with a young professional staff, this is below the norm since this group is more sensitive to opportunities for expression and development.

The fact that 33% give a "3" indicates a neutral perception – there is no inspiring leadership example and probably a systematic strategy for stimulating ideas. Here, the conclusion that almost automatically follows is that management's lack of consistency and purposefulness in encouraging creativity is reflected in the low commitment of their young employees. This limits the cultural development of organisations and establishes creative indifference.

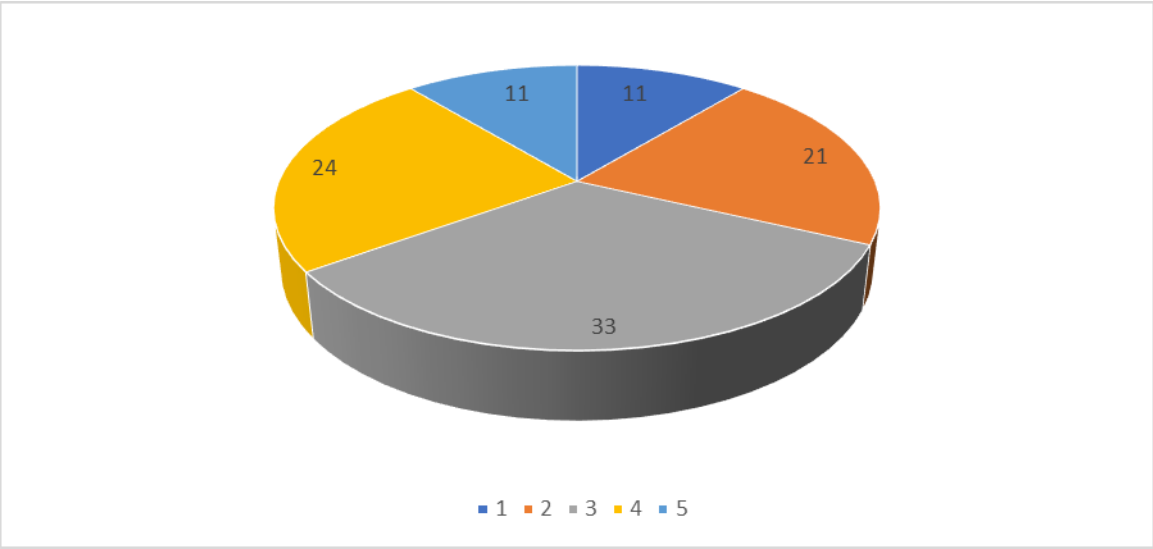


Figure 8. Responds collected to the question: To what extent do managers in your organisation encourage creativity? (in %, the total number of 257 answers)

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The next question was "What most stimulates your creativity?" and the responders were requested to choose up to 3 predefined options of answers (Figure 9).

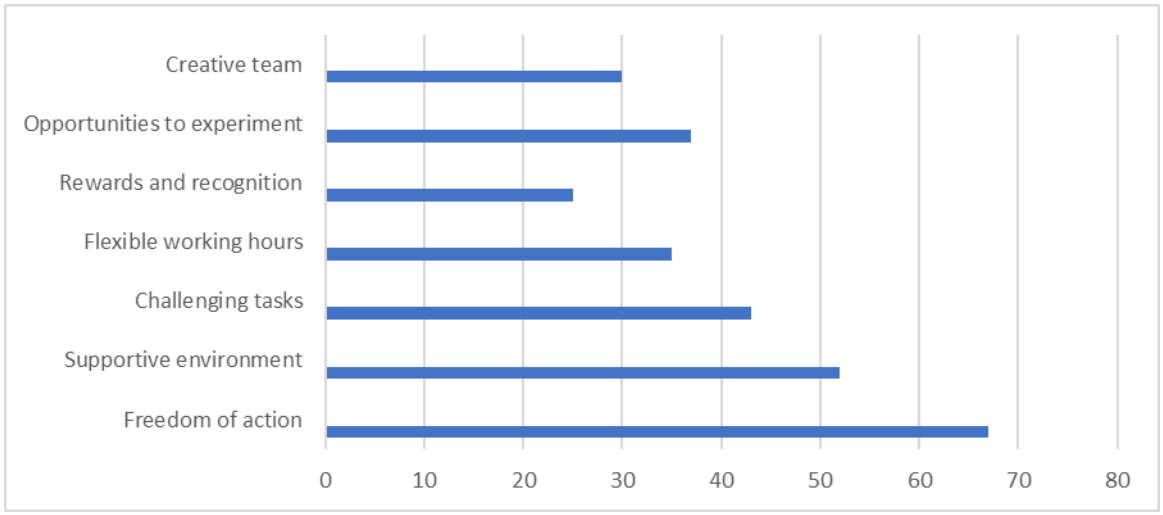


Figure 9. Responds collected to the question: What most stimulates your creativity?
(in %, the total number of 257 answers)

As can be seen from the figure above, freedom is the leading motivator (67%), which corresponds to the answer to question 11. Young people associate independence with the opportunity to express themselves. A supportive environment is also highly rated (52%) – it includes an emotional climate, acceptance of differences, and openness to ideas. High levels are also found in challenging tasks and experimentation – proof that dynamism and innovation attract and inspire. Awards and recognition are not among the leading ones – an interesting fact, as it shows that for young professionals, internal motivation and freedom are more important than external incentives. All the data obtained here suggest that support and freedom are more important for young professionals than formal incentives. They are motivated by the opportunity to contribute, not just to receive.

The next question is, "Do you think structured work can be compatible with creativity?" (Figure 10). More than half of respondents here (44% answering "yes" + 37% answering "depends") believe that structure and creativity are not mutually exclusive as long as they are adapted to the type of work. At the same time, the rejection of structure (19%) aligns with the earlier expressed desire for freedom, but most participants do not deny the benefits of framing and organisation.

The answer "Depends on the specific task" (37%) is also essential – it speaks to reflexivity and the ability to distinguish between types of creative activity (e.g., design vs. concept writing). Here, it can be summarised that participants generally demonstrate maturity in understanding the balance between freedom and structure. The best creative process often requires clear goals and context but, at the same time, flexibility in approach.

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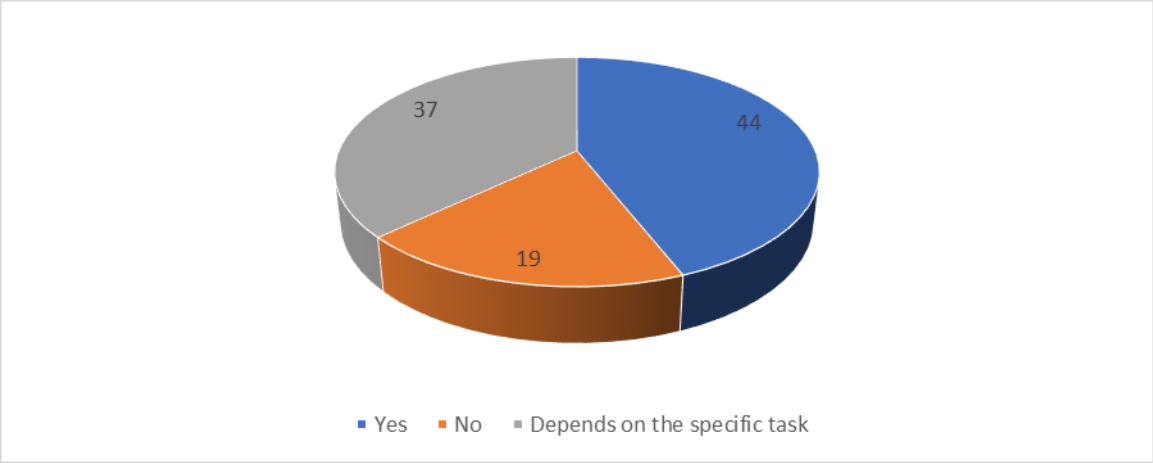


Figure 10. Responds collected: Do you think structured work can be compatible with creativity?
(in %, the total number of 257 answers)

The next question is too direct and is the following: When do you feel least creative? (Figure 11). According to our responders, the biggest blocker to creativity is strict control (35%), which reinforces the results of questions 11 and 12 – control has a demotivating effect. Lack of clear guidelines also limits creativity (24%) – an interesting paradox since too much structure also suppresses it. This reflects the need for clarity but without pressure. Personal interest in the task and state of mind (stress, fatigue) are also factors – a reminder that creativity is not only an organisational, but also a psycho-emotional process. The observation here is that excessive control and a lack of context are equally suppressive. Creative effectiveness is highest in an environment of clarity, inspiration and psychological stability.

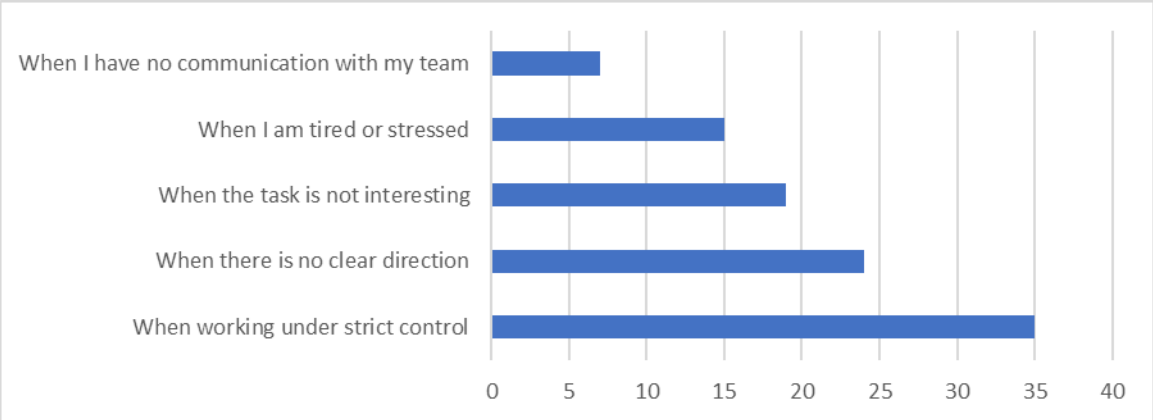


Figure 11. Responds collected to the question: When do you feel least creative?
(in %, the total number of 257 answers)

According to our responders, the biggest blocker to creativity is strict control (35%), which reinforces the results of questions 11 and 12 – control has a demotivating effect. Lack of clear guidelines also limits creativity (24%) – an interesting paradox since too much structure also suppresses it. This reflects the need for clarity but without pressure. Personal interest in the task and state of mind (stress, fatigue) are also factors – a reminder that creativity is not only an organisational, but also a psycho-emotional process. The observation here is that excessive control and a lack of context are equally suppressive. Creative effectiveness is highest in an environment of clarity, inspiration and psychological stability.

The next question is devoted to the balance between control and creativity. How would you describe your work's current balance between control and creativity? The responders were asked to choose from predefined answers (Figure 12).

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Only about 15% of respondents believe there is a perfect balance between control and creativity. This relatively low percentage clearly shows that most young professionals feel some imbalance. Almost 55% are in the zone of increased control (mildly or strongly expressed), which suggests a tendency towards excessive regulation in the organisational environment.

Interestingly, about 30% indicate the opposite imbalance – too much freedom without structure or guidance. This shows that while control is the main "culprit" for limiting creativity, the lack of a clear framework hinders it. These data show that current work environments often do not achieve the desired balance between structure and freedom. This necessitates the expressed need for more flexible leadership and clearly defined frameworks that allow creativity without chaos.

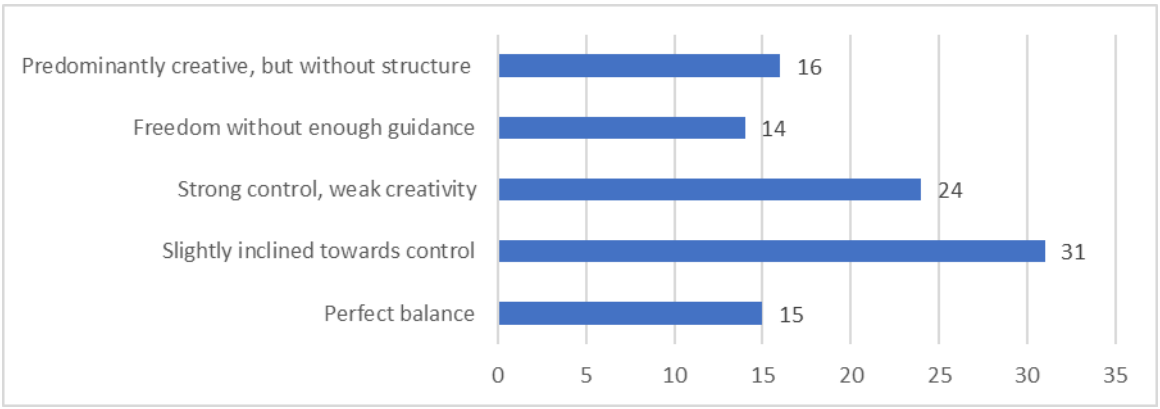


Figure 12. Responds collected to the question: How would you describe the current balance between control and creativity in your work?
(in %, the total number of 257 answers)

"Which of the following phrases best describes your creative freedom?" is the next question, and again, the responders were asked to choose from predefined answers (Figure 13).

Only a quarter of respondents (25%) feel completely free to implement ideas, while the remaining 75% encounter barriers – either in implementation or at the level of acceptance. This speaks of a lack of real mechanisms for introducing new ideas and possibly a culture in which proposals are formally accepted but not implemented. It is particularly worrying that over 12% responded that they are not even expected to be creative – this indicates a traditional management model that suppresses initiative. These results suggest a gap between the ability to give ideas and the ability to accept and implement them, especially among young professionals. Organisations must develop more effective processes for managing innovation and strengthening internal communication and employee trust.

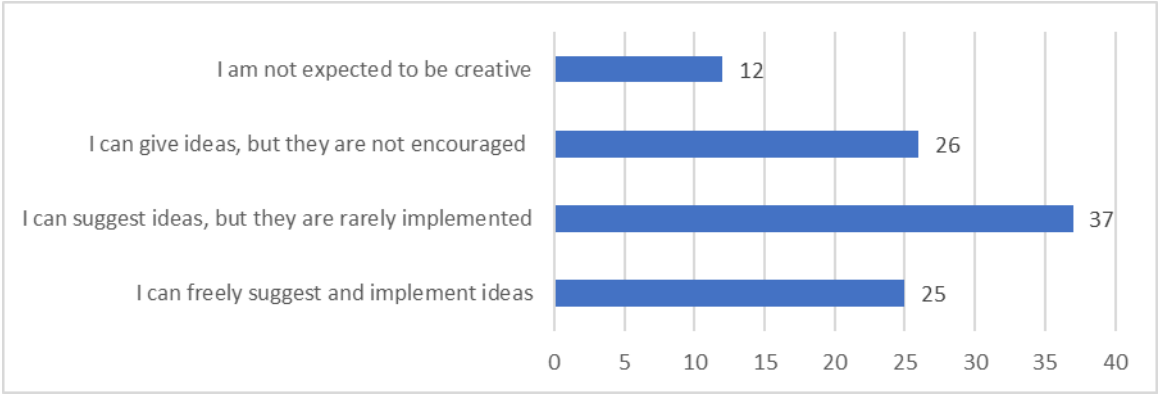


Figure 13. Responds collected to the question: Which of the following phrases best describes your creative freedom?
(in %, the total number of 257 answers)

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The next question of this research is connected to changes. We ask the responders the following: If you could change something in your work environment to be more creative, what would it be? (Figure 14). The most frequently mentioned change is reducing control and bureaucracy (32%) – this confirms the data from the previous questions and clearly shows that too strict procedures stifle creativity. Also, the second most substantial incentive – trust from management (23%) – emphasises the need for internal legitimation of creative efforts and recognition from leaders.

