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Company Demographics and Specialization Trends in Western Balkan Tech Ecosystems

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Abstract

The Western Balkans (WB), comprising Albania, Bosnia and Herzegovina, Kosovo, Montenegro, North Macedonia, and Serbia, are in a transitional phase, seeking to enhance their productivity and competitiveness through the strategic use of Information and Communication Technologies (ICTs). This paper investigates the distribution of company ages within the tech sector across the Western Balkans, revealing varying levels of maturity and development influenced by factors such as foreign direct investments and national policies. The analysis is based on the firm-level data from the Orbis database, with the focus on active companies in the ICT sector (NACE codes 62 and 63). Additionally, data for Croatia is included in the dataset solely for comparative purposes, i.e. to gain insights into potential structural differences between EU and non-EU environments within the region. The results again confirm that Serbia has a robust tech ecosystem, while countries like Albania and Montenegro present younger and emerging ICT sectors. The results of the study emphasize the need for tailored (policy) approaches to digital transformation and highlight the importance of taking account of the unique characteristics of each country's tech ecosystem for future growth and integration into the European economy.

Keywords: ICT sector, NACE codes 62 and 63, company age, Western Balkan

JEL Classification: O33, L11, L86, O52, L25

1. Introduction

The Western Balkans (WB), comprising countries like Albania, Bosnia and Herzegovina, Kosovo, Montenegro, North Macedonia, and Serbia, are in a transitional phase, striving to catch up with the more developed European Union (EU) countries. There is a growing emphasis on leveraging ICTs to enhance productivity and competitiveness in the Western Balkans. The region has an average internet accessibility rate of 70% and annual venture capital investments of approximately

\$100 million (Baush, 2024). However, the region is still lagging behind the EU in building a knowledge-intensive economy and achieving 'smart growth' (Kostoska & Hristoski, 2016). This paper aims to explore the distribution of company ages within the tech sector across the Western Balkans by looking at the varying levels of company age and sectorial development. These are in turn influenced by factors such as foreign direct investments and national policies.

The analysis is based on firm-level data downloaded from the Orbis database, extracting data exclusively on active companies within the ICT sector. The paper aims to contribute to a deeper understanding of the evolving tech landscape in the Western Balkans and the critical factors shaping its future.

The paper is structured as follows. In section 2, theoretical background is discussed focusing on the company age distribution in the Western Balkans and related implications for the tech sector's development. In section 3 the methodology used to gather and process firm-level data from the Orbis database is outlined in detail and in section 4 the findings regarding the distribution of company ages and the insights are presented. Finally, in section 5 the implications of the findings are summarized and some policy approaches for supporting digital transition in the region are proposed.

2. Theoretical background

In the Western Balkans there is a relatively young company age distribution compared to other European regions, which is indicative of a dynamic but nascent tech sector. This is partly due to the recent influx of foreign direct investments (FDI) in the ICT industry, which has led to the creation of new knowledge-based clusters and technology spillovers in the region (Kacani & Shaqiri, 2023). In contrast, more established European regions have a more mature age distribution of companies, reflecting a longer history of industrial development and innovation (see e.g. Pellegrino & Piva, 2019). This maturity is associated with higher levels of competitiveness and economic stability (Berkes et al., 2024). In that sense, this paper primarily aims to explore *how the distribution of company ages varies across Western Balkan countries and Croatia, and what does this reveal about the development of the tech sector*.

The Western Balkans region has seen varying levels of development in its tech industry. Among WB countries, Serbia stands out as having a higher concentration of long-standing tech companies (Savanović et al., 2019), primarily due to its robust ICT sector. The primary industries in these countries are diverse, with a significant focus on ICT, gaming, and digital services. Serbia is also recognized as the largest economy in the Western Balkans, with its IT industry contributing significantly to the national GDP. The IT sector accounts for about 10% of Serbia's GDP, and IT exports reached

nearly EUR 1.5 billion in 2021 (Oxford Analytica, 2022). Montenegro and North Macedonia are making good progress in developing their tech industries, although they lag behind Serbia in terms of scale and impact (Kostoska & Hristoski, 2016). These countries are indeed focusing on improving their competitiveness through the adoption of ICTs and innovation, which are crucial for their EU accession aspirations (Sahiti, 2024). Bosnia and Herzegovina, Kosovo, and Albania also have smaller tech industries compared to Serbia, but they are gradually enhancing their digital capabilities (Mkiyes & Přívara, 2023). From this brief overview, other research questions are proposed for this study; it aims to explore *which countries show signs of mature tech ecosystems (companies spanning multiple decades) versus emerging ones (concentration of recently incorporated companies)* and *how is tech company density distributed across the Western Balkan countries*. In particular, the focus in the paper is on the current distribution of companies across NACE (the official statistical classification system for economic activities used by the European Union), section J (Information and Communication) in each Western Balkan country.

While Croatia is often excluded from political definitions of the Western Balkans, it is included in this analysis due to its economic interconnectedness with the region (Petričušić, 2005), its relevance as an EU benchmark, and the availability of harmonized firm-level data. This inclusion enables better comparisons and provides additional insights into structural differences in the digital sector maturity within a geographically and historically linked area of Western Balkans. Further to this, Croatian companies often operate subsidiaries or engage in joint ventures in Serbia, Bosnia, North Macedonia, etc., especially in the ICT sector. Including data for Croatian tech ecosystem also allows to contrast EU vs. non-EU environments within the same regional context to gain additional insights.

3. Data collection, filtering criteria and preprocessing

Firm-level data were extracted from the Orbis database from Bureau van Dijk, with the latest data available as of March 14, 2025, and exported on March 16, 2025. The search strategy involved a three-step filtering process:

Company status: Only active companies and those with an unknown status were retained.

Industry sector: Firms were selected based on their primary NACE Rev. 2 codes, specifically:

- 62 / 620 – Computer programming, consultancy and related activities
- 63 / 631 – Information service activities, including data processing, hosting, and web portals
- 639 – Other information service activities

Geographic scope: The search was limited to companies based in Croatia and Western Balkan countries, specifically Albania, Bosnia and Herzegovina, Kosovo, Montenegro, North Macedonia, and Serbia.

Applying the three filters yielded a final sample of 36,323 companies. To ensure data reliability and relevance companies with no recent financial data were excluded and public authorities, state-owned entities, and government institutions were omitted. Only the most recent available financial accounts were used for each company.

Post-download, several preprocessing steps were applied:

Data cleaning: Rows with missing or non-numeric values for Operating Revenue (OPRE) were removed to ensure analytical integrity in financial analyses.

Derived variables:

- Year of incorporation was extracted from the "Date of incorporation" field using an automated parsing of date formats.
- Company age was calculated as the difference between the reference year (2025) and the year of incorporation.
- Based on company age, an "Age cohort" categorical variable was created:
 - 0–5 years: *Startup phase*
 - 6–10 years: *Growth phase*
 - 11–20 years: *Mature phase*
 - 20+ years: *Established phase*

These steps resulted in a refined dataset suitable for descriptive, comparative, and inferential analyses on firm demographics and financial structures across the Western Balkans' technology sectors. After removing rows with missing or non-numeric Operating Revenue (OPRE) values, the dataset contains 16,546 valid company observations. Firms registered in Kosovo (ISO code: XK) were excluded from the final analytical dataset due to missing or non-numeric financial information, which rendered them incompatible with the applied filtering criteria. As a result, Kosovo is not represented in the comparative analysis in section 4, even if some considerations are relevant and kept in the introductory and concluding part of the paper.

4. Data analysis

To analyze how does the distribution of company ages vary across Western Balkan countries, and to reveal the historical development and timing of each tech sector, first the proportion of firms in each cohort per country was examined and visualized (Figure 1). The calculations and visualizations were done using Python in JupyterLite.

In examining **the age distribution of technology firms** across the Western Balkans, distinct national patterns emerge that reflect differing stages of digital sector

development and policy influence. Serbia exhibits a broad and mature age profile, with a notable presence of firms in the Mature and Established phases.

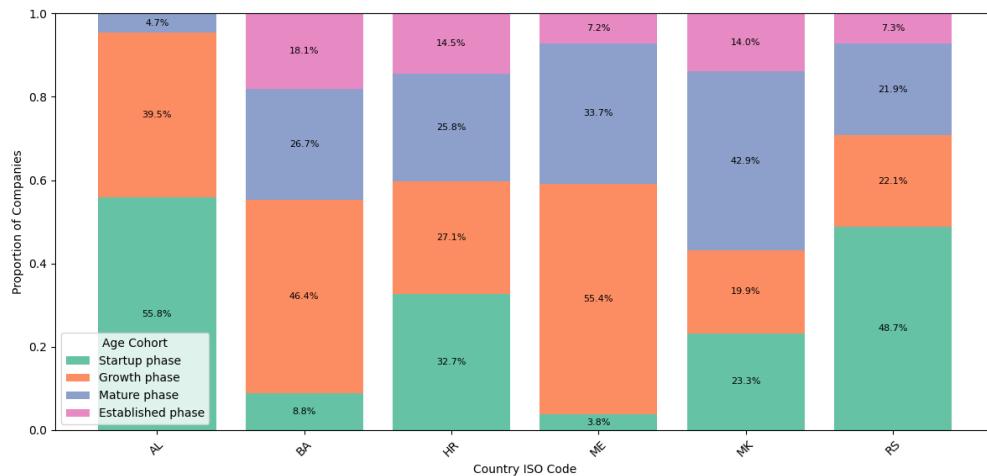


Figure 1. Company age cohorts by country with percentages overlay (source: Author)

This suggests that the country's ICT sector began liberalizing relatively early, potentially supported by strong academic and technical institutions, particularly in Belgrade. Bosnia and Herzegovina shows a concentration of firms in the Startup and Growth phases. This points to a more recent expansion of the tech sector, likely influenced by outsourcing trends, diaspora-driven investments, and the gradual emergence of a domestic innovation ecosystem. Montenegro has a disproportionately high share of young firms – those less than 10 years old – indicating that its tech sector is still in the early stages of development. The pattern aligns with the country's post-independence economic diversification, where technology is gaining traction as a new growth domain. North Macedonia displays a relatively balanced distribution, with significant representation in both the Growth and Mature categories. This suggests the presence of sustained support for IT and digital services, particularly over the past 10-15 years, possibly through targeted national strategies or international partnerships. Albania is skewed toward younger firms, yet a small number of long-standing entities are also present. These may represent legacy state-owned firms or subsidiaries of foreign investors, reflecting a dual structure of ongoing entrepreneurial emergence alongside remnants of earlier industry models. Finally, Croatia (included for comparative purposes) shows the most balanced and mature age structure among the countries studied. With strong representation across all age cohorts – including a substantial proportion of Established firms – Croatia reflects the combined effects of early market liberalization, EU accession, and a relatively developed digital economy. Countries with older firms likely experienced earlier deregulation, access to international markets, and more stable ICT policy environments. On the other hand,

countries with many young firms may be undergoing a digital entrepreneurship wave, possibly linked to foreign outsourcing, remote work, or government incentives.

To assess **whether company age distributions differ significantly** across Western Balkan countries, pairwise Kolmogorov-Smirnov (KS) tests were performed. This non-parametric test compares the cumulative distributions of company age data, offering insight into the structural maturity of national tech sectors. All pairwise comparisons yielded statistically significant results ($p < 0.05$), indicating that company age distributions differ meaningfully across the region. The greatest divergence was observed between Albania and Montenegro (KS = 0.612, $p < 0.001$), suggesting a markedly different firm age structure between these countries. These differences likely reflect country-specific factors such as timing of digital sector liberalization, access to capital, and policy support for startups. Countries with younger age profiles (e.g., Albania, Montenegro) are in the early stages of tech ecosystem development, while others (e.g., Croatia, Serbia) show signs of more established digital sectors.