Interestingly, almost 19% of respondents want more collaborative work – which shows that social dynamics and exchanging ideas are also key to the creative process. In this regard comes the observation that young professionals see creativity not simply as a personal ability but as a function of work structure, interpersonal dynamics and leadership. The strongest recommendations include reducing bureaucracy, building trust and encouraging teamwork.

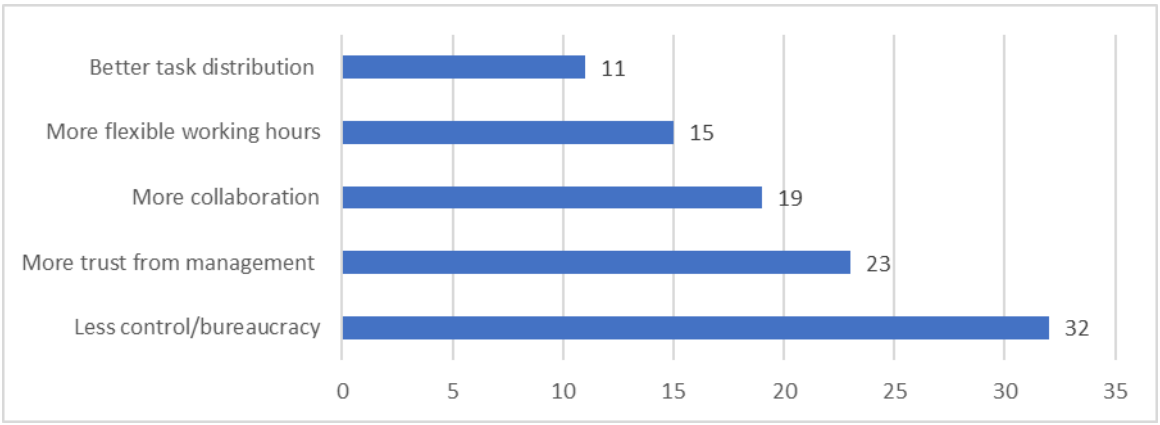


Figure 14. Responds collected to the question: If you could change something in your work environment to be more creative, what would it be?
(in %, the total number of 257 answers)

The last question was open: the respondents were asked, "Describe a situation in which you felt particularly creative or inhibited in expressing ideas at work. What contributed to this?"
After comprehensively analysing the received answers, several main topics were identified in the two opposite cases.
Situations with increased creativity - about 61% of respondents describe positive experiences:

- Freedom of action and trust from management: "When my manager said, 'You have complete freedom to approach it however you see fit', – that unleashed an incredible flood of ideas in me."
- Team support and collaboration: Many respondents noted that their creativity was stimulated by "brainstorming", spontaneous discussions and open communication within the team.
- Short deadlines + challenging tasks: Paradoxically, about 15% shared that constraints (time, resources) mobilise them and "squeeze" their creativity positively.

Situations of suppressed creativity - about 39% of participants described situations in which they felt suppressed in expressing ideas. Main reasons:

- Authoritarian management style: "My idea was rejected without discussion because it 'didn't fit the established protocol."
- Lack of feedback or reaction from management: Some participants shared that their ideas "sink", which demotivates them to engage actively in the future.
- Fear of mistakes and accusations: "When every mistake leads to a reprimand, you don't dare to try something new."
- Excessive hierarchy and formal structures that limit access to decision-making.

Young professionals feel most creative when there is a high degree of autonomy and risk-taking and when a trusting team climate is built. Intentionally challenging tasks also stimulate innovative thinking. At the same time, suppression of creativity most often stems not from a lack of ideas but from an unfavourable culture – a lack of acceptance, dialogue and security when taking risks.

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Correlation analysis and data interpretation

Three questions in the questionnaire, explicitly addressing the level of control, the level of creativity, and the support from management, were designed with predefined numerical response options. This structure facilitated further investigation through correlation analysis.

Table 3. Correlation matrix

	Level of control	Expressing creativity	Management encouragement
Level of control	1	-0.65	-0.30
Expressing creativity	-0.65	1	+0.72
Management encouragement	-0.30	+0.72	1

Source: own calculations

Level of Control and Expressing Creativity (-0.65):
There is a strong negative correlation between the Level of Control and Expressing creativity. This suggests that as the level of control goes up, the worse their employees' ability to advertise originality. In a closely staffed environment, a level of control equals stifling innovation among employees. This finding indicates that a culture of extreme control out of management and mentors damages the creativity young employees need. This correlation confirms the first hypothesis: Excessive control negatively impacts the creativity of young employees despite their need for mentorship and intensive collaboration with their immediate supervisors.

Level of Control and Management Encouragement (-0.30):
The correlation between the Level of Control and Management Encouragement is moderate and negative. This implies that higher levels of control are associated with less encouragement from management. It may suggest that a controlling management style diminishes the support and encouragement employees receive, potentially leading to declining motivation and levels of commitment.
Expressing Creativity and Management Encouragement (+0.72):

There is a strong positive correlation between Expressing Creativity and Management Encouragement. This indicates that as young employees feel more encouraged by management, their abilities to express creativity improve. This finding confirms the notion that employees can work freely when managers are warm and open in style. Management also plays a vital role in helping to enlarge and sustain creativity. This also confirms our second hypothesis: The creativity of young employees is positively influenced by the perceived support they receive from their managers.

Conclusions and recommendations

The study results reveal a deep tension between control and creativity in the modern workplace. Most young professionals feel that control dominates their organisations – bureaucracy, hierarchy, lack of trust and limited access to real implementation of ideas. Only a small proportion – around 15-25% – feel they have the necessary freedom and support to create entirely.

At the same time, however, there is an equally important problem: where there is a lack of sufficient structure, creativity also suffers – especially in the absence of clear guidelines, roles and processes. This highlights that creativity requires not only freedom but a consciously constructed framework that nurtures it, not suppresses it.

According to young professionals, the main obstacles to creativity are strict control and bureaucracy (in the first place), followed by insufficient trust from management, lack of implementation of ideas, expectations for performance, lack of initiative, exhaustion and lack of communication within the team. At the same time, the factors that most strongly stimulate creativity are freedom of action and the opportunity to experiment; a supportive, open environment to ideas; challenging tasks and flexibility in work; and participation in team and cross-functional collaboration.

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Young professionals seek an environment with clear goals but minimal interference in the way they work – their creativity thrives best in autonomy with trust, not control with suspicion. Control is not a problem for young professionals, but it undermines motivation, initiative and creative potential when it is too strict and overly fixed. Young professionals seek an intelligently structured environment where the framework is clear but not dogmatic, and trust is the litmus test of management. With an approach that combines autonomy, respect for individual style and shared responsibility, creativity has the potential to unfold to its full extent.

The survey highlights that young employees do not look for anarchy or rigid discipline – they prefer a balanced, meaningful work environment that values their contributions, allows for mistakes, encourages experimentation and provides clear goals. All data from the study indicate that they want to be heard, included and recognised to be motivated and creative.

The study results are in line with the resent study of Lechler, & Huemann (2024), claiming that young professionals need autonomy in their work.

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PROMINENT EDUCATION PREDICTORS OF WOMEN'S INTENTION TO ENTREPRENEURSHIP IN SAUDI ARABIA

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Abstract. In an era where entrepreneurship is a key driver of economic growth, understanding the role of education in shaping entrepreneurial intentions is crucial—especially for women. This study explores the multi-dimensional impact of education on female entrepreneurship by categorizing educational factors into three dimensions: educational background, education level, and entrepreneurial education. Grounded in education theories and the theory of planned behavior, we analyze a sample of potential women entrepreneurs. Surprisingly, our findings reveal that having a business-related educational background does not significantly affect entrepreneurial intentions. However, education level is decisive in shaping attitudes and subjective norms toward entrepreneurship, though it does not influence perceived behavioral control. Notably, women who have received entrepreneurial training demonstrate stronger attitudes and perceptions of control, highlighting the power of targeted education. These insights provide valuable guidance for policymakers and stakeholders to foster digital entrepreneurship among Saudi women, bridging the gap between education and economic empowerment.

Keywords: women empowerment; sustainable development; women entrepreneurs; entrepreneurship; gender; entrepreneurship education

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JEL Classifications: L29

1. Introduction

Women's entrepreneurship is not just an economic issue but a matter of social progress and economic resilience. Yet, despite their immense potential, women entrepreneurs remain underrepresented in many economies, including Saudi Arabia. Entrepreneurship has long been recognized as a key driver of economic growth, contributing to job creation and the sustainable development of individuals and nations. The role of women in entrepreneurship is gaining increasing significance across various global contexts (Dereñ & Skonieczny, 2025; Rodríguez-Vera et al., 2025; Tükel et al., 2025).

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Entrepreneurship not only promotes women's economic empowerment but also fosters the broader economic advancement of the country. As the entrepreneurial landscape continues to evolve, it becomes evident that women's participation in entrepreneurial activities is essential for achieving inclusive and sustainable economic development.

Since the 1970s, development policies have progressively shifted toward addressing the needs and aspirations of all individuals within society. Including women in all social, economic, and environmental sectors is now seen as indispensable to achieving sustainable development goals. This perspective is particularly relevant in Saudi Arabia, where Vision 2030 underscores the pivotal role of women in the Kingdom's development strategy. Over the past decade, Saudi women have increasingly assumed leadership positions and the government has introduced several reforms that are aimed at advancing gender equality and empowering women. These initiatives seek to create an institutional and regulatory environment that enables women to realize their entrepreneurial potential, thereby contributing to the nation's economic growth and diversification.

Despite these efforts, women exhibit lower entrepreneurial intentions than men, particularly in traditional and emerging economies. Studies indicate that women face significant barriers to entrepreneurship, including socio-cultural, psychological, and institutional constraints. However, some research challenges this notion, suggesting that gender differences in entrepreneurial intentions may not be as pronounced. Smith et al. (2016) and Chaudhary (2017) found no significant disparities between men and women in entrepreneurial intentions, emphasizing that factors such as education and societal norms play a crucial role in shaping entrepreneurial behavior.

The role of education in shaping entrepreneurial intentions has been widely explored in the literature. Hutasuhut (2018) emphasized the importance of understanding the personal and institutional factors that drive entrepreneurial behavior, with education often being a central component. Kelley et al. (2017) argued that women are less likely than men to launch businesses and that the entrepreneurial gender gap tends to widen in economies at more advanced stages of development. However, women with higher educational attainment, particularly in efficiency- and innovation-driven economies, are more likely to pursue entrepreneurship. This raises a critical question: does education similarly influence the entrepreneurial intentions of women and men? And if not, how does education shape the entrepreneurial paths of women differently?

This study seeks to contribute to this body of knowledge by exploring the impact of education and other personal characteristics on women's entrepreneurial intentions in Saudi Arabia. Unlike previous research that examines education as a broad variable, this study dissects its sub-dimensions—level of education, field of study, and entrepreneurial training—to uncover their distinct effects on women's entrepreneurial aspirations. While existing literature acknowledges the role of education in entrepreneurship, the specific ways educational factors influence women's entrepreneurial intentions remain underexplored. By examining these dimensions, this study aims to provide a nuanced understanding of how personal characteristics shape women's entrepreneurial aspirations and to identify the institutional and societal mechanisms that either facilitate or hinder their entrepreneurial endeavors.

Specifically, this paper aims to determine whether education predicts entrepreneurial intention for women and how different educational backgrounds and training experiences influence their entrepreneurial behavior. Furthermore, it seeks to assess the extent to which educational qualifications, both general and entrepreneurship-specific, impact the realization of entrepreneurial success for women. By addressing these questions, this study contributes to the growing field of entrepreneurship research, offering valuable insights for policymakers, educators, and institutions working to foster women's entrepreneurship.

Beyond filling a gap in the literature, this study seeks to present actionable recommendations for institutional reforms that can empower women entrepreneurs. By better understanding the relationship between education, entrepreneurial intention, and institutional support, this paper aims to offer a comprehensive view of how to create an enabling environment for women to pursue and succeed in entrepreneurial ventures. Through these contributions, this research aligns with the broader goals of Vision 2030 and the international movement

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toward achieving gender equality in entrepreneurship, providing theoretical and practical insights into fostering women's entrepreneurship in Saudi Arabia and beyond.

2. Theoretical background

2.1. The context of the study

Entrepreneurial competencies are not exclusive to business students, and the impact of entrepreneurship education continues to spark debate, often showing limited or inconsistent outcomes (Bae et al., 2014; Mabungela & Davids, 2024). Nevertheless, exposure to relevant knowledge, behaviors, and transferable skills during educational experiences can positively influence students, even those not formally enrolled in entrepreneurship programs or lacking clear entrepreneurial ambitions. A common characteristic observed among entrepreneurs is a relatively high educational attainment (Ward et al., 2019; Cabagnols et al., 2022). Despite growing scholarly interest, the intersection between gender and entrepreneurial intention remains relatively underexplored, particularly in Saudi Arabia (Choukir et al., 2019). Nevertheless, research on women's entrepreneurship is gradually expanding (Soria-Barreto et al., 2017; Miralam et al., 2025).

Moreover, in innovation-driven economies, the gender gap in perceived entrepreneurial capabilities tends to be more pronounced (Kelley et al., 2017). However, Ward et al. (2019) reported no significant difference in entrepreneurial intentions between male and female students. Higher education may act as a levelling force across genders by indirectly fostering entrepreneurial skills. Bae et al. (2014) noted that entrepreneurship education does not substantially influence women more than men.

Recent investigations have delved deeper into the role of education in shaping women's entrepreneurship. Pérez-Varela and Cárdenas-Rodríguez (2024) conducted a systematic qualitative review, concluding that while education and several other factors can support women's entrepreneurship, they can also act as barriers. In Uganda, Namasembe and Manzanera Ruiz (2021) found that universal formal education programs, rather than encouraging continued schooling, often push female students toward early school dropout and necessity-driven entrepreneurship to address immediate financial needs. They concluded that the educational level many women entrepreneurs attain remains insufficient to guarantee entrepreneurial success. Ahmadov et al. (2021) corroborated these findings, showing that in Azerbaijan, women with higher educational levels exhibited greater self-confidence and were more proactive in launching social business initiatives.

Paiva et al. (2024) emphasized that while a gender gap persists, the teaching-learning process could be critical in enhancing female students' self-awareness and self-value. They suggested that higher education programs must evolve toward more inclusive practices to foster an entrepreneurial mindset among female students, reinforcing the broader case for entrepreneurial education. Ballesteros et al. (2024) also observed that extrinsic motivation, family environment, innovation, and intrinsic motivation are significant predictors of entrepreneurial attitudes. However, they highlighted that educational programs are key to enhancing entrepreneurial aspirations among women in Colombia.

Mashapure et al. (2022) investigated the challenges confronting women entrepreneurs in rural areas of Manicaland Province, Zimbabwe. They identified barriers such as limited market information, lack of knowledge and skills, and insufficient government support. Their study recommended comprehensive entrepreneurship education and training programs as critical solutions to these challenges.

In a related study, Becsky-Nagy and Fazekas (2025) explored the role of educational background among male and female entrepreneurs. Their analysis of students' perceptions revealed that a lower proportion of female students engage in entrepreneurial activities than their male counterparts. Moreover, women expressed a greater need for university support in building networks and enhancing entrepreneurial skills, suggesting that targeted educational programs for women could be highly beneficial.

Similarly, Zhou et al. (2021) demonstrated that university graduates positively influence entrepreneurship education outcomes. Exposure to entrepreneurial knowledge and skill development during higher education

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increases the likelihood of new business creation. In China, entrepreneurship education was also found to boost entrepreneurial intentions significantly.

Supporting these findings, Maziriri et al. (2022) revealed that entrepreneurial education positively and significantly impacts women's entrepreneurial success. Furthermore, entrepreneurial education substantially moderates the relationship between women's need for achievement and their entrepreneurial outcomes.

Regarding women's empowerment through entrepreneurship, the Middle East notably reports the highest growth expectations among female entrepreneurs (37%) and the highest degree of gender parity globally. Women's growth expectations in this region are approximately 80% of men's. In Saudi Arabia, women demonstrate greater entrepreneurial aspirations than their male counterparts (Kelley et al., 2017). Scholars such as Saeed et al. (2014) have emphasized that environmental factors—especially perceived organizational support through educational and business development initiatives—are crucial to entrepreneurial intentions. These factors influence individuals' perceptions of their socio-economic environments and their roles.

2.2. Entrepreneurship theoretical research background based on the theory of planned behavior

The Theory of Planned Behavior (TPB) has become a widely recognized framework for examining entrepreneurial intentions. Its adaptability has made it particularly suitable for entrepreneurship research, as numerous studies have validated its relevance in predicting individuals' planned behaviors in this context (Lortie & Castogiovanni, 2015; Naskar & Lindahl, 2025).

Originally introduced by Ajzen (1991), the TPB posits that behavioral intention is shaped by three key components: attitude toward the behavior, subjective norms, and perceived behavioral control. Attitude reflects an individual's positive or negative evaluation of the behavior in question. Subjective norms involve perceived social pressures to engage in or refrain from a behavior. In contrast, perceived behavioral control refers to an individual's belief in their ability to successfully perform the behavior (Gird & Bagraim, 2008; Naskar & Lindahl, 2025).

Nonetheless, evidence suggests that the model is highly applicable in such contexts. For example, Choukir et al. (2019) applied the TPB to analyze entrepreneurial intention among Saudi university students and found significant gender-based differences. Specifically, subjective norms and perceived behavioral control more strongly influenced women's intentions than men's. However, perceived behavioral control emerged as a significant factor for both genders.

In their review of TPB applications in entrepreneurship, Lortie and Castogiovanni (2015) advocated adopting a MESO-level approach, which integrates at least two levels of analysis (e.g., individual and organizational). This perspective helps address limitations found in single-level research, offering a more comprehensive understanding of entrepreneurial intentions. By bridging micro-level personal factors—such as education or gender—with broader contextual influences, researchers can better capture the complexity of entrepreneurial decision-making. Interestingly, only a handful of studies have fully implemented the TPB framework in entrepreneurship research.

2.3. Conceptual model formulation

Attitudes

Studies on entrepreneurship and attitudes toward entrepreneurial behavior emphasize the critical role of attitude as a psychological factor influencing human actions. A more positive attitude toward entrepreneurial activities is likely to enhance the performance of entrepreneurial intentions (Soria-Barreto et al., 2017). According to Solesvik (2013), an individual's attitude influences the connection between perceived entrepreneurial motivation and entrepreneurial intentions.

H1: women's attitudes toward entrepreneurs positively affect their intention to be entrepreneurs.

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Subjective norms (social norms)

Subjective norms refer to individuals' perceptions regarding the influence of important others, such as family and close friends, on their behavior (Ajzen, 1991). These referents, including peers, family members, and society, play a significant role in shaping an individual's decisions and actions, especially in entrepreneurship (Quan, 2012). Social norms, therefore, have a profound impact on entrepreneurial behaviors. Entrepreneurship is often seen as the outcome of interactions between personal characteristics and the surrounding environment. Furthermore, an individual's perception of their cultural environment is linked to entrepreneurial intentions, with subjective norms mediating entrepreneurial motivation and intentions (Solesvik, 2013).

H2: women's subjective norms of entrepreneurship positively affect their intention to be entrepreneurs.

Perceived behavioral control

For this study, we focus on Perceived Behavioral Control in the context of entrepreneurship, as it aligns better with our objectives and allows for a deeper exploration of how individuals perceive their ability to engage in entrepreneurial activities. This concept is beneficial because it encompasses perceived controllability and efficacy, integral to understanding entrepreneurial behavior. Perceived behavioral control is individuals' expectations about their ability to carry out a specific behavior (Ward et al., 2019). In the realm of entrepreneurship, Solesvik (2013) found that the link between entrepreneurial motivation and intentions is influenced by perceived behavioral control.

H3: women's perceived behavioral control of entrepreneurs positively affects their intention to be entrepreneurs.

Entrepreneurial intentions

A central element of the Theory of Planned Behavior (TPB) is the intention to carry out a specific action (Karimi et al., 2016). Several entrepreneurial intention models have incorporated the TPB, evolving into recognized theoretical frameworks that have proven relevant across various contexts.

Education background

Hutasuhut (2018) suggested that an individual's education significantly influences the knowledge and skills they acquire, affecting their future career choices. In his study of economics students, he found no clear link between educational background and entrepreneurial intention. Bae et al. (2014) argued that entrepreneurial skills are not exclusive to business students. Ward et al. (2019) further emphasized that exposure to relevant knowledge, behaviors, and skills is beneficial even for students without explicit entrepreneurial intentions or a business-focused education. Consequently, this study hypothesizes that women with a background in business education are more likely to have a positive attitude toward entrepreneurship and perceive it as more achievable.

H4a: women with a business educational background positively moderate the effect of their attitudes toward entrepreneurs on their intention to be entrepreneurs.

H4b: women with a business educational background positively moderate the effect of their perceived behavioral control of entrepreneurs on their intention to be entrepreneurs.

H4c: women with a business educational background positively moderate the effect of their subjective norms of entrepreneurship on their intention to be entrepreneurs.

Education level

As economic development increases, the overall rates of entrepreneurial activity typically decrease while the proportion of entrepreneurs with a college degree or higher rises. This trend reflects the broader population. For example, only a small proportion of female entrepreneurs (14%) in factor-driven economies have a college degree or higher. In comparison, the majority (61%) in innovation-driven economies possess this level of education. The gap in educational attainment between male and female entrepreneurs narrows with economic development. In factor-driven economies, female entrepreneurs are about two-thirds as likely as their male counterparts to have a post-secondary degree. However, in economies at the efficiency-driven stage and beyond, women entrepreneurs are either as likely or more likely than men to hold at least a post-secondary education (Kelley et al., 2017).

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Wu and Wu (2008) suggested that educational attainment affects entrepreneurial intentions by shaping individual attitudes. Solesvik (2013) supported this, showing that individuals with higher levels of education are more likely to pursue entrepreneurship. Hutasuhut (2018) proposed that entrepreneurship may be less appealing to postgraduate students than to those with a diploma or bachelor's degree. He identified two possible reasons: first, diploma and bachelor's degree holders are often more enthusiastic about starting businesses; second, postgraduate students may weigh the high opportunity cost and long time required to achieve a stable income.

Entrepreneurship may be a particularly attractive career option for women with lower education levels. In contrast, women with higher educational qualifications may have more career options but may still choose entrepreneurship due to its opportunities. A negative correlation between education and entrepreneurship rates among women suggests that, especially in the early stages of economic development, entrepreneurship is a key income-generating avenue for women with lower levels of education (Kelley et al., 2017).

As education levels increase, women entrepreneurs tend to shift their motives from necessity to opportunity. Among women with some secondary education but no high school diploma, 35% started their businesses because they had no other employment options. In comparison, only 18% of those with education beyond a bachelor's degree cited necessity as their primary motive. This shows that entrepreneurship is an essential option for women with limited education and job opportunities, and a viable career path for women with higher educational qualifications (Kelley et al., 2017). This raises the question: do women with higher educational levels place more importance on the expectations of significant referents, such as family and friends when considering entrepreneurial behavior in their environment?
H5a: women's education level positively moderates the effect of their attitudes toward entrepreneurs on their intention to be entrepreneurs.
H5b: women's education level positively moderates the effect of their perceived behavioral control of entrepreneurs on their intention to be entrepreneurs.
H5c: women's education level positively moderates the effect of their subjective norms of entrepreneurship on their intention to be entrepreneurs.

Entrepreneurial education

Higher education institutions play a crucial role in fostering entrepreneurial behaviors among future entrepreneurs. As a result, universities face the challenge of evolving into more entrepreneurial environments. These institutions aim to expand their entrepreneurship programs and contribute effectively to the broader entrepreneurial ecosystem (Soria-Barreto et al., 2017).

Researchers have identified various forms of entrepreneurship education, each designed for specific audiences. For instance, awareness-oriented entrepreneurship education targets students who lack prior business experience. This education aims to enhance students' entrepreneurial skills (Bae et al., 2014). Entrepreneurship education is fundamental in increasing entrepreneurial intentions (Nowiski et al., 2017). These findings highlight the importance of entrepreneurship education, which not only imparts essential knowledge but also has the potential to shape students' attitudes. Barba-Sánchez & Atienza-Sahuquillo (2017) found that training programs effectively increased the entrepreneurial intentions of students, particularly those in industrial and computer engineering fields. Similar results were reported by Utamin (2017) in Indonesia and Solesvik (2013) in Ukraine.

Despite these positive findings, prior research has shown inconsistent results concerning the influence of entrepreneurship education on entrepreneurial intentions, particularly concerning gender. Haus et al. (2013) found that women are less likely than men to translate their entrepreneurial intentions into action. They concluded that entrepreneurship education has a more significant effect on women's entrepreneurial intentions. Zhang et al. (2014) argued that entrepreneurship education has a greater impact on the entrepreneurial intentions of men than on women, pointing to possible differences in how women perceive their ability to control entrepreneurial behavior.

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Soria-Barreto et al. (2017) suggested that entrepreneurial education can enhance perceived behavioral control. Additionally, gender is important in shaping effective entrepreneurial education programs to reduce gender disparities in new venture creation. Soria-Barreto et al. (2017) further noted that gender moderates the relationship between perceived behavioral control and entrepreneurial education and the impact of perceived behavioral control on entrepreneurial intentions. This highlights the need to further explore these relationships, especially for women, to generate meaningful insights.

The literature on entrepreneurial education has yielded mixed results (Walter & Block, 2016). Research on entrepreneurial intentions suggests that the Theory of Planned Behavior (TPB) is an appropriate framework for evaluating the effectiveness of entrepreneurship education. For example, a study on the entrepreneurial intentions of Iranian students across six universities found significant positive impacts on students' subjective norms and perceived behavioral control after taking entrepreneurship courses (Karimi et al., 2016). However, empirical research on the relationship between entrepreneurial education and intentions remains limited, particularly in developing countries.

H6a: women's entrepreneurial education positively moderates the effect of their attitudes toward entrepreneurs on their intention to be entrepreneurs.

H6c: women's entrepreneurial education positively moderates the effect of their perceived behavioral control of entrepreneurs on their intention to be entrepreneurs.

H6b: women's entrepreneurial education positively moderates the effect of their subjective norms of entrepreneurship on their intention to be entrepreneurs.

The above-formulated hypotheses are represented in Figure 1 below:

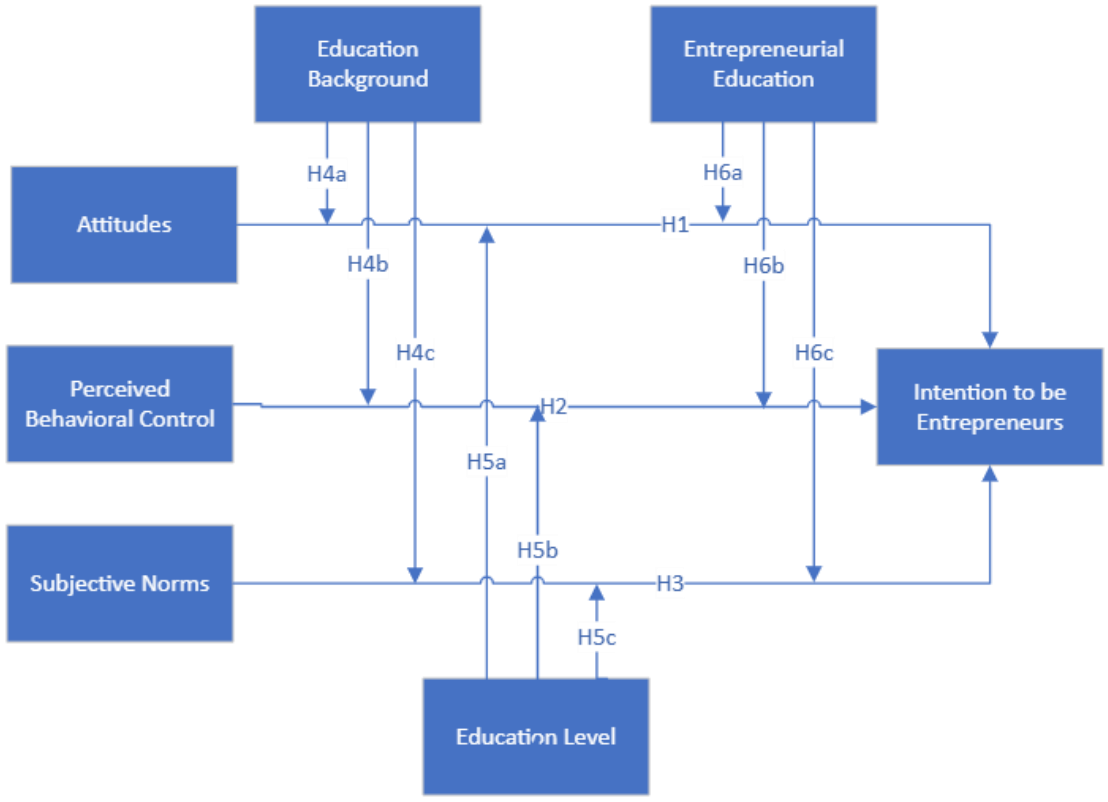


Figure 1. The theoretical framework

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3. Research objective and methodology

This study adopted a quantitative research design to examine a sample of potential female entrepreneurs residing across various regions in Saudi Arabia. A structured survey consisting of closed-ended questions was developed and administered to gather data. This approach was selected to ensure that respondents could easily comprehend the questions, thereby improving the accuracy and consistency of their answers (Sekaran & Bougie, 2016). The purpose of the survey was to empirically test the hypotheses formulated within the study's conceptual framework. The targeted participants were educated Saudi women deemed capable of managing entrepreneurial ventures. Specifically, the study focused on Saudi women who hold university degrees and are considered qualified to initiate and operate small to medium-sized enterprises. A cross-sectional design was employed using stratified random sampling. To maximize participation and accessibility, the questionnaire was distributed online, aiming to collect at least 250 valid responses.

To enhance the reliability and validity of the measurement instrument, the study utilized scales previously validated in the literature. The constructs of attitude, perceived behavioral control, and entrepreneurial intention were measured using the instrument developed by Do et al. (2011), while the construct of subjective norms was assessed using the scale, which includes a minimum of five items. A 5-point Likert scale was employed to evaluate all constructs, where 1 represented "strongly disagree" and 5 represented "strongly agree." Before launching the full survey, a pilot study was conducted to test the questionnaire items' clarity, reliability, and validity. This pre-test also helped confirm the appropriateness of using these instruments within the Saudi socio-cultural context, as they were originally developed in different cultural environments. A total of 366 responses were successfully collected through random sampling. For data analysis, SPSS was used to conduct descriptive statistics and confirmatory factor analysis (CFA) to validate the measurement model. In parallel, Smart-PLS was employed to examine the moderating role of educational dimensions on the relationships between the key constructs. The structural equation modelling (SEM) approach was applied to explore complex relationships, including moderation, composite mediation, and partial mediation, in accordance with the analytical framework suggested by Radu and Redien-Collot (2008).

4 Results and discussion

4.1 Characteristics of demographics

The study first established that most respondents were young (79.5%), aged between 18 and 30 years, middle-aged respondents represented 19.1%, and only 1.4% were over 41 years old. Furthermore, the study established that respondents were equally distributed regarding educational background, as 48.1% had a business educational background, whereas 51.9% were non-business educated. Regarding education level, almost half of the respondents have a bachelor's degree level of education, 33.1% have a diploma, and 15% have a master's degree. Concerning respondents' entrepreneurial education, most respondents (78.1%) had not obtained entrepreneurial training, whereas only 21.9% attended entrepreneurial training. The demographic information obtained is illustrated in Table 1 below.