Looking at the **signs of mature tech ecosystems** (companies spanning multiple decades) versus emerging ones (concentration of recently incorporated companies), this study also aims to explore the maturity of the technology sector across countries in the Western Balkans. The rationale is that older firms typically indicate a more established and resilient ecosystem, while younger firms reflect a more recent or emerging development phase. Based on the age, it can be stated that:

- Bosnia and Herzegovina has a balanced ecosystem. Firms in this market are, on average, over 12 years old, with more than one-fifth of them operating for 15 years or longer. The sector is characterized by moderate firm sizes (averaging 13 employees) and consistent revenue levels. This profile suggests the presence of a resilient and operationally stable tech sector, supported by a base of seasoned companies and gradual scaling dynamics.
- North Macedonia also exhibits signs of a gradually maturing ecosystem. With an average firm age of nearly 13 years and 15% of companies exceeding 15 years of operation, the sector is anchored by a core of experienced businesses. Although firms are generally smaller (averaging 10 employees) and generate more modest revenues, the relative uniformity in these indicators points to a steady expansion phase supported by increasing institutional capacity.
- Montenegro, while showing similar age statistics, reveals a smaller-scale tech environment. Although a notable share of firms has been active for more than a decade, they remain small in terms of both staffing and revenue. The average firm employs only four people, and the typical revenue levels are low. This suggests a market that may be specialized or operating in niche segments, with slower ecosystem-wide growth.
- Croatia presents a contrasting dual structure. It has the highest share of both very young firms (25% under 5 years) and older firms (25% over 15 years),

suggesting a dynamic ecosystem marked by both renewal and legacy. The average firm size (10 employees) and revenue levels (around €600,000) are robust, pointing to the presence of successful scale-ups. However, the strong polarization between new and old companies may reflect uneven development or high turnover within the sector.

- Albania, in contrast, is at an earlier stage of ecosystem formation. Firms are much younger on average (under 6 years), and very few exceed the 15-year mark. While a few high-revenue companies significantly raise the average (€910,000), the median revenue remains much lower, indicating a highly skewed distribution. The overall profile suggests a startup-heavy environment that is still establishing the infrastructure and maturity seen in other Western Balkan countries.

With regards to **tech company density** distributed across the Western Balkan countries, a comparative view is prepared using both absolute numbers and population-adjusted metrics to reveal the depth and concentration of each ecosystem. In terms of sheer volume, as per the given dataset, Serbia leads the region with 6,959 tech firms, followed closely by Croatia with 6,338. North Macedonia ranks third with 1,946 firms, while Bosnia and Herzegovina (753) and Montenegro (507) have significantly smaller ecosystems. Albania, with just 43 registered tech firms, lags far behind its regional peers in absolute terms. When adjusted for population size, a slightly different picture emerges. Croatia stands out with the highest density of tech firms - over 162 per 100,000 inhabitants, reflecting a highly saturated ecosystem. North Macedonia and Serbia follow with roughly 108 and 105 companies per 100,000 people, respectively, indicating well-developed and growing tech markets. Montenegro, despite its small population, maintains a respectable density of 84.5 suggesting concentrated tech activity. In contrast, Bosnia and Herzegovina has a modest figure of 23.5, and Albania ranks last with only 1.5 tech companies per 100,000 people, indicating a relatively undeveloped digital economy.

To understand **how technology companies are distributed across different activity types**, this analysis examines the prevalence of two key NACE codes across Western Balkan countries where NACE 62 denotes Computer programming, consultancy, and related activities and NACE 63 represents Information service activities, including data processing, web portals, and hosting services. The results (Table 1) show that NACE 62 dominates across all countries, representing the core of tech activity, especially in Albania (90.7%) and Croatia (89.8%). NACE 63 activity - which includes data processing, web hosting, and other information services - is more prominent in Bosnia and Herzegovina (21.7%) and North Macedonia (18.6%), suggesting a relatively more diversified digital services sector. Montenegro and Albania have the smallest absolute number of firms, but maintain similar proportions. Indicator for Serbia mirrors the pattern seen in countries like Croatia and Albania,

where the tech ecosystem is heavily concentrated in software development and consultancy, with relatively limited presence in broader information services.

Table 1. Distribution of firms across NACE 62 and NACE 63 (source: Author)

Country	NACE 62 (Count & %)	NACE 63 (Count & %)
Albania	39 (90.7%)	4 (9.3%)
Bosnia & Herzegovina	590 (78.35%)	163 (21.65%)
Croatia	5,689 (89.76%)	649 (10.24%)
Montenegro	425 (83.83%)	82 (16.17%)
North Macedonia	1,584 (81.4%)	362 (18.6%)
Serbia	6,269 (90.08%)	690 (9.92%)

A Chi-square test of independence was conducted to evaluate whether the distribution of companies between these two categories is consistent across countries or reflects country-specific specialization patterns. The Chi-square test returned a statistically significant result of chi-square statistic of 205.04 with degrees of freedom 5 and p-value < 0.0001. There is a significant association between the country and NACE specialization. Namely, tech companies in different countries are not evenly distributed across these two NACE categories - instead, each country demonstrates a unique sectoral focus, indicating national differences in how tech ecosystems have evolved. In Albania, Croatia and Serbia, there is strongest concentration in NACE 62, with over 89% of companies falling into software development, programming, and IT consultancy. This suggests a tech ecosystem highly specialized in software services, driven by strong ICT talent pools, outsourcing for international clients, and an emphasis on client-oriented digital solutions. These ecosystems are software-driven and export-oriented. Bosnia and Herzegovina and North Macedonia feature a more diversified structure, with about 18-22% of companies in NACE 63. This reflects a broader base of activities (such as web hosting, data processing, and information services), in addition to software development. These markets have a slightly more infrastructure-oriented or multi-service tech environment. Montenegro is somewhere in the middle, with about 84% of companies in NACE 62 and 16% in NACE 63. The ecosystem thus leans toward software and programming, but it also shows signs of ongoing diversification, possibly driven by small-scale entrepreneurship and niche service provision.

5. Conclusion

The observed variations between the countries underscore the need for tailored policy approaches to digital transformation across the Western Balkans. A uniform regional strategy may overlook the structural maturity differences revealed by these distributional comparisons. Namely, the differences presented in the previous section likely reflect country-specific factors such as timing of digital sector liberalization, access to capital, and policy support for startups. Countries with younger age profiles (e.g., Albania, Montenegro) are in the early stages of tech ecosystem development, while others (e.g., Croatia, Serbia) show signs of more established digital sectors. Understanding age structure helps policymakers identify whether their tech ecosystem is emerging (needs support for survival and scaling), growing (needs capital and internationalization pathways), or mature (needs innovation renewal and R&D incentives).

There is a slight but statistically significant interdependence between country and sector specialization which underscores the heterogeneity of tech ecosystems in the Western Balkans. Several factors may influence this slight divergence such as human capital specialization (different availability of software developers or systems analysts), investment trends (presence of foreign direct investment in certain verticals), government priorities around infrastructure vs. services and market maturity. Older ecosystems may show more diversification, while younger ones focus on quick-to-scale services like programming. The presented insights may provide a signal for policymakers, investors, and educators aiming to support digital transformation. Recognizing where each country stands on the tech specialization spectrum can help tailor interventions to reinforce strengths or address gaps, whether by expanding support for data infrastructure, promoting innovation in software services, or attracting investment in underrepresented areas.

While the Western Balkans face significant challenges in catching up with the EU in terms of company age distribution and innovation, there are opportunities for growth and development. The region's young tech sector, coupled with strategic investments in digital infrastructure and innovation, can potentially drive economic advancement. However, addressing demographic challenges and enhancing competitiveness remain critical for achieving sustainable growth and integration into the European economy. Challenges such as regulatory, political, and educational frameworks still need to be addressed to fully realize the potential of the tech sector in these countries (Kutlaca et al., 2018). While Serbia is leading the way in the concentration of technology companies, other countries in the Western Balkans are also making progress, albeit at a slower pace. The overall trend points to a positive development in the concentration of technology companies in the Western Balkans, driven by strategic investments and policy initiatives.

Firms registered in Kosovo (ISO code: XK) were excluded from the final analytical dataset due to missing or non-numeric financial information, which rendered them incompatible with the applied filtering criteria. This absence represents a data limitation and should be considered when interpreting cross-country comparisons.

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Personality Insights in Decision Making for a Green Future

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Abstract

The aim of this article is to present a personal perspective in the decision-making process. This process consists of a managerial and a personal perspective. Although the managerial perspective is used, not many people realize that decisions are also made based on their inner nature. People evolve over time, and as their skills, abilities, or knowledge develop, they also evolve psychologically. Therefore, it is appropriate to note this factor and present it in more detail. The article focuses on entrepreneurs in small and medium-sized enterprises who therefore hold managerial positions and for whom the decision-making process falls within their competence. The research included a preliminary phase, which provided initial insight into the issue, and a main phase. It thus combined elements of mixed research, with quantitative research being conducted first, followed by qualitative research in the main phase. A total of 371 respondents from the Czech Republic participated in the first phase of the research, which took place in 2023. The following year 2024, these respondents were contacted again with a request for an interview that would provide a deeper insight into the issue. A total of 114 entrepreneurs from the first phase of the research were involved in the main research analysis. The results demonstrated that more than 90% of Czech respondents have sustainable entrepreneurship as a long-term goal. As a result of these qualitative interviews, it was found that a green future is mainly a topic for younger businessmen and businesswomen. With increasing age and the acquisition of experience and business expertise, they have a different perspective on the current situation.

Keywords: Decision making, Entrepreneurship, Personality, Small and medium enterprises

JEL Classification: L26, M21

1. Introduction

Decision making is an essential aspect of any entrepreneur's activity. Making decisions is also considered one of the most critical processes in an organization and a key responsibility for managers at any levels. For this purpose, individuals use

different decision-making styles that reflect their accustomed pattern used during the decision-making process. Every manager's decision-making style is their individual attitude to understanding and reacting to decision tasks. In contrast to environmental and managerial factors that impact the decision-making styles of managers, behavioural characteristics of managers also lead to variation in their personality traits, and consequently, their decision-making styles diverge from among their peers. Deciding is a process, which includes cognitive functions, including early functions such as active and long-term memory, as effectively complex tasks such as thinking, reflecting, resolving problems, and performance functions like cognition and action (Masoudfar et al., 2025).

The article focuses specifically on the field of cognitive functions and Myers-Briggs' typology of these functions (Myers, 2016). The background presents the Myers-Briggs Personality Type Indicator (MBTI) typology in connection with psychological theories of entrepreneurship, which offer a nexus with the decision-making process in the individuals. A preliminary research was conducted along this theoretical base, which was expanded upon by the main research. It is based on primary data gathering from 114 entrepreneurs from small and medium enterprises (SMEs) background.

The main aim of the paper is to discover the association between personality typologies and the Sustainable Development Goals (SDGs), which will be later introduced in the article. In order to achieve this goal, research questions were set:

RQ1: Do any of the personality typologies have a more predisposition to a green future?

RQ2: What is behind the fact that some people are achieving the SDGs more compared to other people?

2. Theoretical background

Personality traits (Cao et al., 2022) can be generally described as consistent individual reactions caused by external conditions or the environment. Based on the analysis, it is commonly assumed that an individual's entrepreneurial success depends on personality traits because they determine a person's behaviour and decision making, thus affecting success. Entrepreneurs with strong traits achieve higher performance and manage their businesses in the long run (Ciavarella et al., 2004). On the other hand, entrepreneurs who face early failures tend to lack these traits and the desire to continue the engagement. Researchers (Miller, 2015; Martins & Perez, 2020) often consider the joint influence of multiple personality traits that are thought to have some relationship with entrepreneurship. These traits are sometimes examined together only because of their assumed increased connection to entrepreneurial outcomes, including entrepreneurial attitudes, intentions, status, and performance - and more recently, entrepreneurial well-being.

To classify which personality variables are related to entrepreneurial decisions, according to Kritikos (2022), it is necessary to briefly describe typical entrepreneurial

tasks and also how personality can influence the performance of these tasks. The ability to identify and exploit opportunities is crucial for individuals entering entrepreneurship. In their study, Shepherd et al. (2016) highlight several facts to keep in mind. Gender differences can help to account for gender specific disparities in decision making among entrepreneurs, and entrepreneurs are heterogeneous in the amount and nature of their experience and these differences affect entrepreneurial decision making, entrepreneurs are also heterogeneous in their meta-cognitive mindset and these roles influence entrepreneurial decision making, furthermore, entrepreneurs are heterogeneous in their ethnic and cultural wealth and these disparities affect entrepreneurial decision making.

For that reason, social psychologists, in particular, have been intensely interested in the predictive potential of personality traits as they seek to refine information about how personality influences the way individuals perceive and respond to the external environment (Antoncic et al., 2015) and to work situations (Caliendo et al., 2014). Entrepreneurs "outperform" by rejecting the prevailing social norm of seeking employment with another organization or person (Teal & Caroll, 1999). Therefore, according to Kets de Vries (1985), many entrepreneurs are maladjusted, difficult employees who start their own firms because they are unwilling to submit to authority and find it difficult to work in a predetermined structured environment. Entrepreneurs seem to be driven by a grandiose obsession.

The categorization of human personalities (Gosling et al., 2003) is challenging due to the complexity and diversity of individual possibilities. Among the oldest and most popular methods of classification of personality traits within job classifications is the Myers-Briggs Personality Type Indicator (Myers, 2016). This technique was developed by Katharine C. Briggs and her daughter, Isabel Briggs-Myers, during World War II to assist in assigning people to work positions and vice versa (Quenk, 2009). The test measures 4 different dimensions of human preferences through a self-assessment questionnaire (Varvel et al., 2004). The first dimension, extraversion (E) versus introversion (I), indicates whether a person draws energy from the external world of people (extraversion preference) or from the internal world of thoughts and ideas (introversion preference). The second dimension, sensing (S) versus intuition (N), indicates whether one prefers the details of a situation (sensing preference) or the overall picture of an experience (intuition preference). The third dimension, thinking (T) versus feeling (F), refers to describe the way people make decisions. People with a thinking preference tend to make their decisions based on logic, facts, and fairness, whereas individuals with a feeling preference focus on how their decisions will impact the people involved. The last dimension deals with the way people prefer to order their world. People with a reasoning preference (J) are organized, precise, and like to plan ahead, while people with a perception preference (P) are usually spontaneous, adaptable, and open to new ideas (Myers, 2016).

Čakrt (2010) characterises people with these personality types in these terms:

Architect (INTJ) - they are detail and fact oriented, realistic, logical and practical, interested in the inner world and the present rather than the future, disciplined and

organized, and observant but somewhat subjective. The INTJ typology is held by 1 % of the general population.

Logician (INTP) - they are quiet, reserved, thoughtful, flexible and tolerant, very logical and factual, good at thinking outside the box and like theoretical thinking. The INTP typology is held by 1 % of the general population.

Commander (ENTJ) - excellent leadership skills and strong communication skills, they are confident, value organization and orderliness, good at making decisions, like to plan and are assertive, direct and honest. The ENTJ typology is held by 5 % of the general population.

Debater (ENTP) - are innovative, very creative, full of ideas, excellent storytellers, like to talk about different topics with people, place a high value on knowledge, dislike plans and routine, are good at leading others, don't like to be controlled and are overly logical. The ENTP typology is held by 5 % of the general population.

Advocate (INFJ) - they are idealistic, sensitive to the needs of others, very creative and artistic, reserved, withdrawn, future-focused, have deep relationships and like to think about the meaning of life. The INFJ typology is held by 1 % of the general population.

Mediator (INFP) - they are loyal and committed, sensitive to feelings, friendly, caring and concerned about others, have strong communication skills, value close relationships, focus on the "big picture" not the details, and prefer to work independently. The INFP typology is held by 1 % of the general population.

Protagonist (ENFJ) - they prefer harmony to argument, are friendly and good-hearted, have a genuine interest in the feelings of others, often have a wide circle of friends and acquaintances, are excellent at supporting and helping others, excellent organizers, and demand acceptance from other people. The ENFJ typology is held by 5 % of the general population.

Campaigner (ENFP) - they are warm and enthusiastic, empathetic and caring, highly creative, fun and spontaneous, disorganized, have strong communication skills, need approval from others, and are able to think abstractly and grasp complex concepts. The ENFP typology is held by 5 % of the general population.

Logistician (ISTJ) - they are detail and fact oriented, realistic, observant but somewhat subjective, logical and practical, organized and organized, more interested in the present than the future, and interested in the inner world. The ISTJ typology is held by 6 % of the general population.

Defender (ISFJ) - they are reliable, stable, down to earth, kind, good-hearted and considerate, practically minded, aware of the feelings of others, enjoy order and structure, have excellent memory for details and like specific information, dislike conflict and arguments. The ISFJ typology is held by 5 % of the general population.

Executive (ESTJ) - they are practical and realistic, reliable, confident, hardworking, traditionalists, like to lead people, very structured and organised, move to standards, very much dislike inefficiency and disorganisation and look for like-minded people.

The ESTJ typology is held by 13% of the general population. The ESTJ typology is held by 13 % of the general population.

Consul (ESFJ) - they are kind and compassionate to others, fun, highly organized, practical, loyal, selfless, dependable, seek approval, and enjoy helping others. The ESFJ typology is held by 13 % of the general population.

Virtuoso (ISTP) - they are highly logical, confident and carefree, action-oriented, very realistic and practical, like to learn from experience and enjoy excitement and new experiences. The ISTP typology is held by 7 % of the general population.

Adventurer (ISFP) - are strongly aware of their environment, reserved and quiet, prefer concrete, practical information, have a strong need for personal space, like to learn from practical examples, dislike abstract, theoretical information and dislike arguments and conflict. The ISFP typology is held by 5 % of the general population.

Entrepreneur (ESTP) - They are sociable, fun, competitive, impulsive, energetic, good at influencing others, action-oriented, adaptable and resourceful, have strong interpersonal skills, observant with a strong attention to detail, and live for the "here and now". The ESTP typology is held by 13 % of the general population.

Entertainer (ESFP) - they are optimistic, friendly, seek new experiences, spontaneous and sometimes impulsive, sociable, like to meet people, like facts and concrete information, are focused on the present, like variety, dislike monotony and hate theories and abstract information. The ESFP typology is held by 13 % of the general population.

While entrepreneurs often don't acknowledge it, they always act on their personality also. According to Akhalaia & Baratashvili (2019), this process is realized on the basis of traditionally allocated psychological processes (cognitive, emotional, volitional, motivational), but at the same time it is not reduced to them. It performs a regulatory function in the structure of the psyche (as well as processes of goal formation, anticipation, planning). When making decisions, the manager consistently goes through psychological operations: thinks through alternative solutions, writes the decision down in a document, communicates the decision to the decision-makers. Although research on managerial behaviour (Hoek & Kuipers, 2024; Gibbon et al., 2025) is only recently being conducted, some entrepreneurship theories have already suggested the importance of this psychological factor.

Entrepreneurs as individuals often adopt the norms of the groups they are connected to (Obschonka et al., 2012), which, according to Tajfel and Turner (2001), is related to Social Identity Theory, which helps explain why individuals may behave differently depending on which groups they perceive themselves as belonging to. The choice of whether to participate in such behaviour and make an effort to do so is up to individuals, as explained by Ajzen (1991) in his Theory of Planned Behavior. Positive and intense feelings of entrepreneurial passion (Cardon et al., 2017; Murnieks et al., 2020) represent engagement in an activity that is associated with intensity and meaning for entrepreneurs (Stevenson et al., 2024). Frustration with the performance of government or charitable organizations in addressing social problems has led to

the emergence of social entrepreneurship (Dees, 2007). In certain entrepreneurial environments, individuals are required to act impulsively, according to Wiklund et al. (2016) in their study of Impulsivity Theory, because it is impossible to perform a comprehensive analysis due to a lack of clarity, ambiguity, and urgency. Some of these individuals are overly confident to the point of arrogance (Hayward et al., 2006), and thus may harm their ventures and deprive resources (Cassar, 2010; Hogarth & Karelaia, 2012). People are motivated to seek causes for their failures and successes, as well as for the behaviour of others (Shaver et al., 2001), and are more likely to attribute successful events to themselves or their group, while attributing failures to distal forces or external group members.

2.1. *Decision making and personality*

Different entrepreneurs perceive their environments in multiple ways, including industry, competitive and institutional factors. These differences in turn affect how they assess environmental conditions and how they ultimately make entrepreneurial decisions (Shepherd et al., 2016). Nevertheless, factors other than environment can also influence decision-making. Since decisions are made by humans, there are also many human factors that are likely to influence decision making, such as the experience of decision makers, communication between decision makers, stress levels of decision makers, and the cognitive style of decision makers (Mendes et al., 2019). A study conducted by Vinkenburg et al. (2001) identified a stronger emphasis of the importance of performance adaptation by the senior and experienced managers than the younger managers' insights. However, female managers mentioned that they regarded the importance of quality as an essential reason for deciding between different behavioural reactions in managerial situations to a more important extensively than male managers.

Under these circumstances of insecure and challenging environments, biases and heuristics can provide an effective and efficient guidance for decision making (Busenitz & Barney, 1997). Personality, hubris, and heuristics are three concepts that are interrelated. In most cases, a manager's leadership style and strategic decision-making is predicated on behavioural and decision-making patterns that have proven beneficial in ensuring their success. In effect, the manager depends on these behaviours and decision-making practices, including the use of heuristics, to achieve future success, and therefore these behaviours increase in reinforcement over time. A manager's personality traits have the potential to predispose to hubris and accordingly to the application of heuristics. For example, traits such as self-confidence and overconfidence in their ability to influence events may lead a person to refer to "feeling" instead of facts and use cognitive shortcuts of heuristics - to make more effective decisions. If such a decision leads to success, it increases their reliance on heuristics. A difficult element in this interplay is inherent hubris, which in some cases could feed the manager's self-confidence, hubris, and gullibility, making them more prone to dependence on heuristics (Akstinaite, 2023).

Miller (2015) suggests that several pieces of evidence indicate these negatives, are actually inherent in the personalities of many entrepreneurs and some of them are

highly visible and successful. Biographies of entrepreneurs who have shaped the industrial landscape of America constitute the first vein of evidence. The other type of evidence can be seen in reports of the founders' detrimental influence on the development of their enterprises. Regarding this "dark side" of personality, Miller (2015) pointed to positive characteristics (energy, passion, optimism, self-confidence, need for success and power, independence, autonomy, the need for control and dominance), and the negative extremes (grandiosity, overconfidence, narcissism, hubris, aggression, recklessness, social deviance, indifference to others, obsessive behaviour, distrust and suspicion). DeNisi (2015) challenges this classification of dark side personality traits and questions the generality of personality variables. Dealing with personality types always means dealing with labels to some extent, and these can themselves be misleading, and therefore one must be careful with these labels. For instance, terms such as social deviance or obsessive behaviour border on descriptions of psychotic behaviour. Labels such as hubris and narcissism are slightly less problematic, as these generally apply to individuals who do not need specialist support but are not necessarily the most pleasant people.

Dark personality traits are crucial to understanding human behaviour in the emerging entrepreneurial economy (Harms et al., 2024), in terms of the factors that will attract new individuals to these rapidly transforming business paths, and in terms of the extent to which they can be successful in those paths. Those organisations operating in this space need to be mindful of the potential for malicious agents to exploit to damage their companies and their platforms. While most of these individuals will do very little or any harm, organizations must monitor behaviour carefully and should proactively seek to detect, remove, and prevent individuals who could do the most damage from joining them in the future. To the extent that no limits or boundaries on behaviour are set, those individuals with dark personalities will begin to dominate and dictate the environment. In this regard, it must be remembered that whether in a traditional work environment or an emerging entrepreneurial economy, a certain degree of dark characteristics is generally necessary for an individual to effectively advance their intentions. It is possible, therefore, that the increasing frequency of dark traits in subsequent generations makes today's young people more suited to the current environment. Furthermore, the introduction of AI-based technologies and tools may significantly change the nature of these environments in ways which cannot yet be predict (Harms et al., 2024). From this perspective, Bag & Omrane (2021) believe that it is essential for policy makers to develop a more supportive environment for current and potential entrepreneurs and help them to start and sustain and expand their businesses. Additionally, the right motivations will lead young aspiring entrepreneurs to adapt to starting new businesses instead of employment.