Table 1. Participant profile

Item		Frequency	Per cent
Age	18 to 30 Years	291	79.5
	31 to 40 Years	70	19.1
	41 to 50 Years	5	1.4
Education Background	Business	176	48.1
	Non-business	190	51.9
Education Level	Diploma	121	33.1
	Bachelor	190	51.9
	Master	55	15.0
Entrepreneurial Education	Trained	80	21.9
	Not Trained	286	78.1

This demographic distribution provides critical context for the study. The predominance of younger respondents aligns with the findings of Kelley et al. (2017), which suggest that younger populations,

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particularly in innovation-driven economies, show higher entrepreneurial activity. The relatively low participation in entrepreneurial training aligns with prior observations by Barba-Sánchez, Atienza-Sahuquillo (2017), who emphasized the need for enhanced entrepreneurial education to develop skills and motivation.

As depicted in Table 2, the study provides information on each construct's mean and standard deviation. A five-point Likert scale with equal-sized categories was employed in this investigation. To facilitate interpretation, scores falling between 1.00 and 2.33 are categorized as low, scores ranging from 2.34 to 3.66 are considered moderate, and scores falling within the range of 3.67 to 5.00 are regarded as high. Overall, the mean data was categorized between moderate and high scores. The data suggests that respondents tend to rate factors related to entrepreneurial intention and attitude relatively high, as evidenced by higher mean scores; factors related to perceived behavioral control and subjective norms are relatively middling, as evidenced by moderate mean scores.

On the other hand, standard deviations ranged between 1.05 and 1.37, revealing more variability, as indicated by higher standard deviations. These results are consistent with the Theory of Planned Behavior (Ajzen 1991), which identifies attitudes as a critical determinant of intention. The variability in standard deviations (ranging from 1.05 to 1.37) suggests diverse respondent perceptions, echoing findings by Gird and Bagraim (2008) regarding the importance of contextual influences on entrepreneurial intentions

Table 2. Descriptive analysis

	Mean	Standard deviation	Implementation Level
AT1	3.86	1.05	high
AT2	3.96	1.16	high
AT3	3.99	1.16	high
AT4	3.82	1.33	high
AT5	3.72	1.18	high
EI1	3.89	1.21	high
EI2	3.84	1.23	high
EI3	3.84	1.07	high
EI4	3.60	1.13	moderate
EI5	3.82	1.08	high
PBC1	3.15	1.18	moderate
PBC2	3.23	1.12	moderate
PBC3	2.82	1.22	high
PBC4	3.00	1.28	moderate
SN1	2.59	1.37	moderate
SN2	2.66	1.17	moderate
SN3	2.49	1.37	moderate
SN4	2.66	1.28	moderate
SN5	2.74	1.30	moderate

4.2 Results of the measurement model

Under measurement model assessment, the data reliability and validity were measured by examining items in latent variables (Hair et al., 2011).

4.3 CFA for the measurement model

The reliability of each measurement item construct was also examined in which loading with more than 0.4 value is generally considered acceptable (Hair et al., 2006). Loading values ranged between 0.78 to .94; thus, no internal consistency problems, except the PBC5 item, were found with low loading (0.11) and eliminated from further analysis. Meanwhile, internal consistency was used to test whether the scale used could measure the concept that should be measured or otherwise.

Table 3 below displays key reliability and validity measures, including Cronbach's alpha, composite reliability, and Average Variance Extracted (AVE), for various latent constructs in the measurement model. The high values of Cronbach's alpha, ranging from 0.80 to 0.95, indicate strong internal consistency within each construct, surpassing the conventional threshold of 0.70. Composite reliability values, ranging from 0.93

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to 0.99, also affirm the reliability of the constructs. Additionally, the AVE values, ranging from 0.61 to 0.84, exceed the recommended threshold of 0.50, indicating substantial convergent validity. These findings collectively suggest that the measurement model demonstrates robust reliability and convergent validity, supporting the consistency and accuracy of the items in measuring each latent variable (Hair et al., 2017). Table 3 summarizes the CFA results for the measurement model.

Table 3. Results of CFA for the measurement model

Variable	Items	Loadings	Cronbach's alpha	Composite reliability	AVE
Attitudes Toward (AT)	AT1	0.86	0.95	0.95	0.83
	AT2	0.93			
	AT3	0.94			
	AT4	0.91			
	AT5	0.91			
Entrepreneurial intention (EI)	EI1	0.92	0.95	0.96	0.84
	EI2	0.92			
	EI3	0.94			
	EI4	0.88			
	EI5	0.92			
Perceived Behavioral Control (PBC)	PBC1	0.87	0.80	0.93	0.61
	PBC2	0.89			
	PBC3	0.84			
	PBC4	0.90			
	PBC5	0.11			
Subjective Norms (SN)	SN1	0.88	0.92	0.99	0.75
	SN2	0.91			
	SN3	0.86			
	SN4	0.78			
	SN5	0.88			

4.4 Discriminant validity

Discriminant validity shows the extent to which constructs differ from each other by examining the correlations between potentially overlapping constructs using the Heterotrait-monotrait ratio (HTMT) – Matrix. Generally, values below a threshold (commonly 0.85) indicate acceptable discriminant validity, implying that the constructs are distinct (Henseler, 2015). In the matrix presented below in Table 4, the values below the diagonal represent the HTMT ratios. The HTMT values obtained ranged from 0.20 to 0.75, not exceeding the more liberal HTMT level of 0.85. Hence, based on the heuristic rules, the HTMT values proved to have discriminant validity and were submitted for further analysis.

Table 4. Heterotrait-monotrait ratio (HTMT) – Matrix

	AT	EI	PBC
AT			
EI	0.75		
PBC	0.62	0.39	
SN	0.23	0.20	0.46

The F2 test results reflect the effect size of each latent construct on its indicators, indicating the amount of variance in the indicators explained by the latent constructs: the Higher F2 values, the stronger the impact. F-Square is the change in R-Square when an exogenous variable is removed from the model. Following Cohen (1988), F-square is effect size (>=0.02 is small; >= 0.15 is medium;>= 0.35 is large). Table 5 below represents that removing SN and PBC has a small effect size (0.2) in change R2, with a large effect size for AT.

Table 5. F-square results

	EI
AT	0.86
PBC	0.02
SN	0.02

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4.5 Construct validity

Construct validity should be run as if there is a high correlation between a set of constructs in a study; multicollinearity problems can arise within the model (Henseler et al., 2009). Table 6 shows that correlation values ranged between 0.20 and 0.72. Thus, the results indicate no multicollinearity problems were found, and the measurement constructs were ultimately valid.

Table 6. Construct validity (Correlations matrix)

	AT	EI	PBC	SN
AT	1.00			
EI	0.72	1.00		
PBC	0.57	0.36	1.00	
SN	0.20	0.21	0.41	1.00

4.6 Structural model result

The second phase of the analysis was adjusted to measure the structural model used for hypothesis testing. In this phase, the relationship of the constructs was examined by assessing the path coefficient (β), t-statistics, and p values. Table 7 presents the results of the direct hypotheses test. Meanwhile, the results of the coefficient path analysis for the general model (without groups) are revealed in Figure 2.

As expected, the H1 is supported by reflecting that women's attitudes toward entrepreneurs have a significantly strong positive effect (β=0.77, p=0.00) on their intention to be entrepreneurs. In addition, women's subjective norms of entrepreneurship leave a positive effect (β=0.10, p=0.00) on their intention to be entrepreneurs, even a weak effect. Therefore, H3 was supported. Surprisingly, H2 was rejected, as the results reported that women's perceived behavioral control of entrepreneurs harms (β=-0.11, p=0.03) their intention to be entrepreneurs. This emerging need to discover the reasons behind the opposing effect found in H2, as a means of how multi-group differences prove the unexpected adverse effect.

Table 7. Results of path coefficients

H #	Hypothesized path	β	STDEV	T- value	P values	Hypothesis result
H1	AT -> EI	0.77	0.03	22.18	0.00	supported
H2	PBC -> EI	-0.11	0.05	2.14	0.03	rejected
H3	SN -> EI	0.10	0.03	2.93	0.00	supported

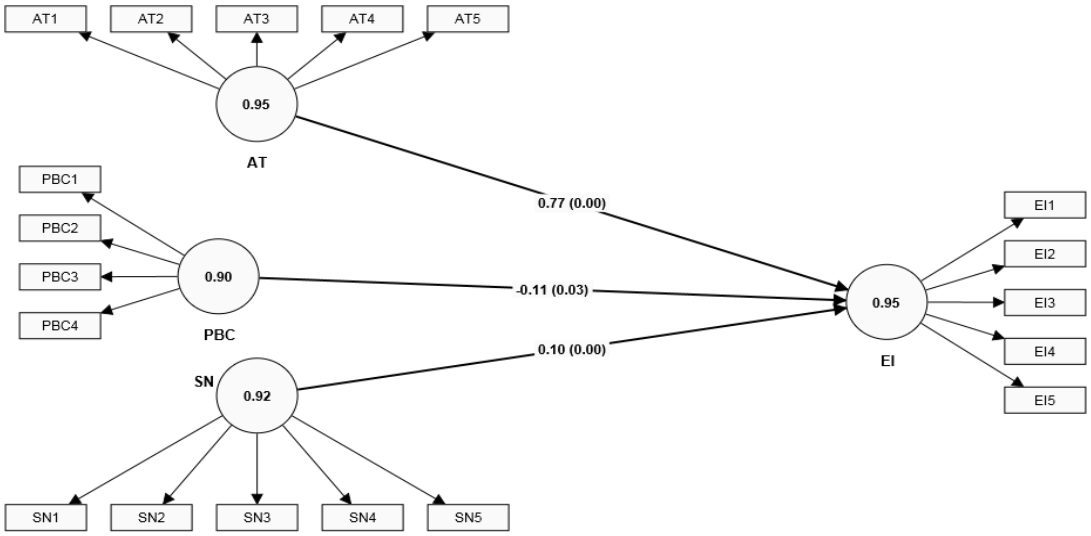


Figure 2. General model path coefficients and Cronbach Alpha

The business group and non-business group differences

Although the results in Table 8 show a positive significant effect for the women business and non-business educational background group (β =0.83, p=0.00), (β =0.72, p=0.00) respectively; with different positive effects (β =0.11) to moderate the impact of their attitudes toward entrepreneurs on their intention to be entrepreneurs. The p-value of the difference between the multi-groups is insignificant (p=0.00). Therefore, the

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H4a is rejected. For H4b, there is no significant effect of women with a business educational background positively moderating the effect of their perceived behavioral control of entrepreneurs on their intention to be entrepreneurs. For H4c, women with a business educational background can increase (β =0.14, p=0.00) their subjective norms of entrepreneurs on their intention to become entrepreneurs. Whereas a non-significant (P>0.05) effect of business educational background women on such relationship. Thus, H4c is not supported.

Table 8. Path coefficients and Multi-group analysis (MGA) results for educational background

	H4a	H4b	H4c
Hypothesized path	AT -> EI	PBC -> EI	SN -> EI
β (Business)	0.83	-0.15	0.10
β (Non-Business)	0.72	-0.10	0.14
STDEV (Business)	0.04	0.09	0.10
STDEV (Non-Business)	0.06	0.07	0.05
t value (Business)	18.61	1.61	1.03
t value (Non-Business)	12.19	1.58	2.90
p-value (Business)	0.00	0.11	0.30
p-value (Non-Business)	0.00	0.11	0.00
Difference (Business - Non-Business)	0.11	-0.05	-0.04
p-value (Business vs Non-Business)	0.11	0.70	0.73

The diploma, bachelor and master educational level groups' differences

As shown in Table 9, there is a positive significant effect for the women's educational diploma and bachelor level groups (β =0.88, p=0.00), (β =0.65, p=0.00) respectively, with different significant negative effects (β =-0.23, p=0.00) to moderate the impact of their attitudes toward entrepreneurs on their intention to be entrepreneurs, but not master educated. The diploma group is more affected than the bachelor group. Therefore, the H5a is supported. For H5b, unexpected results that there is a significant negative effect for the women's educational master level group (β =-0.48, p=0.01), but not for diploma and bachelor groups. Such results reflect that highly educated women (Master's Degree) inhibit their perception of behavioral control of entrepreneurs on their intention to be entrepreneurs.

Therefore, H5b is rejected. H5c is supported as women's educational diploma and master degree level groups (β =0.11, p=0.01), (β =0.48, p=0.00), respectively. The more educated women are, the more affected they are by their subjective norms of entrepreneurship and their intention to be entrepreneurs. The difference between the diploma versus master groups is strong and significant (β =-0.73, p=0.01), as shown in Table 10 below.

Table 9. Path coefficient results for educational level

	H5a	H5b	H5c
Hypothesized path	AT -> EI	PBC -> EI	SN -> EI
β (Diploma)	0.88	0.03	0.11
β (Bachelor)	0.65	-0.15	-0.12
β (Master)	0.31	-0.48	0.84
STDEV (Diploma)	0.03	0.05	0.04
STDEV (Bachelor)	0.08	0.09	0.09
STDEV (Master)	0.34	0.19	0.27
t value (Diploma)	29.07	0.65	2.67
t value (Bachelor)	8.21	1.73	1.33
t value (Master)	0.91	2.49	3.17
p-value (Diploma)	0.00	0.52	0.01
p-value (Bachelor)	0.00	0.08	0.18
p-value (Master)	0.36	0.01	0.00

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Table 10. Results of multi-group analysis (MGA) for educational level

	H5a	H5b	H5c
Hypothesized path	AT -> EI	PBC -> EI	SN -> EI
Difference (Bachelor - Diploma)	-0.23	-0.18	-0.23
Difference (Bachelor - Master)	0.35	0.33	-0.96
Difference (Diploma - Master)	0.58	0.51	-0.73
p-value (Bachelor vs Diploma)	0.00	0.07	0.05
p-value (Bachelor vs Master	0.38	0.13	0.00
p-value (Diploma vs Master)	0.06	0.04	0.01

The entrepreneurial-educated and non-entrepreneurial-educated groups' differences

Table 11 shows a positive significant effect for the trained entrepreneurial women and non-trained groups (β =0.89, p=0.00), (β =0.66, p=0.00), respectively, with considerable difference effects (β =0.23, p=0.00) to moderate the effect of their attitudes toward entrepreneurs on their intention to be entrepreneurs. This reflects that trained entrepreneurial women have higher attitudes toward becoming entrepreneurs. Therefore, H6a is supported. For H6b, as expected, there is a significant negative effect for the non-trained entrepreneurial group (β =0.-20, p=0.00), and a positive effect (β =0.14, p=0.00). This reflects that more entrepreneur-trained entrepreneurs have a higher perception of behavioral control of entrepreneurs based on their intention to be entrepreneurs. The significant statistical difference (β =0.34, p=0.00) proves the H6b is supported. The results show that the non-trained entrepreneurial group is positively affected (β =0.19, p=0.00) by their subjective norms of entrepreneurship on their intention to be entrepreneurs, but not the trained entrepreneurial group (p=0.20). Thus, the H6c is rejected.