2.2. Sustainable entrepreneurship

The current trends in society today generally acknowledge climate change and social sustainability issues such as discrimination based on gender or ethnicity (Gibbon et al., 2025). Sustainability includes the ability to survive and flourish over the long-

term while reducing negative impacts on the environment, society and the economy (Tajpour et al., 2025). For enterprises and organisations, it means adopting procedures that consider environmental, social and economic considerations in order to promote positive and lasting impact (Caradonna, 2022; Walker et al., 2023). The attainment of organisational sustainability, which is concerned with sustaining a viable enterprise through time (Dueñas-Ocampo et al., 2024), requires balancing economic, social and environmental dimensions. Intergenerational, temporal and transgenerational aspects often lead to a preference towards favouring only one dimension over the rest (Álvarez Pérez et al., 2017). In the entrepreneurial stage, determining the preferred dimension or decision point in the present climate would strengthen the sustainability of productive associations of the social and welfare economy.

The evolution of the principles of circular economy is accordingly positioned to redefine the approach of enterprises to the management of resources and the waste minimization (Yi, 2021). Green entrepreneurs are expected to concentrate on creating sustainable business models that include these new principles, which according to Mehta et al. (2024) will drive product innovation in material science, new product development, product design and supply chain management. For example, the adoption of biodegradable materials, closed loop production and systems for the recovery and reuse of waste will be increasingly more common as enterprises attempt to become more closely attuned to circular economy targets. The behaviour of consumers is evolving with increasing focus on sustainability impacting their purchasing decisions (Ali et al., 2023). A green entrepreneurship future will include reacting to this transition by delivering goods and services that satisfy consumers' increasing expectations of environmental accountability. Indeed, corporations that prioritize sustainable methods, eco-sourcing, and transparency are more likely to achieve a unique advantage in competition as consumers increasingly are demanding more and more responsibility from brands (Yin et al., 2022). Such a change creates new opportunities for entrepreneurs to develop innovative solutions that align with consumers' preferences while also contributing to wider climate protection efforts. At the same time, regulations on sustainability are expected to be tightened and broadened. More stringent environmental regulations, standards and initiatives are expected to be introduced and implemented by both governments and international authorities. Participatory cooperative approaches and multiple stakeholder partnerships will be increasingly significant in the future of green entrepreneurship (Zameer et al., 2020). Solving difficult and complex environmental problems often requires team action and cross industry, government, and community cooperation and coordination. Furthermore, the role of education and outreach will be important in helping to create the future of green entrepreneurship (Mehta et al., 2024).

Besides, a study by Ahmad et al. (2025) demonstrated the effectiveness of board competence and good financial health on corporate philanthropic activities. Competent boards and financially healthy companies are able to return money to the society and the environment and achieve SDGs. The United Nations (UN, 2023) defines these goals as 1) end poverty in all its forms everywhere; 2) end hunger, achieve food security and improved nutrition and promote sustainable agriculture; 3) ensure healthy lives and promote well-being for all at all ages; 4) ensure inclusive and

equitable quality education and promote lifelong learning opportunities for all; 5) achieve gender equality and empower all women and girls; 6) ensure availability and sustainable management of water and sanitation for all; 7) ensure access to affordable, reliable, sustainable and modern energy for all; 8) promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all; 9) build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation; 10) reduce inequality within and among countries; 11) make cities and human settlements inclusive, safe, resilient and sustainable; 12) ensure sustainable consumption and production patterns; 13) take urgent action to combat climate change and its impacts; 14) conserve and sustainably use the oceans, seas and marine resources for sustainable development; 15) protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss; 16) promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels; 17) strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development.

The implementation of these SDGs is linked directly to the pro-environmental behaviour (PEB) of entrepreneurs. The significance of personality traits for environmental performance is not only reflected, in other words, in routine ecological practices (Busic-Sontic et al., 2017), but also in rare high cost decisions motivated by more thoughtful deliberation. Personality traits should therefore be accepted as one of multiple factors as a candidate for influencing ecological decisions, including, but not limited to, preference, norms, and socioeconomic drivers.

3. Research Methodology

The research focuses on the use of primary data. These data sets were collected in a small open Central European economy in the Czech Republic. For this purpose, a preliminary study was first conducted, in which data were collected using the Computer-Assisted Web Interviewing (CAWI) method, where respondents completed an electronic questionnaire and, at the same time, a standardized MBTI psychological test. The questionnaire focused on sustainable entrepreneurship and the creation of added value for the company. The questions in the questionnaire first concerned sustainability and then the creation of value for the enterprise. This was followed by items from the MBTI test for measuring personality typology. At the very end of the questionnaire, there were demographic questions about the participants. A total of 371 respondents out of a total of 1200 randomly selected respondents from the business registry participated in the preliminary survey (the response rate was 30.92%). This preliminary survey was conducted in 2023 from March to November of that year.

In the following year, 2024, the main research was completed when respondents from the preliminary survey were contacted for qualitative interviews. A total of 114 interviews (30.73% of the total preliminary survey sample) were conducted between

March and November 2024. The respondents received information about the SDGs in advance via email, which they were able to read and get prepared for the interview. Before data collection, participants were provided with research and data management details, whereby the data will only be used for research purposes and their security will be ensured and access to the data will be prevented to people outside of data management. Participants had the right to withdraw from the research and withdraw their responses. By participating in the research, they have agreed to these terms and conditions. The qualitative data was collected electronically via Google Meet, MS Teams or Discord. The aim of these interviews was to gain a deeper insight into the issue of sustainability as well as respondents' perspectives on the SDGs goals. The thematic areas explored in the interviews were (a) sustainable entrepreneurship and (b) SDGs. These topics were addressed in two questions that were included in the interview: (1) Can you tell me what your opinion is on sustainable entrepreneurship and whether you try to implement it in your own corporate activities? and (2) Can you tell me what your opinion is on SDGs and whether you try to apply this in your entrepreneurship? The interviews were an average of 25 minutes long. The total time for the qualitative interview was 50 hours. The interviews were conducted in Czech, which was the respondents' native language, and every interview was audio recorded with the respondents' agreement. The audio recordings were coded with alphanumeric codes (as shown in Table 6) to preserve the anonymity of the respondents. They were then transcribed into text form and translated into English.

The information obtained was subsequently analyzed. No qualitative data analysis software was used for the analysis. Text responses were coded (Deterding & Waters, 2021) and the data was classified according to the codes. This led to the identification of several themes. Sentiment extraction was also performed, based on which respondents were classified into three groups. The first cluster (positive) consists of respondents who are meeting the SDGs and aiming for sustainable business. The second group (neutral) consists of respondents who do not implement the SDGs but are trying for sustainable entrepreneurship. Lastly, the category of respondents not fulfilling the SDGs and not attempting sustainable entrepreneurship is the third group (negative).

3.1. Research procedure

Out of total 371 respondents, males (69 %) were the most represented over females (31 %). In terms of age structure, the most represented age category was 41 to 55 years (43.7 %) followed by 26 to 40 years (28.6 %), 18 to 25 years (14.3 %), 56 to 65 years (10.8 %) and over 66 years (2.7 %). The personality of the sample respondents is illustrated in Table 1 (MBTI personality of the sample) for better overview. The sample is represented by 56.9 % of the extroverted type of participants, and 43.1 % is made up of a portion of the introverted people.

Table 1. MBTI personalities of sample (source: own research)

MBTI personality	Frequency	Percent	Cumulative percent
ENFJ	7	1.9	1.9
ENFP	18	4.9	6.7
ENTJ	48	12.9	19.7
ENTP	14	3.8	23.5
ESFJ	14	3.8	27.2
ESFP	13	3.5	30.7
ESTJ	31	8.4	39.1
ESTP	66	17.8	56.9
INFJ	14	3.8	60.6
INFP	5	1.3	62.0
INTJ	29	7.8	69.8
INTP	45	12.1	81.9
ISFJ	11	3.0	84.9
ISFP	19	5.1	90.0
ISTJ	11	3.0	93.0
ISTP	26	7.0	100.0

The most frequently represented personality type based on the MBTI test in the sample is the ESTP typology (17.8 %), followed by the ENTJ typology (12.9 %) and the INTP typology (12.1 %). Comparatively, the least numerous personality types are the INFP typology (1.3 %), the ENFJ typology (1.9 %), and the ISFJ typology with the ISTJ typology having an identical 3.0 %. When the personality components of this test are individually analysed, Extraversion (14.22 %) is superior to Introversion (10.78 %) in the first dimension. Sensing (12.87 %) is above Intuition (12.13 %). In the dimension of decision making, the largest percentage of Thinking (18.19 %) is visible over the function of Feeling (6.81 %). For the last fourth dimension, Perceiving (13.88 %) is the predominant function over Judging (11.12 %).

4. Research findings

The survey found that 91.4 % of Czech entrepreneurs have sustainable entrepreneurship as one of their long-term goals. This target is already a long-term goal for 61.73 % of men and 29.65 % of women. Only 8.6 % of all respondents do not have sustainable as their long-term goal. Regarding age distribution, the results are for the age group 18 to 25 years (13.48 %), 26 to 40 years (26.98 %), 41 to 55 years (39.08 %), 56 to 65 years (9.43 %) and over 66 years (2.43 %). At the same time, the survey also found that up to 85.2 % of Czech entrepreneurs also aim to increase the value of their business. From a gender context, the growth in the value of the enterprise for males is represented at 56.87 % compared to 28.33 % for females. Also, for creating enterprise value, there were some respondents (14.8 %) those who do not

consider this as their long-term goal. In terms of age representation, the results are for the age group 18 to 25 years (12.69 %), 26 to 40 years (25.34 %), 41 to 55 years (36.39 %), 56 to 65 years (8.89 %) and over 66 years (1.89 %). Cronbach's alpha is 0.756 for the long-term goal items. The long-term goal results from the personality perspectives are presented in Table 2.

Table 2. The long-term goal results from the personality perspectives (source: own research)

MBTI personality	Sustainable entrepreneurship (%)	Value of their business (%)
ENFJ	1.62	1.62
ENFP	4.31	4.05
ENTJ	12.65	11.05
ENTP	3.50	3.26
ESFJ	3.50	2.96
ESFP	3.23	2.70
ESTJ	7.28	7.28
ESTP	16.44	15.36
INFJ	3.77	3.77
INFP	1.35	1.62
INTJ	6.47	6.74
INTP	10.80	9.97
ISFJ	2.96	2.96
ISFP	4.60	4.58
ISTJ	2.70	1.89
ISTP	6.20	5.39
Total	91.4	85.2

From a personality perspective, most often set ESTP (16.44 %), ENTJ (12.65 %) and INTP (10.80 %) personality typologies as their primary long-term sustainable entrepreneurship goal. This composition of personality typology is also when setting the long-term goal of creating business value. ESTP (16.36 %), ENTJ (11.05 %) and INTP (9.97 %) are the top three personality typologies.

Indeed, only 27.2% of the total sample actively participates in achieving SDGs. Of these, more often male participants meet the SDGs at 59.41 % over female (40.59 %) participants. The results of the descriptive statistics are reported in Table 3. A Likert scale of 0 to 5 was used during the SDGs items (where 0 indicated that the SDG goal was not implemented at all and 5 indicated that the goal was 100 % implemented).

Table 3. Summary of descriptive statistics on the SDGs (source: own research)

SDGs	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Mode	0	0	5	5	5	5	5	5	0	0	0	5	5	0	0	0	5
Median	2	2	4	4	4	3	3	4	3	3	3	4	3	2	2	3	4

The analysis of the SDGs goals found that of the sample of all entrepreneurs who meet these goals, 28.0% are trying to meet all goals to the highest possible effort while 23.6% of the sample are not meeting any of the goals at all. The most frequently met targets are SDG3, SDG4, SDG5, SDG6, SDG7, SDG8, SDG13 and SDG17. The least fulfilled goals are SDG1, SDG2, SDG9, SDG10, SDG11, SDG12, SDG14, SDG15 and SDG16. The reason for not satisfying these goals could be found from a geographical point of view, but also from a psychological point of view, where the mentality of the sample is different from the rest of Europe and the world (Kolaříková, 2020).

From a personality viewpoint, the pre-research was able to illustrate the involvement of the different MBTI typologies in the achievement of the SDGs (Table 4). Through the Cramer's V, a weak association was found (Cramer's V = 0.25) and a level of significance at 0.115.