Table 11. Path coefficients and multi-group analysis (MGA) results for entrepreneurial education

	H6a	H6b	H6c
Hypothesized path	AT -> EI	PBC -> EI	SN -> EI
β (Not-Trained)	0.66	-0.20	0.19
β (Trained)	0.89	0.14	-0.03
STDEV (Not-Trained)	0.05	0.07	0.06
STDEV (Trained)	0.03	0.04	0.02
t value (Not-Trained)	13.00	3.02	3.22
t value (Trained)	27.43	3.71	1.27
p-value (Not-Trained)	0.00	0.00	0.00
p-value (Trained)	0.00	0.00	0.20
Difference (Trained - Not-Trained)	0.23	0.34	-0.22
p-value (Trained vs Not-Trained)	0.00	0.00	0.01

5 Findings and discussion

5.1. Descriptive analysis

This study employed a five-point Likert scale to gauge attitudes (AT), entrepreneurial intention (EI), perceived behavioral control (PBC), and subjective norms (SN). Results indicate high mean scores for AT (e.g., AT1 = 3.86, AT3 = 3.99), reflecting favourable attitudes toward entrepreneurship. EI also exhibited high scores (e.g., EI1 = 3.89, EI5 = 3.82), suggesting a strong inclination toward entrepreneurial activities among respondents. Conversely, PBC and SN recorded moderate scores, such as PBC1 (3.15) and SN3 (2.49), indicating less confidence and perceived support for entrepreneurial endeavours.

5.2. Measurement model reliability and validity

The confirmatory factor analysis (CFA) results demonstrated robust reliability and validity. All constructs exceeded the recommended thresholds for Cronbach's alpha (e.g., AT = 0.95, EI = 0.95), composite reliability (e.g., AT = 0.95, EI = 0.96), and average variance extracted (AVE) (e.g., AT = 0.83, EI = 0.84). Discriminant validity was confirmed using the Heterotrait-Monotrait ratio (HTMT), with values ranging from 0.20 to 0.75, well below the 0.85 threshold. These findings align with prior studies, such as Solesvik (2013), which highlight the role of validated models in understanding entrepreneurial behaviors. The high internal consistency further supports the robustness of the constructs in explaining entrepreneurial intentions.

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5.3. Structural model results

The structural model analysis highlights significant relationships between constructs:

- H1: Attitudes toward entrepreneurship (AT) have a strong positive effect on entrepreneurial intention (EI), consistent with findings by Soria-Barreto et al. (2017).
- H2: Perceived behavioral control (PBC) negatively influences EI, contrary to expectations. This finding aligns with Choukir et al. (2019), who noted the influence of external barriers and cultural norms on perceived control.
- H3: Subjective norms (SN) have a weak but positive effect on EI, supporting Quan (2012) and Solesvik (2013), who emphasized the role of social pressures and cultural settings.

These results underscore the central role of attitudes in shaping entrepreneurial intentions, consistent with the TPB framework (Ajzen, 1991). For group differences in educational background, it's noted that both business and non-business groups demonstrated significant positive effects of AT on EI, with business-educated respondents showing a slightly stronger relationship. These findings corroborate Ward et al. (2019), who highlighted the broader utility of entrepreneurial skills beyond specific fields of study.

- Educational Level: Respondents with diplomas exhibited the strongest positive relationship between AT and EI, followed by those with bachelor's degrees. Interestingly, master's degree holders showed a negative effect of PBC on EI, reflecting findings by Hutasuhut (2018) that postgraduate students may perceive higher opportunity costs or risk aversion.
- Entrepreneurial Education: Trained respondents exhibited significantly higher AT effects on EI compared to non-trained respondents. Barba-Sánchez & Atienza-Sahuquillo (2017), who found that entrepreneurial education significantly enhances intentions and attitudes.

Implications and recommendations

1. Enhancing Entrepreneurial Education: The findings underscore the importance of targeted entrepreneurial training programs to strengthen attitudes and perceived behavioral control, consistent with recommendations by Nowiski et al. (2017).
2. Addressing Perceived Barriers: The negative influence of PBC suggests a need to identify and mitigate external constraints, such as financial, cultural, or policy-related barriers, as emphasized by Kelley et al. (2017).
3. Tailored Interventions: Different educational backgrounds and levels require customized strategies. For instance, highly educated individuals may benefit from advanced risk management training to enhance perceived control, echoing Hutasuhut (2018).
4. Supportive Ecosystems: Strengthening subjective norms through mentorship programs, peer networks, and societal support systems could encourage entrepreneurial pursuits, as suggested by Quan (2012).

These insights provide a comprehensive understanding of the determinants of entrepreneurial intention among women, offering actionable strategies for policymakers, educators, and practitioners to foster entrepreneurship.

Conclusions

Entrepreneurship is a cornerstone of economic growth and social development, and understanding the factors that influence entrepreneurial intentions is crucial for fostering a vibrant and inclusive entrepreneurial ecosystem. This study specifically examines the role of socio-demographic characteristics, including educational background and level, in shaping entrepreneurial aspirations among women in Saudi Arabia. Through this lens, the research provides valuable insights into the complex dynamics that drive women's entrepreneurial intentions and the underlying factors that promote or hinder these aspirations.

The findings of this study underscore the centrality of attitudes toward entrepreneurship, which emerge as the most significant predictor of entrepreneurial intentions. While subjective norms also contribute to shaping entrepreneurial behaviors, their influence is relatively weaker than those attitudes. Notably, the research

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highlights the unexpected negative impact of perceived behavioral control on entrepreneurial intentions, suggesting the presence of external or internal barriers that women perceive in the entrepreneurial process despite their level of education. This counterintuitive result calls for further investigation into the obstacles faced by women, particularly in overcoming the psychological and societal barriers that may restrict their entrepreneurial potential.

A particularly striking observation is the variation in entrepreneurial intentions based on educational background. Women with business-related educational qualifications exhibit stronger entrepreneurial intentions, indicating the positive influence of specialized knowledge and training. However, women with higher education levels, such as master's degrees, report lower perceptions of behavioral control, signalling a potential misalignment between their academic achievements and their perceived ability to succeed in entrepreneurship. This suggests that highly educated women face unique barriers that hinder their entrepreneurial ambitions, including a mismatch between their skills and the resources required to translate these skills into entrepreneurial ventures.

Furthermore, the study highlights that educational background plays a nuanced role in shaping entrepreneurial intentions. The varying influence of entrepreneurial attitudes, perceived behavioral control, and subjective norms across different educational groups emphasize the need for tailored policies and initiatives. Education systems and policy frameworks should consider the diverse needs of women entrepreneurs, offering targeted interventions that address specific challenges depending on their level and type of education.

In summary, this research significantly contributes to the growing body of knowledge on women's entrepreneurship by offering empirical evidence on the role of education and socio-demographic factors in shaping entrepreneurial intentions. The study provides actionable insights for policymakers, educators, and development stakeholders working to promote gender-inclusive entrepreneurship and close the gender gap in entrepreneurial activities. By acknowledging the complexities and variations in entrepreneurial intentions, this research highlights the importance of creating a supportive environment that nurtures and empowers women entrepreneurs at all stages of their educational and professional lives.

Building on the valuable findings of this study, several promising avenues for future research are identified:

1. *Psychological and Cultural Factors:* Future studies should explore the psychological barriers (e.g., fear of failure, lack of self-confidence) and cultural expectations that may constrain entrepreneurial intentions, particularly among highly educated women. Additionally, the role of work-life balance and societal pressures in shaping entrepreneurial aspirations should be considered.
2. *Longitudinal Studies:* Longitudinal studies are recommended to gain deeper insights into how entrepreneurial intentions evolve and how interventions affect women's entrepreneurial behaviors. These studies could track the progression of entrepreneurial intentions from education to actual entrepreneurial activity.
3. *Sector-Specific Analysis:* Future research could focus on sector-specific entrepreneurial intentions, identifying industries where women are more likely to thrive as entrepreneurs and uncovering the reasons behind their success or challenges in specific sectors.
4. *Impact of Policy Interventions:* A critical area for future research would be assessing the impact of recent policy reforms and initiatives, such as those under Saudi Vision 2030, on women's entrepreneurial activities. Evaluating the effectiveness of these policies will help identify which reforms are most conducive to promoting women's entrepreneurship.
5. *Entrepreneurial Training:* Investigating the role of structured entrepreneurial training programs in enhancing women's entrepreneurial attitudes, perceived behavioral control, and subjective norms could lead to more effective training initiatives to reduce the gender gap in entrepreneurship.
6. *Comparative Studies*: Comparative analyses across different countries or regions, especially those with distinct socio-economic and cultural contexts, could offer a broader understanding of the global factors influencing women's entrepreneurial intentions. These studies would also provide insights into women's challenges in diverse environments.

7. *Technology and Digital Entrepreneurship*: Given the increasing importance of digital transformation, future research could explore how technology enables women's entrepreneurship, especially in emerging fields such as digital and innovation-driven industries. This could shed light on new opportunities for women in entrepreneurship, particularly in a post-pandemic digital economy.

By addressing these research directions, future studies can expand the understanding of women's entrepreneurship and contribute to formulating effective, evidence-based policies and strategies to foster inclusive and sustainable economic growth. Such efforts will enhance women's entrepreneurial engagement and contribute to broader social and economic development goals.

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POLICY MIX UNDER STRESS: REVIEW OF ECONOMIC REACTIONS TO FISCAL AND MONETARY POLICIES USING DSGE

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Abstract. The paper aims to review the studies with a particular emphasis on the response of selected economies to the central bank's monetary policy and the government's fiscal policy during various economic shocks developed using DSGE models. Countries generally have different financial structures, institutional frameworks, and macroeconomic policy transmission mechanisms. The authors better explain why some economies respond more effectively to central bank and government actions than others. The article uses a bibliometric analysis of the policy mix and DSGE, and presents a case study of theoretical policy mix modelling using DSGE. The central bank's monetary policy and the government's fiscal policy play a key role in stabilising the economy. Analysing their impact in different economic conditions allows for identifying optimal strategies depending on the nature of shocks. The study shows that the response of economies to various shocks (e.g., financial crises, pandemics, supply shocks) allows us to assess the effectiveness of stabilisation policies and their long-term consequences. DSGE models, extended with fiscal reaction functions and considering household financial constraints, help us understand how monetary and fiscal policy interactions affect economic fluctuations and inflation. A properly selected combination of monetary and fiscal policy can stabilise the economy. Still, its effectiveness depends on the type of economic shocks and the degree of activity of both policies.

Keywords: policy mix; DSGE models; monetary policy; fiscal policy; financial crisis; COVID-19; equilibrium

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JEL Classifications: E52, E62, E12, E40, D50

1. Introduction

The ongoing progress in globalisation, economic integration, and information technology continues to impact national economies significantly. Firstly, contemporary economies are distinguished by unparalleled openness regarding international trade and capital movements. While this facilitates efficient resource allocation, it also increases the susceptibility of national economies to external shocks. Secondly, economic and market-related news is disseminated more rapidly and frequently than ever, with economic activities occurring almost continuously (Bergstrom & Nowman, 2007).

The real business cycle (RBC) approach and its offshoot, the dynamic stochastic general equilibrium (DSGE) modelling, have shaped mainly contemporary macroeconomic theory for the last fifty years. RBC models typically depict markets as Walrasian, free from real, nominal, or informational obstacles. In these models, as exemplified by Prescott and Kydland's (1982) seminal work, prices, wages, and economic agent interactions are

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characterised by perfect elasticity, with no friction impeding market operations. Dynamic Stochastic General Equilibrium (DSGE) models provide a special framework for analysing monetary and fiscal policy interactions, particularly in response to economic shocks. These models highlight how different policy mixes can stabilise economies under various conditions. The macroeconomic analysis employs dynamic stochastic general equilibrium (DSGE) modelling, a technique frequently utilised by monetary and fiscal authorities for several purposes, such as policy evaluation, historical data interpretation, and future predictions. Monetary-fiscal interactions constitute an essential element of the economy, and the direction and strength of their impacts should be considered in policy modelling. Therefore, DSGE models are macroeconomic frameworks designed to study the interactions of economic variables over time. These models are employed to interpret and forecast economic activities and to assist in shaping policy decisions. DSGE models integrate contemporary macroeconomic theories with microeconomic foundations and include random disturbances to account for economic variability (Beetsma & Jensen, 2002; Muscatelli, Tirelli & Trecroci, 2004; Ferroni, Fisher & Melosi, 2024).

Considering the limited number of publications on policy mix issues, this article will focus on these relevant topics. Examining the literature on policy mix and DSGE models is crucial for modern macroeconomic analysis. This examination enhances our comprehension of how monetary and fiscal policies interact under various economic circumstances. Within the framework of DSGE models, which dynamically simulate these interactions, the literature survey helps determine the impact of different factors, such as interest rates, government expenditure, or taxation, on the economy throughout various stages of the business cycle. DSGE models are among the most frequently utilised tools for analysing monetary and fiscal policies. Reviewing the literature helps identify their strengths and weaknesses, particularly in actual economic crises, like the global financial crisis or the COVID-19 pandemic. DSGE models facilitate analysing how monetary and fiscal policies influence the economy through various channels, including investment, consumption, employment, or inflation. The literature review provides a more profound understanding of these transmission mechanisms and enables better prediction of policy mix effects in different scenarios.

Hence, the study will aim to review the studies with a particular emphasis on the response of selected economies to the monetary policy of the central bank and the fiscal policy of the government during various economic shocks developed using DSGE models.

The structure of the paper is as follows. Section 1 introduces the study, and Section 2 reviews the impact of fiscal and monetary policies on economies under various economic shocks. Section 3 performs a bibliometric analysis in the context of policy mix and DSGE models. In section 4 the significant importance of DSGE models in policy mix research is presented; section 5 details the modelling of the policy mix considering the DSGE framework. Section 6 contains conclusions.

2. Policy mix and the economy

Due to the appearance of various economic shocks in economies, i.e., financial crisis, debt crisis, COVID-19 pandemic, inflation shock, energy crisis, and others, the forecasting process of macroeconomic variables has become extremely important, especially from the point of view of players making important decisions regarding the economy, such as the central bank and government. Therefore, these decisions should be supported with appropriate tools. Among these tools, literature (Leeper, 1991; Smets & Wouters, 2003; Woodford, 2003; Christiano, Eichenbaum & Evans, 2005; Gali & Monacelli, 2005) has introduced dynamic stochastic general equilibrium models (DSGE), which are currently a monetary policy tool that can describe the monetary transmission mechanism, starting from the monetary impulse to the reaction of the main macroeconomic variables (namely fiscal variables).

Indeed, in examining and forecasting the impact of monetary and fiscal impulses on the economy, it is crucial to thoroughly understand the relationships and interactions that occur between the decisions of central banks and governments in the context of their policies (Tetik, Ceylan, Ulucan & Bari, 2021; Tetik & Ceylan, 2021; Stawska & Reis Mourao, 2023). These players make decisions with differentiated levels of coordination, and

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each result significantly impacts the economy. Sargent and Wallace (1981) signed the seminal "Theory of Unpleasant Monetarist Arithmetic" based on the idea that at the time of fiscal dominance, the monetary authorities can no longer keep inflation under control, regardless of the used strategy. Hence, the conclusion is that the central bank's decisions regarding the conduct of monetary policy are affected by fiscal policy. In the short term, stabilisation of the economy is difficult due to the differences in goals or preferences of the central bank and fiscal authorities. The optimal solution for both authorities is to coordinate their actions and decisions (Sargent & Wallace, 1981).

Another influential model related to monetary and fiscal policy interactions comes from the Fiscal Theory of the Level Price (FTPL), initially developed by Woodford (1994). Its author assumed that the price level was determined by public debt and fiscal policy. Although FTPL has been criticised (Buiter, 2000, 2002; McCallum, 2001, 2003), the existence of this approach is important in interpreting the development of many economic issues. What is worth mentioning Samuelson-Balassa hypothesis (Samuelson, 1964; Balassa, 1964), which also underlines the importance of interactions between monetary and fiscal authorities in the context of price differences in various countries. According to the authors of this hypothesis, the faster productivity growth in catching-up (converging) countries, compared to developed economies, is attributed to a higher level of inflation or appreciation of the nominal exchange rate (Samuelson, 1964; Balassa, 1964). Hoffmann and Schnabl (2008, 2011), Jorda, Schularick and Taylor (2015), and Brunnermeier and Schnabel (2015) based their analyses on Taylor's rule (Taylor (2007). These studies noticed that too expansionary monetary policy was the cause of excessive financial boom, which contributed to the financial crisis of 2007-2009.

The financial crisis of 2007-2009 and the sequent debt crisis changed the approach to monetary and fiscal policy. As a result of this financial crisis, the debate on the effectiveness of monetary and fiscal policy in economic activity was resumed. Guerguil, Mandon and Tapsoba (2017) and Özer and Karagöl (2018) emphasised that, as a consequence of the financial crisis, the monetary policy of the autonomous central banks had a limited impact on economic activity in many countries (mainly during the zero lower bound phenomenon). In turn, fiscal instruments were considered countercyclical tools of macroeconomic policy. However, according to Pečarić, Slišković and Kusanović (2018), the impact of fiscal policy on economic growth increased during these times, which was particularly due to the activation of automatic fiscal policy stabilisers during the crisis. In response to the crisis, economic authorities tried to stimulate demand in economies through increased public spending and tax reforms. However, with expansionary fiscal policy, public deficits and debt tend to increase (Ettmeier & Kriwoluzky, 2024). This was observed in several EU countries when, due to an expansive fiscal policy during the financial crisis of 2008-2009, public deficits and debts of individual countries increased significantly, which additionally created inflationary pressure (van Riet, 2010).

The central bank and the government, using the available monetary and fiscal policy instruments, respectively, are assumed to affect the economy. The rationale for this phenomenon can be summarised as follows. The impact of monetary policy on the economy takes a special dimension through transmitting monetary policy impulses to the real economy (Rotemberg & Woodford, 1997; Clarida, Gali & Gertler, 1999). According to the IS-LM paradigm, a reduction in the money supply leads to higher interest rates and, consequently, to a decrease in investment activity (Gerdesmeier, 2009). The central bank influences other interest rates by controlling short-term money market interest rates (Tobin, 1978). Bernanke and Blinder (1990) recognised that the interest rate is one of the most frequently mentioned monetary policy instruments influencing economic growth in the literature. According to Boivin, Kiley and Mishkin (2010), neoclassical channels consider the direct impact of interest rates on investment spending, wealth and intertemporal substitution on consumption and the effect on foreign trade through exchange rates. Talpos, Avram and Hetes (2013), focusing on the research on the impact of monetary and fiscal policy on economic growth in European Union (EU) countries, noted a substantial effect of interest rates on GDP. Altavilla and Ciccarelli (2007) emphasised that stabilising inflation is vital for the entire economy, including the level of investment. Borio and Lowe (2002) noted earlier that low and stable inflation determines financial stability. However, unexpected fluctuations in inflation tend to increase the economy's susceptibility to crises. Changes in the level of interest rates also have a significant impact on household savings and consumption.

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Since the 2008-2009 financial crisis and the subsequent recession, negative nominal interest rates have become an additional policy tool for central banks in many developed countries (Bernoth & Haas, 2018). As Coeure (2016) argued, negative interest rates strengthen other monetary policy instruments. Many central banks adopted unconventional monetary policies (UMP) (Tillmann, 2016). Michael (1998) pointed out that the ultimate consequence of such policies was the loss of the ability to stimulate savings in a low-interest-rate scenario. When real interest rates (in both developed and emerging economies) are negative, a cap on deposit interest rates encourages savers to hold government bonds (Reinhart, Kirkegaard & Sbrancia, 2011). An interest rate at or close to zero also supports fiscal stimulus because it creates conditions for the government to achieve a significant budget deficit by lowering debt service costs. Low economic growth usually leads to problems related to the deepening deficit of the general government sector, most often during or after financial crises or, more broadly, economic crises. In most cases, an interest rate of zero or close to zero contributes to a larger deficit because it prevents the central bank from stimulating overall demand.

Some studies have noted the dominance of fiscal policy during the crisis, especially in combination with accommodative monetary policy (maintaining low interest rates) (Spilimbergo, Symansky, Blanchard, & Cottarelli, 2009). The authors of these studies emphasised that fiscal policy instruments are easier to use and stimulate the economy in a shorter period than monetary policy measures (Summers, 2008). In the wake of the 2007-2009 financial crisis, numerous governments implemented discretionary fiscal policies that increased deficits and debt in the general government sector. These fiscal packages, driven by discretionary fiscal policy, were designed to stabilise financial systems and boost aggregate demand in affected economies (Spilimbergo, Symansky, Blanchard, & Cottarelli, 2009). Macroeconomic policy significantly influences sustainable economic growth, encompassing monetary and fiscal policies as its key components (Sen & Kaya, 2015). Authorities in EU countries have prioritised fiscal stability to mitigate the impact of fiscal shocks on national budgets (Voda, Dobrotă, Dobrotă & Dumitrașcu, 2002). Suescun (2020) argues that fiscal policy should be considered a long-term financial strategy rather than a single-period shock, as it involves the government's implementation of socio-economic measures to prevent fiscal unpredictability that could lead to economic instability and hinder sustainable development. Chugunov, Pasichnyi, Koroviy, Kaneva and Nikitishin (2021) suggest that fiscal policy should foster economic growth by managing revenues, expenditures, and budget deficits, while monetary policy should aim to maintain price stability. Corsetti, Dedola, Jarociński, Maćkowiak and Schmidt (2016) propose that coordinated monetary and fiscal policies are essential for economic stabilisation, particularly during severe recessions. Furthermore, Corsetti, Higgins and Pesenti (2016) emphasise that monetary policy cannot achieve its intended objectives without substantial support from fiscal policymakers.

While there is no universal agreement in academic literature or practical application regarding the ideal monetary or fiscal policy, a significant body of research supports inflation targeting as the preferred approach. This view is reflected in the increasing number of countries adopting this strategy (Ball & Sheridan, 2004). Numerous scholars have contributed to this discourse, including Leiderman and Svensson (1995), Bernanke and Mishkin (1997), Svensson (2000), Mishkin and Schmidt-Hebbel (2001), Amato and Gerlach (2002), Truman (2003), Gonçalvesa and Salles (2008). Concurrently, fiscal rules are gaining traction in theoretical discussions and real-world applications. This trend is evidenced by the work of researchers such as Alesina and Bayoumi (1996), Fatas and Mihov (2006), Hallerberg, Strauch & Hagen (2007), Krogstrup and Waelti (2008), Caceras, Corbacho and Medina (2010), de Jesus, Besarria and Maia (2020).

3. A bibliometric analysis of DSGE

In the last decade, scientific studies on bibliometric analyses have "exploded" in numbers, citations and interest. In 1969, the SCOPUS referencing database identified one work using the terms' bibliometrics/bibliometric'; in 2023, the same database identified more than 44 thousand works with the same criteria.

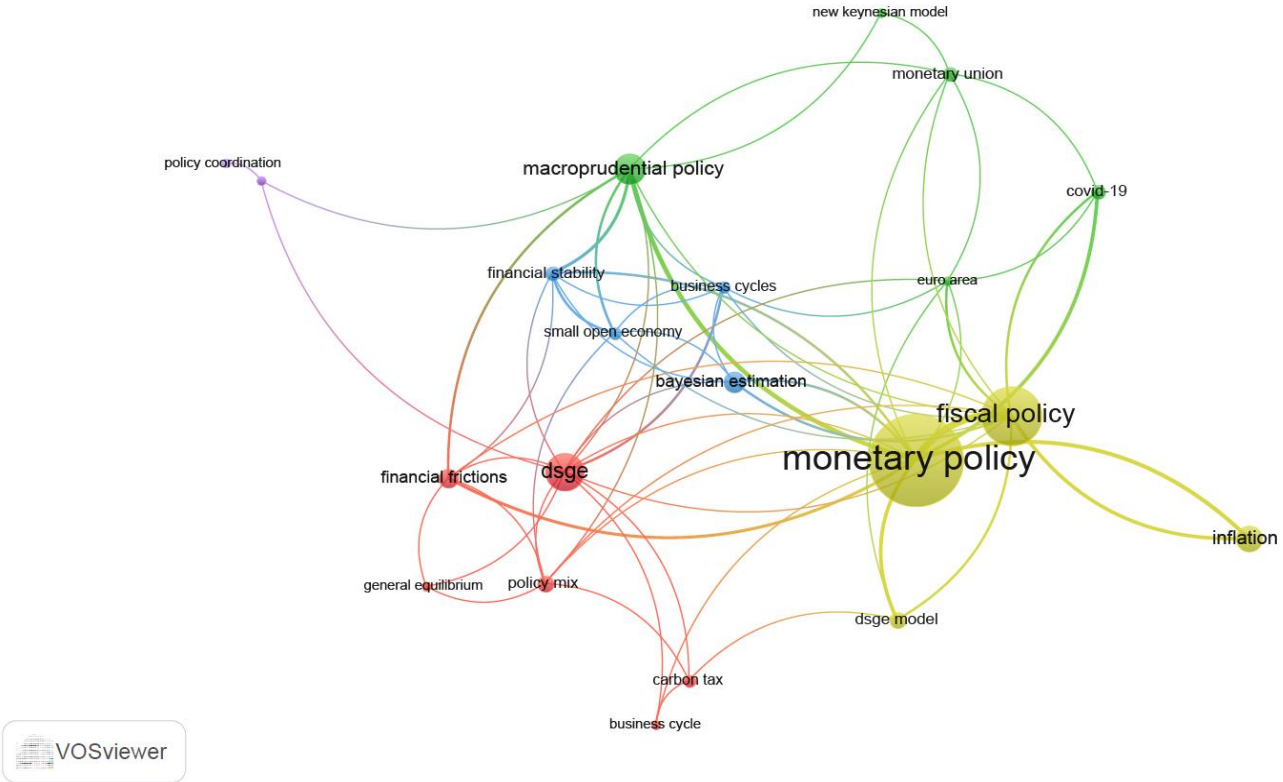
Generally speaking, a bibliometric analysis is a response based on methodological procedures to a simple question: what is there in the published knowledge on a given topic? In a simplified image, bibliometric analysis resembles the response of a bookseller or librarian when we ask them what books there are in the bookstore or the library (respectively) on a given topic.

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In addition, bibliometric analysis identifies a set of complementary fields and makes a series of alternative observations. Using the image of a visit to a bookstore or library, bibliometric analysis points out the oldest books, derivative publications, or the most verbose authors.

The methodology for researching policy mix and DSGE models using VOSviewer software involved the following steps (Gorzeń-Mitka, Bilska, Tomaszeska & Kołożyn-Krajewska, 2020; van Eck & Waltman, 2019):
1. Locating publications in the chosen scientific database (SCOPUS) using specific search criteria (specifically, "policy mix" AND "DSGE models" yielding 190 publications in the years 2009 - 2024).
2. Generating and extracting the bibliographic information for the identified publications from SCOPUS in .csv format.
3. Selecting the VOSviewer option that enables map creation based on bibliographic data, adhering to the software's guidelines (specifically, importing SCOPUS-downloaded data and choosing the keyword occurrence research option).
4. Reviewing and refining the software-selected terms by eliminating "noise" such as the repeated word "new - Keynesian policy", and eliminating the keywords "e52" and "renewable energy" - the latter is not related to the research topic - other than that, it did not show any relationship with the different keywords.
5. Producing a keyword relationship map and examining it using the "items" and "analysis" features.

In the articles examined from the Scopus (which were extracted by entering the phrases "policy mix" and "DSGE model"), 190 articles appeared, and in them, 576 keywords of which, after making some restrictions, it was noted that a given keyword should appear at least four times, which allowed for a reduction to 24 keywords. Three keywords were excluded from these, as mentioned above, which either repeated, were irrelevant to the studied area, or had no connection with other keywords. Thus, 21 keywords remained, grouped into five clusters (see Scheme 1 and Table 2).



Scheme 1. Keywords occurrences based on literature related to "policy mix" and "DSGE"
Source: Own collaboration in VOSviewer based on SCOPUS data

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Analysing the information contained in Table 1, we can see that the most frequently appearing keyword was "monetary policy" (39 times), followed by "fiscal policy" (25 times) from cluster 4 and DSGE (16 times) from the first cluster, and adding "DSGE model" (7 times) from cluster 4, it can be suggested that DSGE also appeared frequently in the examined articles. In Table 1, the Occurrence Ratio (OR) quantifies the frequency of keyword pairs appearing together in publication titles, abstracts, or keyword lists; the Links (L) means the number of keywords that the keyword we are examining is connected to; the Total Link Strength (TLS) means the number of all occurrences of a given keyword with other keywords. TLS of the keywords such as "monetary policy" (45), "fiscal policy" (33) and "DSGE" (14) and "DSGE model" (8) show that in the examined area, these keywords can be considered the central ones.

Table 1. Keywords and their occurrences in the bibliometric analysis related to policy mix and DSGE models conducted in VOSviewer

Cluster	Colour	Keywords	Occurrences	Links	Total link strength
Cluster 1 (six items)	red	Business cycle	4	3	3
		Carbon tax	5	4	4
		DGSE	**16**	**13**	**14**
		Financial frictions	8	7	10
		General equilibrium	4	3	3
		Policy mix	7	8	8
Cluster 2 (five items)	green	Covid-19	6	4	8
		Euro area	4	7	8
		Macroprudential policy	13	11	20
		Monetary union	6	6	6
		New Keynesian model	4	2	2
Cluster 3 (four items)	blue	Bayesian estimation	9	6	8
		Business cycles	5	7	8
		Financial stability	6	7	11
		Small open economy	5	6	8
Cluster 4 (four items)	yellow	**Dsge model**	**7**	**4**	**8**
		Fiscal policy	**25**	**13**	**33**
		Inflation	11	2	9
		Monetary policy	**39**	**13**	**45**
Cluster 5 (two items)	purple	Policy coordination	4	1	1
		Welfare analysis	4	3	3

Source: Own presentation based on VOSviewer.

Other conclusions can be drawn from the above bibliometric analysis performed in VOSviewer. First of all, the topic of policy mix and DGSE model is still worth exploring. We noticed that some keywords are connected with the subject studied. The highlighted keywords that appeared at least four times in the studied group of publications were grouped into five clusters. Each cluster also indicates specific leading research trends in DSGE models used for policy mix research.

Complimentary steps of a bibliometric analysis

The steps of a bibliometric analysis will depend on the main objectives of the research team. When we consult the literature, we find many steps or methodological stages. However, for operational purposes, we can identify the following as the main steps:

- definition of terms and keywords that are effective in identifying and filtering the works that we want to analyse within the phenomenon;
- identification of the appropriate search engines for this purpose;
- recognition of the most important languages of the texts of the publications;
- identification of the period we want to cover in relation to the date of the publications, as well as the period in which the bibliometric survey was carried out.

Within the list obtained, it is then worth noting the following:

- removal of homonymous publications (due to being associated with different versions of the articles or works);
- analysis of the existence or lack thereof in all publications and of all the fields that are expected to be studied (for example, names and academic affiliations of authors, abstracts, keywords, etc.).

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After these preliminary stages, bibliometric research moves on to an initially descriptive dimension. This dimension analyses the work identified by type (articles, books, conference proceedings, etc.) and its temporal evolution. Although there is a tendency for the most recent years to be those in which there have been more publications identified, both cumulatively and on an annual average (there are several reasons – from the growth in the number of journals included in the consulted databases to the increase in the number of researchers at a global level), this temporal analysis may, among other reasons, indicate 'peaks' or decreases in the number of publications, generally around a specific academic (and also media) prominence on the phenomenon.

The principal authors of the works are then identified, with attention paid to the years of publication, as well as the associated universities and their respective nationalities. Although scientific research does not have to be dependent on the binomial "observation of the phenomenon in a location/researchers from that location," the identification of the main authors and universities shows where the phenomenon has localised discussion focuses, which helps to identify more specialised work and research groups for the respective debate. A similar analysis concerns the discussion of the language of the publications, identifying phenomena reported for a more globalised discussion (generally published in English) or for a more localised discussion (published mainly in languages spoken around the world).