Table 4. MBTI typologies in the achievement of the SDGs (source: own research)

MBTI personality	Proactive implementation of the SDGs	
	Yes	No
ENFJ	4	3
ENFP	7	11
ENTJ	18	30
ENTP	3	11
ESFJ	1	13
ESFP	1	12
ESTJ	11	20
ESTP	16	50
INFJ	2	12
INFP	2	3
INTJ	7	22
INTP	13	32
ISFJ	4	7
ISFP	7	12
ISTJ	3	8
ISTP	2	24

Among the sample, the ENTJ, ESTP and INTP typologies are the most likely to actively pursue SDGs targets. At the same time, these typologies are also the least frequently engaged in meeting these goals. This discrepancy is due to the limitation of the research, where it was not possible to involve the same number of participants in all personality types. Also, even the majority of the respondents involved are not actively involved in the SDGs although they are working towards sustainability. As part of the research findings, the SDGs in Table 5 were tested via Cramer's V and individually with MBTI types at a significance level of alpha = 0.05.

Table 5. The relationship between MBTI types and SDGs (source: own research)

MBTI types*SDGs	Cramer's V	Sig.
SDG1	0.35	0.842
SDG2	0.39	0.453
SDG3	0.34	0.901
SDG4	0.33	0.962
SDG5	0.37	0.697
SDG6	0.36	0.806
SDG7	0.39	0.413
SDG8	0.38	0.628
SDG9	0.40	0.271
SDG10	0.40	0.318
SDG11	0.39	0.471
SDG12	0.35	0.829
SDG13	0.40	0.317
SDG14	0.40	0.336
SDG15	0.38	0.535
SDG16	0.40	0.259
SDG17	0.38	0.578

Based on the association analysis performed between MBTI types and SDGs, a moderate relationship (Budíková et al., 2010) was found for all variables. All variables did not demonstrate statistical significance on any of the SDGs. Since the result of the statistical finding performed through the association test was not able to satisfactorily answer the current scientific problem, it was necessary to continue with the main research.

4.1. Results of the qualitative analysis

After the findings of the preliminary research, the research continued into the main research phase. To this end, qualitative interviews were conducted with willing and consenting respondents from the pre-survey. A total of 114 respondents were

involved in this research. Out of this total sample, 66 were male (57.89 %) and 48 were female (42.11 %). The age categories were 18 to 25 years (26.32 %), 26 to 40 years (24.56 %), 41 to 55 years (41.23 %), 56 to 65 years (7.02 %) and above 66 years (0.87 %). The personality typologies represented included ENFP (7.02 %), ENTJ (17.54 %), ENTP (8.77 %), ESTJ (18.42 %), ESTP (27.20 %), INFP (4.39 %), INTP (11.40 %), and ISTP (5.26 %). The Table 6 below presents the representation of different respondents in the cluster (see Research Methodology). In analysing these interviews and then clustering them, it was a pleasant surprise that each group contained the same number of participants, which helps to minimize the limit that any one group would have more influence on the analysis performed.

There were identified 5 broad themes, including climate change, the European Union and its rulings, protecting the planet, entrepreneurship and decision making, and view on sustainability.

Table 6. Summary of qualitative interviews (source: own research)

Cluster group	Sample representation	Interview codes
Group1	The gender composition: male (34.85 %), female (47.92 %)	E4, E5, E11, E14, E15, E21, E23, E24, E25, E26, E30, E45, E47, E53, E54, E55, E78, E80, E82, E87, E88, E90, E94, E95, E96, E98, E100, E101, E103, E104, E105, E106, E107, E108, E109, E111, E112, E114
	The age composition: 18 to 25 years (33.33 %), 26 to 40 years (42.86 %), 41 to 55 years (23.40 %), 56 to 65 years (37.50 %), 66+ (0.00 %)	
	The personality composition: ENFP (25.00 %), ENTJ (40.00 %), ENTP (10.00 %), ESTJ (76.19 %), ESTP (3.22 %), INFP (100.00 %), INTP (53.85 %), and ISTP (33.34 %)	
Group2	The gender composition: male (27.28 %), female (35.41 %)	E2, E7, E9, E12, E13, E16, E18, E22, E27, E29, E31, E33, E35, E36, E38, E41, E42, E43, E44, E51, E52, E57, E58, E59, E62, E63, E64, E65, E69, E71, E74, E75, E77, E79, E85, E89, E92, E102
	The age composition: 18 to 25 years (33.34 %), 26 to 40 years (21.43 %), 41 to 55 years (12.77 %), 56 to 65 years (0.00 %), 66+ (0.00 %)	
	The personality composition: ENFP (75.00 %), ENTJ (10.00 %), ENTP (50.00 %), ESTJ (14.29 %), ESTP (25.81 %), INFP (0.00 %), INTP (15.38 %), and ISTP (33.33 %)	
Group3	The gender composition: male (37.87 %), female (16.67 %)	E1, E3, E6, E8, E10, E17, E19, E20, E28, E32, E34, E37, E39, E40, E46, E48, E49, E50, E56, E60, E61, E66, E67, E68, E70, E72, E73, E76, E81, E83, E84, E86, E91, E93, E97, E99, E110, E113
	The age composition: 18 to 25 years (33.33 %), 26 to 40 years (35.71 %), 41 to 55 years (63.83 %), 56 to 65 years (62.50 %), 66+ (100.00 %)	
	The personality composition: ENFP (0.00 %), ENTJ (50.00 %), ENTP (40.00 %), ESTJ (9.52 %), ESTP (70.97 %), INFP (0.00 %), INTP (30.77 %), and ISTP (33.33 %)	

Climate change

The theme of climate change is relevant to all groups of respondents, but different groups have contrasting opinions. While younger age groups are more familiar with this topic and it resonates more with them, with increasing age it becomes less important and they consider it to be another development of the planet, which can cope with it on its own without further intervention. It is precisely the need for intervention and help to stop the negative effects of climate change that has led some young people to start their own entrepreneurship so that they can contribute more to protecting and improving the situation. With age and experience, these people's enthusiasm gradually wanes and they become more aware of their own reality. New events come to the fore and original plans change.

Protecting the planet

Climate change is linked to the issue of protecting the planet, which is regarded as important by the respondents. The difference lies in how to protect it. There are differing opinions on this matter, with two camps of opinion on the issue. One camp believes that we need to start with ourselves and take small steps to show that it is possible without cooperation with others (continents, policymakers, entrepreneurs, etc.). The opposing camp believes that everyone needs to get involved, preferably at the same time, in order to achieve stable improvement.

The European Union and its rulings

The individual camps also relate to the European Union and its rules on climate and planet protection. While most younger entrepreneurs support these measures, older entrepreneurs see them as obstacles to their enterprise. They no longer feel a freedom in their entrepreneurship, but often see reasons to end their entrepreneurial activities. There is little public discussion of the individual actions, and decisions are made more at the level of individual state representatives than through broader discussion. Older age groups have more experience, including in the field. Thanks to their extensive business experience, they are able to see the situation more realistically.

Entrepreneurship and decision making

Entrepreneurs focus primarily on their own ventures, which they say they strive to keep alive for as long as possible. At the same time, their families and financial security are also important to them. That is why they often consult with their families on important aspects of their decisions, who help them make decisions. They do not want their bad decisions to negatively affect their families. Although they do not realize it, in addition to their family, they also make decisions based on their own characteristics, both positive and negative. These characteristics are more noticeable among entrepreneurs with more experience, and entrepreneurs rely on them more strongly when making decisions. Unlike younger entrepreneurs, they have clearly defined priorities that guide them and are more individualistic when it comes to important decisions. They build their businesses on the experience they have gained over time.

View on sustainability

While younger age groups have a better understanding of sustainability and sustainable entrepreneurship, older age groups are still unfamiliar with this concept. They do not understand this concept and are therefore unable to assess whether or not they are fulfilling the SDGs. For some respondents, the issue of such entrepreneurship is a matter for the future, in which young people should be more involved than established entrepreneurs. Every entrepreneur wants to maintain their existing entrepreneurship however, they are uncertain whether it is already sustainable. There is little discussion or training in this area on the part of the state. More information is available in the media about the European Union's steps in these matters, and entrepreneurs subsequently feel left out of this discussion. This is why there is growing opposition to individual steps taken by the European Union or climate change.

In the paragraphs of text that follow, the results of qualitative interviews with Czech entrepreneurs on the topic of sustainability and the SDGs are reported. Naturally, these are not transcripts of all interviews, but certain excerpts from these interviews.

Group1: *"I have been burnt several times during my business and when I first heard about sustainability and the SDGs I thought it was crazy, but after consulting with my family I changed my mind and now I believe I will not get burnt again in this way (E88)." "Our goal is long-term sustainability and to this end we are also striving to meet the SDGs set at the same time (E54)" ... "we have already invested significant resources to ensure that our company contributes to creating a green future (E4)". "It is in our hands what we leave to the next generation (E114)". "It will also be our future (E53)". ... "and I would like to live to see such a future (E107)". "I don't want my children to grow up in a scorched earth that we have destroyed ourselves (E82)". "We must therefore start working today for a better and greener future (E5)" ... "I have also started a business for this purpose (E95)". "And even though my business is also contributing to the pollution of nature I have also contributed to a better future (E47)". ... "our business will disappear one day, but that doesn't mean that our planet has to disappear because of it (E100)". "And even if we are already doing something, it is still not enough (E11)" ... "we have to do more for our planet (103)". "The European Union should not be alone in this in my opinion (E94)" ... "I think the rest of the world should also get involved to a greater extent (E15)" ... "well, because, um, how should I put it, well, we are just a small fish in a giant sea (E25)". "And I think if the whole world doesn't get involved, then hardly anything will change (E23)". "Together we can do it and it doesn't matter if it's just one person or the whole world behind them (E87)". "Although I have no idea what the future will bring, there is no doubt that we need to protect our nature (E103)". "That is why my business is meeting the SDGs, well I admit not all of them (E21)".*

Group2: *"So, in the context of my entrepreneurship, I'm trying to make it, well, a sustainable business (E102)" ... "and even if I'm not implementing the SDGs I don't see that as a problem (E38)" ... "because my business is doing well and I think if I started applying the SDGs now that might not be the case (E7)". "Even though I'm not defending the SDGs (E92)" ... "I don't see the potential to apply them to my business yet (E44)". "I'm sure it will cost me considerable funds that I could use elsewhere and more meaningfully (E41)". "Well, in short, I don't have the resources (E77)". "To be honest, I can't, my wife*

doesn't like the idea of it (E69)". "I would like to apply these goals to my business, but the current situation doesn't favor me (E62)" ... "they haven't developed enough technology to do it yet (E27)". "Well, I've already thought about it, I just haven't decided yet (E16)". "So, I'm only doing what the European Union has stipulated (E2)". "Maybe in the future I would also apply these goals (E64)" ... "when the time is more suitable (E35)". "Because the future is still far away, but my business is now and here (E89)". "I don't like change that's the reason (E71)". "I would hate for any SDGs to put my business down (E43)". "And I don't like the goals either (E36)". "Why would I want to protect an ocean when I'm miles away from it (E33)". "Even if I don't meet them, nature needs to be protected (E62)" ... "and me setting something doesn't do anything as an individual so I don't do it that way (E18)" ... "but I'm slowly preparing to apply these goals to my entrepreneurship (E12)" ... "one day for sure (E13)". "In the meantime, I'm considering my options (E51)". "So, to sum it all up, not now and not here, but sometimes it certainly depends whether by choice or by compulsion (E29)".