We analysed the main journals published on the topic and where the identified works were most concentrated. It is interesting to observe the impact indexes of these journals, generally positively associated with the number of citations expected of an article published in each journal. In this regard, it may be stimulating to compare the impact index of each of these journals with the number of citations of each of the articles under analysis, showing whether, depending on the year of publication of the article, it performed better than expected. Content analysis may also prove relevant and associated with elements such as the title, abstract, or keywords. This analysis will highlight the most used terms/words, identifying them as the core of the discussions developed, the most used methodological resources or the concepts of a broad debate. For this purpose, software such as Atlas.ti or Iramuteq can be referenced.

We consider it relevant to differentiate the values by publication language (English, French, German, Italian, and Spanish). As will be presented, different lines of observation were found. Thus, on 27th November 2024, we began by surveying the works that mention "DGSE" in the Scopus and WoS databases. It is worth noting that Scopus and WoS identified 53 documents containing "DGSE" in the title, abstract or keywords. As expected, a concentration of work has been identified over the most recent years (particularly since 2006).

Figure 1 shows the evolution of the number of publications regarding DGSE in the observed period. Notably, there is no clear trend in the number of publications, which shows that this topic is still an emerging field in economics, with a limited number of identified publications over the years.

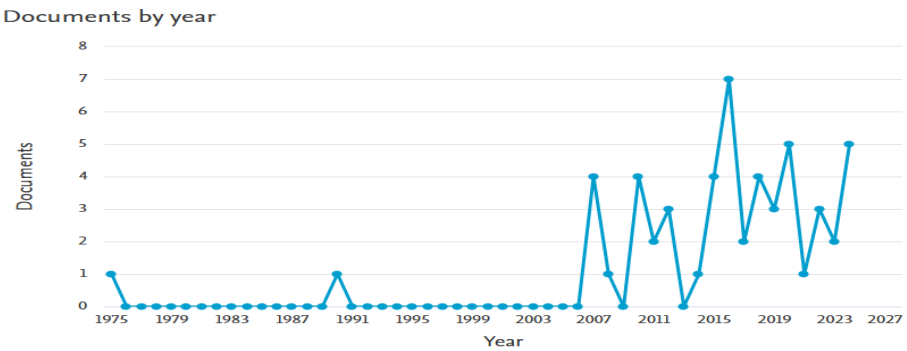


Figure 1. Evolution of the number of documents referenced with the DGSE term
Source: Own study based on SCOPUS and Web of Science

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Bharadwaj, Choudhuri and Roy are the authors with the highest number of publications (4). They are followed by a group of seven authors with two publications on DGSE: Ali, Ghosh, Gartner, Hertel, Reuner, Schaferling and Vetter. The universities affiliated with the authors who have published the most on the topic are the Indian Institute of Technology and the Indian Institute of Science. Eight countries with universities that have published the most on the subject are the United States, China, France, Italy, Germany, India, South Korea, and the Netherlands.

The areas that contributed most to this number were Economics, Econometrics and Finance (21.7%), Social Sciences (12.1%), and Business, Management and Accounting (8.7%). The dominant types of documents are articles (77.4%), Books and Book chapters (1.9%), and Conference papers (9.4%). The predominant language is English.

Recurring to VosViewer, the most frequent keywords are 'DGSE models', 'forecasting', 'inflation', 'DGSE models', 'VAR models', 'indirect inference', and 'expectations'. The most notorious co-occurrences of these keywords are signalled as yellow clouds in Figure 2, associating 'inflation' to 'DGSE models', 'forecasting' to 'expectations' and 'density forecast', or 'expectations' to 'Bayesian econometrics'.

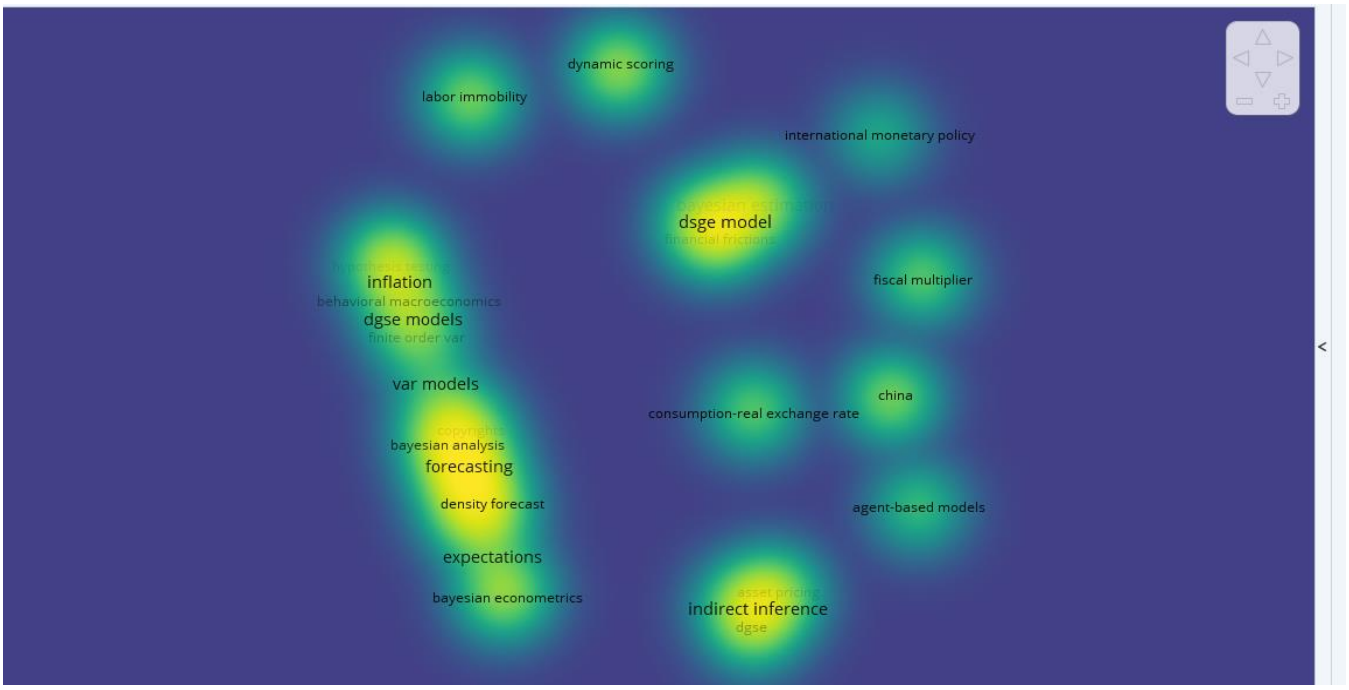


Figure 2. Keywords' frequencies regarding the documents about DGSE
Source: Own collaboration in VOSviewer based on SCOPUS and Web of Science

49 journals have published the identified articles containing DSGE. Among these titles, we find some established titles in the field of Economics like Economics Letters (2 published works), Studies in Economics and Finance (1), Public Choice (1), Journal of Strategic Studies (1), Journal of Money Credit and Banking (1), Journal Of Monetary Economics (1), Journal Of Forecasting (1), Journal of Economics And Business (1), Journal of Economic Dynamics And Control (1), Journal Of Economic Behavior And Organization (1), or Journal of Econometrics (1).

4. DSGE models and policy mix

Interdependence of Policies and Impact of Government Debt

DSGE models have been applicable to illustrate the interdependence between monetary and fiscal policies, especially during financial crises (Csápai, 2022). DSGE models have gained prominence in macroeconomic and economic policy literature and have been extensively implemented in real-world scenarios. Numerous central banks, such as those of the United States (Federal Reserve System), England, Switzerland, Canada, the

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Czech Republic, New Zealand, and France, rely on DSGE models for policy analysis and forecasting (Coenen Motto, Rostagno, Schmidt & Smets, 2017; Hlédik, Madjoska, Miteski & Vlcek, 2024).

The most commonly employed methods for estimating DSGE models are Bayesian techniques, whose properties have been highlighted in multiple studies, including Schorfheide (2000), Smets and Wouters (2003), Rabanal, Rubio-Ramirez (2005), Lubik and Schorfheide (2007), An and Schorfheide (2007), Edge, Kiley and Laforte (2010). DSGE models employ contemporary macroeconomic theory to elucidate and forecast the synchronised movements of aggregate time series throughout the business cycle. The DSGE model classification encompasses various macroeconomic frameworks, ranging from the conventional neoclassical growth model outlined by King, Plosser and Rebelo (1988) to advanced New Keynesian monetary models. These latter models incorporate numerous real and nominal frictions and are founded on the research of Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2003). A unifying characteristic of these models is the derivation of economic agents' decision rules from assumptions regarding preferences, technologies, and the current fiscal and monetary policy environment. This is achieved by resolving intertemporal optimisation challenges. Consequently, the DSGE model framework yields empirical models with a robust theoretical foundation, making them valuable tools for conducting policy experiments.

Central banks have also increasingly used sophisticated macroeconomic models for policy analysis and forecasting. Dynamic Stochastic General Equilibrium models have become standard tools in developed and emerging economies. Consequently, more central banks in developing markets are adopting DSGE models. Due to structural changes in these economies, it is essential to incorporate specific technological trends and wedges alongside total factor productivity to align models with real-world data. The DSGE approach is now a predominant technique for examining macroeconomic policy issues and is widely used by practitioners and academics (Hlédik, Madjoska, Miteski & Vlcek, 2024). The level of government debt significantly influences the effectiveness of fiscal policy: higher debt ratios can increase vulnerability to economic shocks (Bobaşu & Murarașu, 2021). Mixed monetary-fiscal policies can yield different stabilisation effects depending on the nature of the economic shock, emphasising the need for tailored approaches (Wang, Li & Zhang, 2022). We must point out that while DSGE models provide valuable insights into policy interactions, they may oversimplify real-world complexities, such as political constraints and market imperfections, which can affect policy effectiveness and economic outcomes.

Table 2 presents an overview of research results on the impact of the policy mix on economies using DSGE models. The focus is on results indicating how monetary and fiscal policy affects selected economic variables, emphasising what information DSGE models can provide.

Table 2. Literature review on policy mix research results using DSGE models

Literature in chronological order	**Countries, research time and methodology**	**Policy mix research findings using DSGE models**
Ratto, Roeger, and Veld (2008)	- The study outlined the assessment of a DSGE model for an open economy in the euro area. While most evaluated DSGE models have primarily focused on monetary policy examination, this model was enhanced by including fiscal reaction functions, enabling its use for fiscal policy analysis.	The model demonstrates the effectiveness of fiscal policy by incorporating financial market constraints that compel some households to spend their current wages and transfer income. This research distinguishes itself from other evaluated DSGE models by treating the euro area as an open economy and utilising non-detrended data for estimation, allowing for examining non-stationary productivity shock impacts.
Kirsanova and Wren-Lewis (2012)	-This DSGE model incorporates nominal rigidities (e.g., price and wage rigidities) and other classical economic mechanisms (such as responses to demand and supply shocks).	The paper investigated how varying levels of fiscal feedback affect debt when monetary policy is optimally determined rather than following a simple rule. When fiscal responsiveness grows, the optimal monetary policy becomes less active, as fiscal measures tend to counteract inflationary pressures. If fiscal responsiveness drops below a certain threshold, monetary policy shifts to a highly passive approach, significantly declining economic well-being.

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Hayo and Niehof (2014)	-Open-economy DSGE model with monetary and fiscal policy. -Stochastic differential equations for continuous-time framework. -Theoretical model for two open economies	An adjusted Taylor rule mitigates the effects of financial market turmoil on the actual economy. Implementing a mix of loose monetary policy and restrictive fiscal policy helps to bring stability to economies. Within a monetary union, it becomes more challenging to stabilise output in the nation where the financial disruption begins. Additionally, regarding prices, the country experiencing the crisis faces deflation, while the other nation sees a rise in inflation rates.
Bianchi and Ilut (2014)	-The phenomena described in this study were evident during the early 1980s and can be explained by the shift in the policy approach itself. -A micro-founded Dynamic Stochastic General Equilibrium model is employed to reevaluate the described occurrences. This framework incorporates regime changes in the interaction between monetary and fiscal policies and the volatility of structural shocks.	This study demonstrates that fluctuations in US inflation can be attributed to shifts in the power dynamics between monetary and fiscal authorities. When fiscal authorities take the lead, fiscal imbalances result in sustained and enduring inflation increases, diminishing the monetary authority's capacity to regulate inflation. These shock effects persist as long as the public anticipates the fiscal authority's continued dominance in the future. When the monetary authority attempts to reduce inflation without support from the fiscal authority, inflation remains largely unchanged. However, as soon as the fiscal authority aligns with the central bank's actions, inflation rapidly decreases, the economy experiences a downturn, and the debt-to-GDP ratio rises.
Kliem, Kriwoluzky and Sarferaz (2016)	-An estimated Dynamic Stochastic General Equilibrium model was employed to provide a structural interpretation of the low-frequency measure and to demonstrate how fiscal policies influence inflation over extended periods. -The cross-country data from 1965 to 1999 for Germany, the US, and Italy.	The interplay between monetary and fiscal policies influences fiscal-driven inflation. The effects of these policy interactions on inflation rates vary across different nations. Results from the DSGE model indicate that modifications in monetary-fiscal policy interactions, in conjunction with corresponding alterations in the transmission of structural shocks, can effectively elucidate shifts in the low-frequency relationship between fiscal stance and inflation.
Cavalli, Naimzada and Pecora (2019)	-The paper uses rigorous analytical tools combined with numerical simulations. -The stability conditions of the unique steady state and the emergence of different endogenous dynamics are investigated.	The study examines the complex interactions between fiscal and monetary policies, emphasising their impact on output fluctuations and their ability to generate endogenous fluctuations within a real economy model. Appropriate fiscal and monetary measures can help achieve desired employment levels. Additionally, policy mix tools can potentially create endogenous variations in economic performance.
Drygalla, Holtemöller and Kiesel (2020).	- A standard medium-scale dynamic stochastic general equilibrium model was extended to include non-optimising households and the fiscal sector. -Feedback rules to model spending and revenue variables were used.	Based on the conducted research, it was noted that fiscal policy, mainly public consumption, investments, transfers and changes in labour tax rates, including social security contributions, counteracted a more substantial and long-term decline in production in Germany at the beginning of the Great Recession - which indicated a timely response of fiscal policy. The article assessed the effects of fiscal stimulus packages within the estimated DSGE model. The study indicated the overall positive effects of fiscal policy on German production in 2009 and 2010.
Wang, Li and Zhang (2022)	-This study examines how monetary and fiscal policies interact within China's Dynamic Stochastic General Equilibrium model. -It focuses on determining the optimal combination of these policies to mitigate macroeconomic volatility when faced with various economic disturbances.	The most effective combination of economic policies changes depending on the nature of economic disruptions. When faced with shocks related to government expenditure, a proactive fiscal approach coupled with a passive monetary strategy is recommended.
Adrian, Gaspar and Vitek (2022)	-This research thoroughly examines the most effective ways to implement various	To achieve optimal inflation control and economic stability, it is advisable to modify all available policies in response to

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	economic policies. These include monetary strategies, interventions in foreign exchange markets, fiscal measures, macroprudential regulations, and management of capital flows. -This policy analysis utilises a dynamic stochastic general equilibrium (DSGE) model of the global economy. This model incorporates various nominal and real rigidities, comprehensive macro financial connections with endogenous risk, and multiple spillover transmission mechanisms. The model's scope is estimated to be medium-scale, encompassing the complexities of worldwide economic interactions.	fluctuations in both domestic and global financial cycles when possible. This includes implementing foreign exchange interventions and managing capital flows under certain circumstances. The extent of these adjustments can vary significantly based on the specific structural framework of the economy. This framework incorporates various distortions linked to nominal rigidities and financial frictions while accounting for the extensive interplay between the policies under examination. Monetary policy assumes primary responsibility for stabilising consumption price inflation and economic output without constraints. Foreign exchange intervention serves a complementary function by enhancing monetary autonomy, specifically in its capacity to facilitate the stabilisation of consumption price inflation. However, any potentially destabilising effects on economic output that may arise from foreign exchange intervention under these circumstances are mitigated by fiscal policy measures.
Hlédik, Madjoska, Miteski and Vlcek (2024).	- The National Bank of the Republic of North Macedonia (NBRNM) developed a new calibrated New Keynesian DSGE model to reflect the unique traits of North Macedonia's small open economy with a fixed exchange rate. This research outlines the model's structure, calibration, and empirical validation. It includes features typical of DSGE models like monopolistic competition, Calvo sticky prices and wages, habit formation, and multilayer goods production, which are crucial for capturing business cycle dynamics. Additionally, it features sector-specific technology and trends to align with Macedonian economic narratives.	The compact DSGE model for an open economy is a supplementary analytical instrument for policy evaluation, offering a more consistent, theoretically grounded framework for structural examination and policy recommendations at the NBRNM. This model is built on microeconomic foundations, considering the interrelated actions of consumers and firms, technological aspects, and the institutional structure (including budget limitations, market clearing, and monetary policy rules). Consequently, it facilitates the examination of monetary policy's impact on economic agents' decisions by assessing the effects of various economic shocks. As a result, this model provides a valuable new resource and benchmark for comprehensive research on numerous policy-relevant issues.

Source: Own study based on the subject literature

When discussing the results obtained in policy mix studies using DSGE models, it is worth emphasising several of their results. Ratto, Roeger and Veld (2008) extend the DSGE analysis for the euro area by including fiscal policy responses and the impact of financial constraints on households, which allows for the study of monetary and fiscal policy interactions in an open economy. Kirsanova and Wren-Lewis (2012) employed an expanded model incorporating micro-foundations and price rigidities characteristic of the new Keynesian theory, which includes anticipating agents. Within this framework, they developed optimal and simplified fiscal and monetary rules. They also considered the social utility function, enabling them to evaluate the welfare impacts of various policy combinations. Their findings indicated that the optimal monetary policy rule involved an active approach, specifically increasing the real interest rate when inflation rose. The costs associated with implementing a basic fiscal rule, where expenditures only responded to debt changes, were relatively minor. However, the debt level played a crucial role. An active monetary policy might not be optimal when the accumulated debt is substantial and interest rate fluctuations significantly affect the budget. The more proactive the fiscal policy is, characterised by government expenditures being less sensitive to debt levels, the less active monetary policy should be.

In DSGE models, monetary and fiscal policies are interconnected, jointly affecting economic output and inflation rates. These models often incorporate modified policy rules to enhance economic stability during crises, especially in open-economy scenarios (Hayo & Niehof, 2014). Cavalli, Naimzada and Pecora's (2019) research finds that stability conditions affect economic dynamics and employment targets, and fiscal and monetary policies can induce endogenous fluctuations. The study (Bianchi & Ilut, 2014) shows that inflation volatility in the US was driven by changes in the power relationship between monetary and fiscal policy, particularly in the 1980s. When fiscal policy dominated, it led to persistent increases in inflation and a weakening of the central bank's ability to control it. Attempts by the central bank to curb inflation without fiscal

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policy support were ineffective. In contrast, when fiscal policy began to cooperate with monetary policy, inflation fell quickly, but at the cost of an economic slowdown and an increase in public debt. These results underscore the crucial importance of cooperation between monetary and fiscal authorities for stabilising the economy.

Kliem, Kriwoluzky and Sarferaz (2016) examine how monetary and fiscal policies interact within Dynamic Stochastic General Equilibrium (DSGE) models. It explores how these interactions can result in fiscal inflation, specifically analysing the economic frameworks of three distinct nations – Germany, the US, and Italy (Kliem, Kriwoluzky & Sarferaz, 2016). Cavalli, Naimzada and Pecora (2019) show that appropriate coordination of fiscal and monetary policies can effectively stabilise output fluctuations and support achieving desired employment levels. At the same time, policy mix tools can generate endogenous fluctuations in economic outcomes, highlighting the complexity of the interactions between these policies.

DSGE models have incorporated both monetary and fiscal policies. Fiscal policy within DSGE frameworks is typically represented through feedback mechanisms that impact government spending, investment, and transfer payments, thereby influencing the dynamics of economic output during periods of fluctuation (Drygalla, Holtemöller & Kiesel, 2020).

A dynamic stochastic open economy general equilibrium model has also been employed to examine the effects of monetary and fiscal policies on macroeconomic fluctuations in China (Wang, Li & Zhang, 2022). The study utilises an impulse response and welfare analysis to evaluate the stabilising impact of various combinations of these policies. Findings reveal that the ideal mix of monetary and fiscal measures varies depending on the scenario. A proactive fiscal approach coupled with a passive monetary strategy proves most effective in government spending shocks. Conversely, when faced with domestic interest rate shocks, foreign interest rate shocks, or foreign consumption shocks, a passive fiscal stance paired with an aggressive monetary policy yields better results (Wang, Li & Zhang, 2022). Other studies on the selection of fiscal and monetary strategies to optimise fiscal space and fully utilise the effects of proactive fiscal policy in China using NK-DSGE were conducted by Yang and Liu (2024).

Adrian, Gaspar and Vitek's (2022) study shows that optimal stabilisation of inflation and economic growth requires a flexible policy mix, including monetary policy, currency intervention, macroprudential regulation, and capital flow management. The DSGE model considers nominal rigidities, financial constraints, and global transmission mechanisms, which allows for assessing the effects of different policies depending on the economy's structure. In yet another case, we notice that the new DSGE model developed by the National Bank of the Republic of North Macedonia enables a more coherent and theoretically justified analysis of macroeconomic policy in a small, open economy with a fixed exchange rate (Hlédik, Madjoska, Miteski & Vlcek, 2024). The new model for the National Bank of the Republic of North Macedonia (NBRNM), taking into account microeconomic foundations and key market mechanisms, allows for assessing the impact of monetary policy on economic agents' economic decisions. As a result, it is a valuable tool for analysing the effects of various economic shocks and formulating policy recommendations for the NBRNM. DSGE models are widely used in economics to assess the impact of different monetary policies.

5. Influential models in DGSE

Hayo and Niehof (2014) integrated and expanded upon the frameworks developed by Smets and Wouters (2002) and Bekaert, Cho and Moreno (2010) to create a New Keynesian model incorporating fiscal and monetary policy, as well as a financial market component. Their research examined various fiscal and monetary policy responses to domestic and foreign financial market disruptions. Hayo and Niehof (2014) constructed a New Keynesian DSGE model for two open economies using stochastic differential equations. They investigated the interconnected effects between financial markets and the transmission of financial market disturbances to the real economy, both within individual economies and across borders. The study then explored different policy stabilisation scenarios, including (1) a conventional open economy with the Taylor (1993) rule aimed at stabilising output, inflation, and exchange rates; (2) an enhanced the Taylor rule that also considers financial market stabilisation; (3) an expansionary fiscal policy based on increased expenditure; and (4) an austere fiscal

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approach. In their analysis, Hayo and Niehof (2014) distinguished between market participants indifferent to high government debt levels and those who are averse to such debt. Below, we present the equations for building DSGE models that incorporate monetary and fiscal policy into a dynamic stochastic general equilibrium model.

Households

Households receive income through various sources: wages from employment, rental income, and dividends from company ownership. Additionally, the government provides some household payments based on previously issued risk-free government bonds. The typical household aims to maximise the following utility function (Hlédik, Madjoska, Miteski and Vlcek, 2024):

$$\max_{C_t L_t B_t J_t K_t} \mathrm{E}_t = \left\{ \sum_{t=0}^{\infty} \beta^t \left(\frac{(C_t - \chi \bar{C}_{t-1})^{1-\sigma}}{1-\sigma} - \frac{L_t^{1+\psi}}{1+\psi} \right) \right\}$$

Where: C_t – consumption of goods; $\bar{C}\,t-1$ - previous total consumption adjusted to account for technological advancements; L_t – the number of hours worked; β - the intertemporal discount factor; σ - the relative risk aversion coefficient; ψ - the marginal disutility of labour; χ - the habit persistence parameter.

Production sector

The production of intermediate goods is produced under monopolistic competition using the Cobb-Douglas production function:

$$Y_t(i) = A_t K_t(i)^{\alpha} N_t(i)^{1-\alpha}$$

where: Y_t – production; A_t - technological efficiency; K_t - capital; N_t – labour; α – the share of capital.

$$K_t = K_{t-1}(1-\delta) + \left(1 - V\left(\frac{I_t}{I_{t-1}}\right)\right) I_t$$

where δ is the depreciation rate; V is an adjustment cost function

In the manufacturing process, intermediate goods serve as inputs for creating various final products, including consumer items (Y_t^C), capital (investment) goods (Y_t^J), exports (Y_t^X), and public goods (Y_t^G) (Hlédik, Madjoska, Miteski & Vlcek, 2024):

$$Y_t = Y_t^C + Y_t^J + Y_t^X + Y_t^G$$

The government and the central bank

In the research by Hayo and Niehof (2014), it was assumed that the government's fiscal policy aims to achieve two goals: stabilising output and managing debt. A smoothed fiscal spending rule based on debt evolution is implemented. The degree of budgetary smoothing affects how spending and taxes respond to debt and income, with the latter serving as a proxy for the output gap. Higher fiscal smoothing reduces government spending and taxation sensitivity to income and debt levels. These budgetary rules are considered ad-hoc and assume governments face no short-term borrowing restrictions. This approach aligns with Leith and Von Thadden (2008), who developed a workable New Keynesian model where a budget does not constrain government debt.

$$G_t = G_{t-1}^{\varsigma_G} \left(Y_{t-1}^{\varsigma_Y} V_{t,t+m}^{\varsigma_b} \epsilon_t^G \right)^{1-\varsigma_G}$$

$$T_t = T_{t-1}^{\varsigma_T} \left(Y_{t-1}^{\varsigma_{YT}} V_{t,t+m}^{\varsigma_{bT}} \epsilon_t^T \right)^{1-\varsigma_T}$$

Where: G_t – government consumption; T_t - tax revenues; $V_{t,t+m}^B$ – government issues m-period nominal bonds; ς_G and ς_T – degree of fiscal smoothing; ς_Y; ς_T; ς_b; ς_{b_z} - the reaction of the government to the last period's income and bonds; ϵ_t^G; ϵ_t^T - shocks that cause the deviations between planned and actual government spending and revenue.

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The central bank implements monetary policy through two mechanisms: issuing bonds for the banking sector B_t^{CB} and establishing the cost of money via the bank interest rate (R_t^{CB}). The central bank employs the Taylor rule, which takes the following:

$$\log(R_t^{CB}) = \phi_R + \nu_R * \log(R_{t-1}^{CB}) + (1 - \nu_R) * ((\varrho_\pi * \log(\pi_t) + \varrho_y * \log(GDP_t))$$

ϕ_R - through its control over the interest rate, it determines the steady-state level of inflation. A fluctuation in this variable is recognised as a monetary shock, representing the central bank's deviation from the Taylor rule's steady-state form (the discretionary aspect of monetary policy); ν_R - determines the relative weight that the central bank attaches to deviations of current inflation and current GDP from their stationary values, at the rule level; ϱ_π and ϱ_y- the relative role of both deviations within the rule.

Following the conventional Taylor rule, Hayo & Niehof (2014) developed an alternative monetary policy response model incorporating financial market conditions alongside traditional factors.

$$\frac{\mathrm{R}_t}{\mathrm{R}} = \left(\frac{R_{t-1}}{R_t}\right)^{\rho R} \left[\left(\frac{\pi_t}{\pi_{t-1}}\right)^{\psi_{p^i}} \left(\frac{S_t}{S_{t-1}}\right)^{\psi_S} \left(\frac{R_t^E}{R_{t-1}^E}\right)^{\psi_E}\right]^{1-\rho E*} \eta_{mp,t}$$

Where: $\eta_{mp,t}$ – monetary policy shock; R_t – the domestic interest rate; π_t - inflation

The exchange rate S_t is determined by the proportion between the overall price levels in the domestic and foreign markets.

$$S_t = \frac{P_t^f}{P_t^d}$$

Where: P_t^f - foreign currency price index; P_t^d – domestic currency price index.

Conclusions

Studying the response of economies to various shocks (e.g., financial crises, pandemics, supply shocks) allows us to conclude the effectiveness of multiple stabilisation policies and their consequences for the economy in the short and long term. The combination of accommodative monetary policy and restrictive fiscal policy can effectively stabilise the economy, especially in conditions of financial turmoil, but within a monetary union, stabilising the economy of a country affected by the crisis becomes more difficult. DSGE models show that monetary and fiscal policy can lead to endogenous economic fluctuations, which means that their inappropriate implementation can generate instability in output and prices.

Interactions between fiscal and monetary policy significantly impact inflation, and their effects may vary depending on the country and the specifics of the economy. The DSGE model shows that changes in how fiscal and monetary policy interact and the transmission of structural shocks can explain the long-term relationship between fiscal policy and inflation.

Monetary policy remains a key tool for stabilising inflation and output, and currency interventions can increase monetary autonomy, although fiscal measures must balance their adverse effects on production. The DSGE model indicates that the more active fiscal policy is in responding to economic shocks, the less aggressive monetary policy must be because fiscal measures can effectively stabilise inflation and public debt. If the fiscal policy response is insufficient, monetary policy switches to a passive mode, which can lead to a deterioration in economic welfare and more substantial declines in economic activity. A properly selected policy mix can not only help to achieve the optimal level of employment but also affect the dynamics of the economy in the long run, changing the equilibrium conditions and potentially creating new economic cycles.

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The study notes that effective inflation control in the US depended on cooperation between monetary and fiscal policy, and its absence led to long-term increases in inflation and the weakening of central bank actions. The optimal combination of fiscal and monetary policy depends on the type of economic shocks – for example, when government spending increases, an approach with active fiscal policy and passive monetary policy is more effective.

In summary, this study expands theoretical knowledge and provides practical guidelines for economic policy in changing macroeconomic conditions. A literature review will allow us to identify their strengths and weaknesses and indicate potential directions for their improvement, e.g., by including new variables or adjustment mechanisms. Keyword analysis will enable us to determine which aspects of policy mix and DSGE models are most frequently studied, e.g., the impact of fiscal policy on macroeconomic stability or the interaction of monetary policy with economic shocks. Bibliometric analysis contributes to the systematisation of knowledge and can become a starting point for further research in policy mix and DSGE models.

This study may have several limitations, as follows: a) The selection of literature and interpretation of bibliometric analysis results may be subject to subjective decisions of the researcher, which may affect the conclusions; b) Bibliometric analysis is based on databases (e.g. SCOPUS, Web of Science), which may not include all relevant publications, especially newer studies or those published in less accessible sources; c) Bibliometric analysis takes into account the number of citations and keywords, but does not always reflect the quality of the content or the contribution of a given publication to the development of policy mix theory and DSGE; d) DSGE models are based on assumptions that may not fully reflect reality (e.g. rational expectations, linear structure), which may lead to simplifications in the policy mix analysis.

This study may enhance further research as follows. The selection of literature and interpretation of bibliometric analysis results may be expanded by including other sub-topics. Bibliometric analysis is based on databases (e.g., SCOPUS, Web of Science), which may complement other relevant publications, especially the latest studies or those published in less accessible sources. Our bibliometric analysis can also consider the number of citations and keywords. Finally, DSGE models are based on assumptions that may not fully reflect reality (e.g., rational expectations, linear structure), which may lead to simplifications in the policy mix analysis. Therefore, we can highlight and detail, in further studies, the empirical achievements published in the literature.

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