Group3: *"I think sustainable entrepreneurship is nonsense, no business is sustainable. It is just a set of coincidences, where it depends on the will of the individual to sustain these coincidences (E1)". "The whole enterprise is about the person and their abilities, how are these goals supposed to help me not to collapse and go mentally insane from the business because that is their goal from my point of view, the psychological destruction of the person (E110)" ... "it is already a challenging business and I don't need any more nonsensical tasks added to it (E17)". "I mean, I didn't start the business for this, for a future like this (E3)" ... "I had a completely different idea of the future, not the one they force us into (E76)". "The reason I started the business was for freedom (E20)" ... "to achieve maximum profit (E40)" ... "and the feeling of power, I wanted my acquaintances to look at me as a person who has power (E50)". "I was the one who wanted to make rules, to establish rules that my subordinates would have to follow (E72)". "I didn't want to be governed by someone else (E49)" ... "and that's what's happening, someone is telling us something and not even asking us what we think about it (E17)". "And that seems wrong to me, it's me as an entrepreneur creating value, that value that somebody else is appropriating (E91)". "If it goes on like this I'll quit (E67)". "I don't like what's going on at the moment (E99)" ... "I don't want to be part of it (E28)". "I'd like to do what I want to do, naturally inside some limits (E61)" ... "because it's important to set some limits and not exceed them (E97)" ... "but I think some people have already done that (E32)". "I'm of the opinion that these people are scared, they're worried about themselves, they've created invisible castles that they live in and they're somewhere completely out of touch with reality (E8)". "It's only going to be a matter of time in my opinion before this whole system collapses. Maybe it will be the next months, maybe years, but it will collapse (E93)". "I would like to be there when that happens, when the whole world then realises that their sustainability is inherently unsustainable (E19)". "Why else explain the fact that most of the world doesn't care about this issue. Yes, from my point of view, it is necessary to prevent inequalities in the world, but it is required to do it systematically and everybody has to be involved in it, not in the way it happens nowadays that a certain group of people tells you to do it and does not do it properly. They preach water and drink wine, that's the way it is (E46)". "So, these people are even bigger hypocrites in my opinion than I or anyone else (E81)".*

"And my opinion on this subject is final. At the moment, seeing what's going on, I'm hardly going to be persuaded to change my opinion on the issue of sustainability and the SDGs (E39)". As I sit here thinking about it now, well, as we talk and talk about these issues, it makes me think I would rather quit this business. Yeah, definitely. I would rather quit my business than continue to move forward into a future that a certain group of people have convinced us is better, but at the same time those certain people refuse to have a discussion with us about how we feel about it. Well, or at least I don't know that there are any discussions about it, and as far as I have asked others as well as people in my field, but also others, they have no awareness about it either (E34)". "I have been in entrepreneurship for a really, really long time and I have been through all kinds of things in my lifetime, but if I am going to tell the truth, what I really think, my real truth, it is that the current times we are living in now are the worst times to live in, in my opinion. And it's not so much about what we humans have done to our planet and what we continue to do to it, but it's about how humans treat other humans. Once upon a time in the past people were friendlier to one another, helped each other more and while it wasn't talked about at all and probably most of us as humans didn't even know about it so from my point of view we helped our planet Earth more than we do now. Today it is just talked about. Everybody is talking about it. But the action is passed. When we were young, we used to help our parents on the farm and during the weekend we were cleaning up the forests and planting new saplings. And nowadays what's happening? A protest is organized for something, it doesn't matter what it is now, because the people standing there don't really know what it's all about, and after they are gone, the place is such a mess, as if there was a war going on. But I've already digressed. I would rather stay on the topic at hand. Well, in short, I don't follow it and don't plan on doing it. And those who want to, let them do it. Make them do it. But also let us do it the way we do it. Let neither of these two camps jump into each other and cause more riots, because there are enough of those already. Live and let live (E70)".

5. Discussion and conclusion

The research focused on insights into the personality of green future decision-making conducted in the setting of the European Union, a small open economy in the Czech Republic. This entrepreneurship environment is a bit specific as it has gone through a Soviet-socialist history (Salat, 2023). This is also related to the mentality (Kolaříková, 2020; Cabada, 2024), which is different compared to other EU countries. For this reason, one would expect that the results made in other European Union countries would reach different conclusions.

The study of the model (Nikonova & Krasilnikova, 2022) concludes that all players representing any sector tend not to downgrade their status provided the rules of the game. Therefore, it is required to transform the "rules of the game" and the "playing of the game" towards compatibility with the SDGs, considering the specificities of the country, the systemic relationships and the sector interactions, in which the social sector (environmental subsystem) has the main role, as society constitutes the informal institutional environment and also the intellectual and moral environment.

With regard to the link between the SDGs and the outcome of careers and well-being (Parola & Felaco, 2024), there is obviously a need to increase the attention on the SDGs' potential benefits for engaging with and guiding youth within and across school systems in order to develop a sustainable future. Because of the dangers and opportunities in today's society, the sustainability goals should make young people increasingly conscious of how the SDGs can affect their future studies and their future pathways.

The current preliminary survey showed that more than 90% of Czech respondents have sustainable entrepreneurship as a long-term goal, although based on qualitative data, the older cohort of entrepreneurs in particular does not understand this concept. The dominant personality types according to the MBTI personality test include ESTP (16.44%), ENTJ (12.65%), and INTP (10.80%). In addition to sustainable entrepreneurship, these typologies also most often have the creation of corporate value as a long-term goal. At the same time, they also contribute the most to the fulfillment of sustainable development goals (SDGs) compared to other personality types. The results also show that the most frequently achieved goals are SDG3, SDG4, SDG5, SDG6, SDG7, SDG8, SDG13, and SDG17. Compared to China, the most important goals are SDG3, SDG4, and SDG1 (Chen et al., 2021).

Additionally, a study by Chen et al. (2021) demonstrated the existence of significant associations between attitudes, interest, motivation and self-efficacy in connection with the SDGs. In contrast, the recent research conducted has established a moderately strong association between MBTI personality type and SDGs. No statistically significant variables were found during this process. Under the current conditions, the question therefore arises whether the use of different personality tests (Mendes et al., 2019) would confirm this association or would change the association. Meanwhile, Di Fabio & Rosen (2020) argue that these findings could also support the development of public policy and organisational implementation of sustainability goals by considering the psychological dimensions that facilitate the fulfilment of the SDGs.

After the preliminary research phase, the study moved on to the main research, which consisted of conducting qualitative interviews and analysing them. A study of Polish small and medium-sized enterprises (Bajdor et al., 2021) conducted using cluster analysis concluded that the Polish SME sector can be divided into five different categories, which are characterized by significantly different approaches and levels of implementation of the sustainable development framework. The study shows that several companies implement sustainable business only at a declarative level. This finding could also be applied to the current sample of Czech entrepreneurs. Based on the research results, it can be concluded that environmental goals are a bigger problem for Polish companies than meeting social goals. Polish companies that implement sustainable business practices the most often use advanced IT solutions. They also focus on improving cooperation between employees and strive to standardize and simplify organizational procedures. Sustainable businesses strive to innovate more quickly. This is evidenced by a higher number of innovations and the use of the power of information. The managers of these companies are also more

inclined to introduce environmental and philanthropic activities. They display a more optimistic approach than companies in the least sustainable group (Bajdor et al., 2021).

In the case of Czech companies, these are mainly social enterprises that apply sustainable entrepreneurship to a greater extent and fulfil SDGs. In the Czech SMEs environment, the research identified three groups. The first group consists of entrepreneurs who strive for sustainability, but at the same time are actively involved in the implementation of the SDGs. The second group consisted of people who are striving for sustainability but are not currently implementing the SDGs and the last group consists of entrepreneurs who are not implementing the SDGs and are also not involved in sustainable entrepreneurship.

As a result of these qualitative interviews, it was found that a green future is mainly a topic for younger businessmen and businesswomen who are already engaged in sustainable entrepreneurship and the SDGs from the start of their careers. In some cases, these issues were the reason why these individuals started their entrepreneurship. They invest financial resources in such businesses because they believe they will help. They want to leave the planet in better shape than previous generations have left it. They hope that by getting involved themselves that other people will join in because of it.

In the second and third groups, the so-called silver generation (Barković Bojanic et al., 2024) is the most frequently represented. For the second group it was found that even though they are not meeting the SDGs they are beginning to realize the need to protect nature and improve the current state of affairs. Therefore, they are striving for sustainability. It is aware of the fact that some things are not as simple as the first group imagines and they do not have "rose coloured glasses". They are also more realistic compared to the first group. They understand that they cannot do anything as individuals and need to work together. Due to the experience they have gained and their business experience, they have a different overview of the current situation. As in the case of the first group, during the qualitative analysis it was possible to find already established business theories that they follow, even if perhaps unconsciously, during their decision making.

Within the third group, entrepreneurial theories are perhaps the most visible. People in this group are mostly dissatisfied with having something imposed on them. They rebel against it. They want to be their own masters. When they see someone telling them what to do and how to do it they get upset. They don't need to be told how to do something. They want a future in which they too will have a say. If they participated in building the current state, they want to be part of building the next one. At certain moments they feel inequality in the way one generation's opinion is privileged over another.

Based on the research conducted, policymakers are advised to create training programs on sustainable entrepreneurship for groups of entrepreneurs so that they can better understand this concept and become more involved in these activities. This also involves introducing metrics for measuring entrepreneurship sustainability, which

could be promoted and educated more among entrepreneurs. Another recommendation is to open a broader discussion with entrepreneurs, who have best knowledge of their specific entrepreneurship environment and industries. By involving entrepreneurs in this discussion, they will not feel side-lined, but rather directly involved, which could encourage them to become more engaged.

However, even this study was not without its limitations. The first is the size of the sample studied. It is low by the standards of the Czech business environment. In future research, this sample needs to be expanded. Another limitation of the research is the unequal representation of genders, ages, and personality types. It is understandable that such a representation is very difficult, but it would contribute to better conclusions of the study. A closer focus on the SDGs and other long-term goals of SMEs is needed in the future. The use of other personality tests may also provide new insights. Future work may also benefit from comparing individual Czech SMEs with SMEs in other EU countries. Although the qualitative interviews were able to sort an even number of respondents into three groups through analysis, here too there is a disparity in gender, age and personality which affected the study's conclusions.

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KRÁL, Š., KRÁĽOVÁ, L., HERICHOVÁ, B. / *The Importance of Business Digitalization in the Context of E-Commerce*

The Importance of Business Digitalization in the Context of E-Commerce

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Abstract

The COVID-19 pandemic has been a challenge for companies operating in various industries. Many companies have been forced to make significant changes and implement solutions based on digital technologies in a very short time. The aim of the paper was to analyze the connections between consumer online shopping and business digitalization in the post-pandemic period in the V4 countries in 2022 and 2024. The results showed an increasing trend between 2022 and 2024 in both variables studied. In examining the connections between business digitalization and online shopping, they showed the existence of a certain connection, however, from a statistical point of view, the relationship was not proven to be significant. These facts indicated the need for further research into the issue and conducting a deeper analysis including other factors over a longer period. The research highlights the need for successful digital adaptation and its strategic importance in the context of e-commerce for the competitiveness of businesses in a rapidly changing economic environment.

Keywords: digitalization, electronic commerce, e-commerce, consumer behavior

JEL Classification: M10, M20, M30

1. Introduction

Official The COVID-19 pandemic has had a dramatic impact on the global economy, business activities and consumers. The increase in the use of technology in the daily lives of consumers and companies to face the exceptional situation caused by the pandemic has been evidence of the process of digital acceleration. The COVID-19 pandemic has posed a challenge to many companies from different sectors. Many of these organizations have been forced to adopt new internal working practices and have felt strong pressure to offer products through digital channels. Companies have therefore made significant changes and implemented solutions based on the use of digital technologies in a very short period (Almeida, Santos, Monteiro 2020).

Digital transformation is characterized by the convergence of modern technologies with physical and digital systems. Innovative business models, new production processes, and the creation of knowledge-based products and services are prevalent. Although digitalization is not a new phenomenon, the challenges and opportunities associated with it are constantly changing. Before COVID-19, the challenges associated with digital transformation were essentially focused on the fourth industrial revolution associated with the concepts of Industry 4.0, the Internet of Things, and Web 4.0. The challenges concerned the disruption of traditional concepts and technologies, as well as the speed of this digital transformation. In the COVID-19 era, these challenges were fundamental and involved all stakeholders in organizations in the digitalization process. Moreover, the pace at which this change was taking place was enormous. Organizations have been literally forced to make this change regardless of their previous position and experience with digital transformation processes (Pflaum, Gölzer 2018; Fonseca 2018; Verhoef et al. 2021).

The development and advancement of digital technologies is changing the way consumers live, socialize and work. The digitization of products and services is a rapidly developing global megatrend that is fundamentally changing existing value chains. Companies in almost all industries are undertaking initiatives to explore new digital technologies and exploit their benefits. The potential benefits of digitalization in terms of its value creation for businesses are diverse. Two complementary dimensions are outlined to achieve success in digital transformation. On the one hand, digital technologies transform internal operations and innovate production processes and internal value chains. On the other hand, they reshape the external dimension, such as customer value propositions and newly created products and services (Nyagadza 2022; Tagscherer, Carbon 2023). In recent years, the advancement of new digital technologies, such as Blockchain, Internet-of-Things, Big Data, Artificial Intelligence, and Cloud Computing, has also forced companies to rethink their business models. Companies have moved towards digitalization, in which digital technologies are used to change existing processes to achieve greater efficiency and better value for the customer. However, digital technologies can also support a complete digital transformation of business models by introducing new logics for creating, delivering, and capturing value (Favoretto et al. 2021; Favoretto et al. 2022).

One of the likely consequences of COVID-19 is the accelerated trend of digitalization of business models associated with the shift of business activities from pre-dominantly offline brick-and-mortar stores to online stores. This trend can be observed even in the post-pandemic period. The pandemic has fundamentally changed consumer behavior, from visiting physical stores to shopping online (Amankwah-Amoah et al. 2021). The COVID-19 pandemic has had a significant impact on the growth of online shopping, which has been driven primarily by the closure of brick-and-mortar stores and restrictions on consumer mobility. One of the most

significant benefits of the online shopping industry is the increased convenience for consumers. Online shopping allows customers to shop whenever they want without having to make greater physical effort. In addition, online shopping can also provide consumers with a wider choice of products. Online shopping platforms also offer efficient and comprehensive price comparison, which leads to informed purchasing decisions. Online shopping often offers lower prices compared to brick-and-mortar stores, as e-commerce businesses often have lower operating costs and can pass these savings on to consumers. The use of artificial intelligence technologies allows e-commerce entities to collect data on consumer preferences and behavior, which enables the creation of personalized marketing strategies. This leads to increased customer satisfaction and loyalty (Rosário, Raimundo 2021; Moiseev et al. 2023; Gupta et al. 2023).

It is expected that in the future, consumers will prefer models in which they can independently choose and conclude a contract for a service or product without the need for physical and time-consuming mediation. Simplifying purchasing processes is a key path to better customer experience. Introducing new technologies into organizational processes helps not only build customer loyalty, but also reach new audiences in the international market. Digitalization allows organizations to establish their operations anywhere in the world, especially through faster communication and shared services (Grewal et al. 2020). Digital platforms and technologies are becoming more prominent among consumers and companies, and their role in business competitiveness is constantly growing. Digital transformation has become not only a tool for business diversification and competitiveness, but also a reason for the entire business paradigm to shift towards a digital reality (Fedushko et al. 2023). Online retail sales grew during the pandemic, but also in the post-pandemic period, with some differences between countries and years. In this regard, the specificities of selected countries are of particular interest to researchers. Global online consumers continue to shop from websites and online marketplaces, while the shift in consumer behavior patterns and the digitalization of businesses was the motivation for conducting this study.

This study begins by describing the importance of digitalization in general, but also in the context of e-commerce. The Methods and Data section defines the research objective, sub-objectives, research questions, analytical methods, and characteristics of the variables under study. The results of the analyses are presented and discussed in the Results and Discussion section. The conclusion of the paper provides a synthesis of the most important findings, theoretical and practical implications of the study, and potential limitations associated with the research, as well as possible future directions for research.

2. Methods and Data

The aim of the study was to identify the relationships between consumer online shopping and business digitalization in the post-pandemic period within the Visegrad Four (V4) countries. The years considered were 2022 and 2024.

The main objective was subsequently divided into two sub-objectives (PO):

PO1: To analyse the average values of the variables under study within the V4 countries in 2022 and 2024.

PO2: To analyse the link between the level of business digitalization in the post-pandemic period and consumer online shopping in 2022 and 2024.

Based on the set objectives, two research questions (RQ) were formulated:

RQ1: Is there a statistically significant link between the level of business digitalization in the post-pandemic period and consumer online shopping in 2022?

RQ2: Is there a statistically significant relationship between the level of digitalization of enterprises in the post-pandemic period and online shopping of consumers in 2024?

Secondary data from professional international publications, scientific studies and relevant internet sources were used to process the research study. Secondary data used for the analyses come from the Eurostat database (2025). Within online shopping, the variable "share of consumers in the V4 countries who have purchased online in the last 12 months" was examined. Digitalization of enterprises was monitored through the variable "share of enterprises that have reached a certain level of digital intensity in a given year". Digital intensity was measured using the Digital Intensity Index (DII), which assesses the extent to which enterprises in the V4 countries implemented various digital technologies and practices in 2022 and 2024. The variable digitalization of enterprises included, for example, companies with e-commerce solutions, online payments, cloud services, etc., while companies engaged in agriculture, fishing, mining or financial sectors were not considered. The obtained data were processed in the Gretl program, where descriptive and correlation analysis was also performed.

3. Results and Discussion

Table 1 shows the results of a descriptive analysis of the variables under study, namely consumer online shopping and the level of enterprise digitalization in 2022 and 2024.

Table 1. Descriptive characteristics of the variables under study in 2022 and 2024 (source: own elaboration)

V4 (2022, 2024)	Mean	Median	Minimum	Maximum	Standard Deviation
Online Shopping (2022)	72.15	73.52	64.58	77.00	5.92
Online Shopping (2024)	61.51	61.95	53.01	69.12	6.60
Business Digitalization (2022)	75.25	76.18	67.41	81.24	5.97
Business Digitalization (2024)	66.14	67.12	58.47	71.85	6.05

Based on the values obtained, it can be stated that the trend of online purchases has increased year-on-year. While in 2022 the average value within the V4 countries was 72.15% and the median was 73.53%, in 2024 the average value increased to 75.25% and the median to 76.18%. The minimum and maximum values show a relatively stable range.

Regarding the digitalization of enterprises, the average value increased from 61.51% in 2022 to 66.14% in 2024, indicating that enterprises continue to digitalize in 2024. The median increased from 61.95% to 67.12%, which also confirms that most countries have seen an improvement in digitalization. The increase in the minimum value from 53.01% to 58.47% indicates that even countries with a lower level of digitalization are catching up with others.

The standard deviation ranges from 5.92 to 6.60, which means that the variability of values between countries is not extreme, but it can be stated that there are differences between individual V4 countries.

The growth of online shopping to some extent copies the growth of business digitalization. Correlation analysis was used to obtain answers to the research questions (Table 2).

Table 2. Correlation analysis output (source: own elaboration)

V4 (2022, 2024)	Correlation Coefficient	p-value
Online Shopping (2022)	0.4074	0.5926
Business Digitalization (2022)		
Online Shopping (2024)	0.5935	0.9407
Business Digitalization (2024)		

The results of the correlation analysis between variables for 2022 show a correlation coefficient of 0.4074, which could indicate a moderate to moderately strong positive association between online consumer purchases and business digitalization in 2022. It could therefore be argued that higher business digitalization is associated with a higher proportion of consumers shopping online. However, the p-value is higher than the significance level $\alpha=0.05$ (0.5926), which means that the result is not statistically significant. In conclusion, it must be stated that it is not possible to confirm with certainty that there is a statistically significant association between the variables.

In 2024, the correlation coefficient increased to 0.5935, which could indicate a stronger connection between the variables under study. The increase may indicate that the impact of business digitalization has intensified in the post-pandemic period. However, the high p-values (0.9407) again point to the fact that the results are not statistically significant. In the final statement, it is therefore again not possible to confirm with certainty that there is a significant relationship between the variables under study.

Our findings on the strengthening of the relationship between the level of digitalization of enterprises and the rate of online shopping in 2022-2024 are consistent with current European trends. According to Eurostat, 77% of EU internet users aged 16-74 shopped online in 2024, confirming the continued post-COVID growth of e-commerce. At the same time, the gap between internet use and online shopping is narrowing, indicating a high rate of conversion of internet users into online shoppers (European Commission 2025). The 'post-COVID' framework also adds a perspective on the resilience of SMEs. OECD (2024) shows that digital tools increase the ability of SMEs to cope with shocks and transitions (e.g. supply disruptions, changes in demand, etc.), indirectly supporting the maintenance or growth of online sales in uncertain times.

From a business perspective, the digitalization of SMEs is increasing, but the Digital Decade target has not yet been met. In 2023, 58% of SMEs in the EU achieved at least basic digital intensity (DII). The target for 2030 is >90% of SMEs with basic DII, with around 30-32% of SMEs remaining to achieve this target in 2023/2024. This supports the interpretation that there has been a significant shift in the digitalization of firms between 2022 and 2024, which translates into a stronger connection with online demand (Directorate-General for Communication of EC 2025).

Previous studies further explain the mechanism of why higher digitalization increases the likelihood of online purchases. A panel analysis for the EU shows that countries with higher innovation performance show a higher propensity of residents to shop online, while innovation-driven digital transformation strengthens both demand and supply in e-commerce (Roszko-Wójtowicz et al. 2024). In the V4 environment, research shows that online sales have grown at a double-digit rate in

recent years and trade has been moving to omnichannel, or D2C models, which has accelerated the shift of transactions to the online channel. Similarities, but also differences in the pace and depth of adoption of digital solutions between V4 countries have been noted, which may be significant in interpreting our cross-country deviations and which may be reflected in the heterogeneity of our results (Kozák et al. 2023; Siuta-Tokarska et al. 2025).

4. Conclusion

The aim of the presented research study was to identify the connections between consumer online shopping and business digitalization in the post-pandemic period within the Visegrad Four (V4) countries for the years 2022 and 2024. This objective was divided into two sub-tasks – analysis of the average values of the variables under study and examination of the statistical connection between the level of business digitalization and consumer online shopping. Based on the analysis performed, it can be stated that the objective of the study was met.

The results showed that the trend of online shopping in the V4 countries increased between 2022 and 2024. The level of business digitalization also showed an improvement, measured by the Digital Intensity Index, with a growing share of companies using digital solutions such as e-commerce platforms, online payments or cloud services. Correlation analysis did not confirm a statistically significant relationship between business digitalization and the level of online shopping, even though the facts indicate that digitally mature companies have a greater ability to reach the online consumer.

Possible limitations of the research include the limitation to secondary data obtained from the Eurostat database, which may affect the accuracy of the information. Another limitation may be the geographical focus only on the V4 countries and the exclusion of specific sectors (e.g. agriculture, mining, finance), as well as the time limitation, which may limit the generalizability of the results. Future research directions could therefore include expanding the analysis to a wider set of EU countries, examining individual sectors in more detail, and supplementing primary data collection, which would also allow capturing qualitative factors, such as consumer attitudes towards new technologies or barriers to digitalization on the part of businesses.

The research has brought significant benefits both theoretically and practically. In terms of theoretical implications, the research expands knowledge about the relationship between business digitalization and consumer behavior in the online environment and provides a framework for examining digital transformation in the context of the post-pandemic economy. In terms of practical implications, the research

results can serve as a basis for managers and policymakers in formulating digitalization strategies, improving customer experience, and more effectively using digital channels to increase competitiveness in a changing economic environment.

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The Emergence of Dynamic Capabilities in Startups: Triggers and Developmental Stages

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Abstract

This study explores the emergence of dynamic capabilities in entrepreneurial contexts. Dynamic capabilities are generally defined as the organizational processes and routines that enable firms to sense opportunities and threats, seize them, and reconfigure their resources accordingly in order to remain competitive in changing environments. While prior research has highlighted the importance of dynamic capabilities for firm survival and growth, less is known about the developmental process through which they emerge, and in particular, about the triggers that initiate or accelerate their evolution. Our research is based on a multiple case study design involving four startups. Data collection combined semi-structured interviews with document analysis, allowing for a rich understanding of the capability-building processes across different organizational settings. The analysis reveals that dynamic capabilities emerge through a series of distinct stages rather than as a one-time outcome. Importantly, each transition between stages can be linked to identifiable triggers, such as dissatisfaction with the current state, personal motivation, or perceived resource limitations, which propel the further development of the capabilities. These findings suggest that the evolution of dynamic capabilities is not linear but path-dependent, with triggers acting as catalysts that shape both the pace and the direction of development. By tracing these patterns in startup contexts, the study contributes to a more nuanced understanding of how dynamic capabilities are formed over time, highlighting the role of external shocks and internal decision-making in this process. The results have implications for both theory and practice, offering insights into how entrepreneurs and managers can better anticipate and leverage triggers in order to foster organizational adaptability and resilience.

Keywords: dynamic capabilities, startups, capability development, triggers, organizational change

JEL Classification: M13, L26

1. Introduction

The concept of dynamic capabilities has become a cornerstone in strategic management research, representing a firm's ability to adapt, renew and reconfigure its internal and external competencies in order to thrive in rapidly changing

environments. As originally articulated by Teece, Pisano and Shuen (1997), dynamic capabilities refer to "*the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments*" (p. 516). Building on this, Teece (2007) emphasises the role of sensing, seizing and transforming routines that enable firms not only to exploit existing resources but also to explore and realign when required. These capabilities are especially important in contexts characterised by high technological turbulence, competitive intensity and uncertainty (Teece, 2018).

In today's environment, achieving a sustainable competitive advantage through static (non-evolving) resource combinations is increasingly unattainable, as competitive advantage tends to migrate between organizations (McGrath, 2013). Firms capable of renewing their short-term advantages continuously are the ones most likely to sustain competitiveness over the long term (Teece et al., 1997). Alternatively, organizations may achieve lasting advantage by developing capabilities that are inimitable and cannot be easily replicated by competitors (Veresné Somosi, 2014).

The importance of dynamic capabilities thus lies in their role as the mechanism by which firms achieve and sustain competitive advantage in environments where traditional resource-based advantages erode quickly (Eisenhardt & Martin, 2000). In such turbulent settings, operational or static capabilities may ensure short-term performance, but they are insufficient for long-term adaptation; instead, higher-order dynamic capabilities provide the flexibility and foresight needed to reposition the firm (Schilke, Hu & Helfat, 2018). Moreover, dynamic capabilities have been linked empirically to improved performance, innovation, resilience and organizational renewal (Pulsiri & Vatananan-Thesenvitz, 2022).

Despite the growing attention to dynamic capabilities, much of the literature has focused on their deployment and impact, rather than their emergence and formation process. For example, while antecedents such as organisational learning, human capital, environmental dynamism and digital technologies have been identified (Barrales-Molina et al., 2013; Michaelis et al., 2022), fewer studies explore why and how these capabilities begin to develop—i.e., what triggers initiate the capability-building process. The "emergence" or initial formation of dynamic capabilities is often under-studied even though it is pivotal: without appropriate triggers, a firm may remain stuck in exploitation of existing routines rather than initiating renewal (Kay, 2018; Farkas, 2023).

In this context, investigating the triggers of dynamic capability development is critical. Triggers—such as external shocks, shifts in technology or customer demand, competitive threats, or regulatory discontinuities—create awareness of the need to adapt and thus stimulate the capability-building mechanisms (Donada et al., 2016). Understanding these triggers helps scholars and practitioners identify when and why firms embark on a path of dynamic capability formation, and under what conditions this process is likely to succeed.

The present study focuses on the formation of dynamic capabilities within four Hungarian start-ups, examining the specific patterns of triggers that led to the

development of their dynamic capabilities. This empirical focus is important because younger firms and high-growth start-ups often face more volatile environments and have fewer established routines, making the process of capability formation especially salient (Zahra et al., 2006; Farkas, 2023). The research question guiding this study is: *What patterns of triggers are associated with the emergence of dynamic capabilities in start-ups?*

The contribution of the article is two-fold. First, it extends the dynamic capabilities literature by focusing explicitly on the initiation phase—that is, how triggers set in motion the formation of dynamic capabilities rather than merely how they are deployed. Second, it offers new empirical insight to an under-represented context, thereby enhancing our understanding of dynamic capability formation in entrepreneurial and emerging-market settings.

The remainder of the article is structured as follows: Section 2 provides a theoretical overview of dynamic capability formation and triggers; Section 3 describes the methodology and case selection of the four Hungarian start-ups; Section 4 presents the empirical findings and identifies pattern types of triggers; and Section 5 discusses the implications, limitations and future research directions.

2. Theoretical overview of dynamic capability formation and triggers

While the dynamic capabilities framework has become central to strategic management research, much of the literature has traditionally emphasised their deployment and impact rather than their formation and evolution (Eisenhardt & Martin, 2000; Schilke, 2014; Teece, 2007). The formation of dynamic capabilities refers to the process by which firms develop higher-order routines that enable them to sense opportunities, seize them, and transform their resource base in response to environmental changes (Teece, 2007; Helfat & Peteraf, 2003). This process is inherently path-dependent, shaped by prior experience, learning mechanisms, and the organisational context in which routines evolve (Zollo & Winter, 2002; Schreyögg & Kliesch-Eberl, 2007).

A central stream of research conceptualises dynamic capability formation as an organisational learning process. Zollo and Winter (2002) describe capability evolution as the outcome of deliberate learning through three interrelated mechanisms: experience accumulation, knowledge articulation, and knowledge codification. Firms first accumulate operational experience, then articulate and codify that knowledge into replicable organisational routines (Zollo & Winter, 2002; Verona & Ravasi, 2003). This aligns with Teece's (2007) microfoundational approach, which locates the origins of dynamic capabilities in managerial cognition and collective learning. Eisenhardt and Martin (2000) and Schilke (2014) further argue that dynamic capabilities evolve through iterative experimentation, improvisation and feedback, gradually stabilising into higher-order processes that facilitate adaptation.

Recent scholarship has added a more granular understanding of how dynamic capabilities emerge across organisational levels. Salvato & Vassolo (2018) propose a

multi-level model explaining that dynamic capabilities arise through the interaction of micro-, meso- and macro-level mechanisms. At the micro level, individual employees integrate habit, cognition and emotion in their actions, which allows them to recognise the need or opportunity for change. At the meso level, these individual insights become connected through productive dialogue and relational engagement, enabling collective sense-making and coordination of change initiatives. Finally, at the macro level, such interactions coalesce into firm-level routines and patterns that constitute dynamic capabilities and enable systematic resource reconfiguration. This model thus portrays dynamic capability formation as a three-level emergent process—from individual integration, through interpersonal participation, to organisational embedding—clarifying how dynamic capabilities originate and take shape inside firms (Salvato & Vassolo, 2018).

From a developmental perspective, Helfat and Peteraf (2003) describe the capability lifecycle, illustrating how new capabilities are founded, developed, matured and sometimes decline. The early formation stage typically begins when firms recognise performance gaps or environmental shifts that necessitate new capabilities. Through experimentation and internal learning mechanisms, these nascent routines evolve, stabilise and eventually become institutionalised within the organisation (Helfat & Peteraf, 2003; Ambrosini & Bowman, 2009). However, over-embedded capabilities may later limit flexibility, requiring reactivation of adaptive learning cycles to sustain renewal (Schreyögg & Kliesch-Eberl, 2007).

Empirical studies support this processual view. Verona & Ravasi (2003) show how firms in product development contexts develop dynamic capabilities through iterative knowledge integration and reflective learning. Pavlou & El Sawy (2011) find that learning and knowledge reconfiguration routines mediate the relationship between environmental turbulence and organisational agility. Together, these studies confirm that dynamic capability formation is cumulative, recursive, and context-dependent—driven by the interplay of learning, cognition, emotion, and interaction across levels.

In sum, the formation of dynamic capabilities can be conceptualised as a recursive process encompassing awareness of change pressures, learning and knowledge transformation, and the embedding of new routines into organisational structures (Zollo & Winter, 2002; Teece, 2007; Salvato & Vassolo, 2018). It is not a one-time event but a continuous balancing act between reliability and renewal—between organisational memory and strategic adaptation. Understanding this formation process thus requires examining both its cognitive and social dimensions, as well as the temporal interplay between micro-level individual learning and macro-level organisational capability development.

2.1. Triggers of dynamic capability formation

The development of dynamic capabilities is rarely spontaneous; it is usually initiated by identifiable *triggers*—stimuli or events that disturb established routines and prompt organisations to reconfigure their resource base (Donada et al., 2016; Hart & Dowell, 2011; Schilke, Hu & Helfat, 2018; Zollo & Winter, 2002). Capability formation often

begins when firms perceive a misalignment between their current competences and changing environmental conditions (Pablo et al., 2007). In the absence of such stimuli, inertia and path dependence tend to preserve existing routines (Felin & Foss, 2005). Understanding what initiates capability development is therefore essential to explain why firms start to build dynamic capabilities rather than merely how they deploy them.

The literature typically differentiates between external and internal triggers. External triggers include market and technological shifts, regulatory or institutional change, and competitive turbulence that signal a need for adaptation (Narayanan, Colwell & Douglas, 2009; Donada et al., 2016). Internal triggers arise from within the firm, such as dissatisfaction with performance, strategic renewal initiatives, or learning outcomes that challenge existing routines (Zollo & Winter, 2002; Hart & Dowell, 2011). Other internal factors include the accumulation of new knowledge and information, or the emergence of novel organisational competences that open up possibilities for reconfiguration (Bergman, Jantunen & Saksela, 2004; Braganza et al., 2017). Donada et al. (2016) describe triggers as events or stimuli that initiate capability-building, while enablers—such as governance structures, relational assets, or knowledge codification routines—facilitate and sustain this process. In this article, the term trigger is used broadly to encompass both external and internal antecedents that set in motion the development of dynamic capabilities.

Once such a trigger occurs, organisations may react in several ways: some ignore or buffer the disturbance, others make short-term operational adjustments, while a smaller subset deliberately embark on capability-building processes (Zollo & Winter, 2002; Donada et al., 2016). In these cases, managerial decision-making plays a crucial role. Leaders interpret environmental signals and decide whether to allocate attention and resources toward capability development (Pablo et al., 2007). Even when the process is not consciously labelled as “building a dynamic capability,” managerial choices initiate a structured pattern of interaction and learning among employees that eventually becomes codified into a new organisational routine (Cepeda & Vera, 2007; Salvato & Vassolo, 2018).

Studying triggers of dynamic capability formation therefore provides a critical bridge between environmental dynamism and organisational adaptation. Triggers represent the *starting point* of the dynamic capability lifecycle: they ignite sense-making, motivate resource reconfiguration, and mobilise individuals toward collective learning and renewal. By recognising both external and internal triggers, researchers can better understand not only how dynamic capabilities operate, but also the contextual conditions that cause them to emerge in the first place.

3. Methodology

This study applies a qualitative, multiple case study design to explore the triggers that initiate the development of dynamic capabilities in early-stage ventures. Case studies are particularly appropriate when the boundaries between a phenomenon and its context are blurred, and when the research question asks how and why a process

unfolds (Yin, 2018). Given that capability formation processes are complex, context-dependent and path-specific (Zollo & Winter, 2002), a qualitative process approach enables a more nuanced understanding of their antecedents (Wilden et al., 2016).

3.1. Research design and sample

The empirical setting comprised four Hungarian start-up firms, each representing a different technological or service domain. Firms were anonymised and coded as P, Q, R, and S. Start-ups were chosen because they provide a particularly fertile ground for studying capability emergence—these organisations must continuously adapt to survive, and their founders and managers are typically still accessible for retrospective inquiry. The selected firms operated in artificial intelligence, software development, biotechnology, and sport-technology sectors. All cases were privately owned and based in Hungary.

3.2. Data Collection

Data were collected through semi-structured interviews and document analysis, allowing triangulation across multiple sources (Bingham et al., 2015). In total, 22 interviews were conducted with 12 key informants, including founders, CEOs, and senior team members. Each interview lasted between 60 and 120 minutes and was audio-recorded and transcribed verbatim. The interviews were guided by a protocol structured around three core themes:

organisational changes and decision-making episodes
the routines and processes involved in sensing, seizing, and transforming activities
(Teece, 2007), and
the triggers and actors associated with these changes.

Documentary data—including business plans, investor reports, internal process notes, and online materials—were also analysed to validate and enrich interview findings (Bowen, 2009). Where possible, preliminary results were validated through follow-up discussions or short workshops with participants in two of the cases.

3.3. Data analysis

The data were analysed using an iterative coding process inspired by Gioia et al. (2012) and Tabaklar et al. (2021). First, first-order codes were assigned to statements and events describing changes in routines, stimuli, or managerial interpretations. These were then aggregated into second-order themes representing categories of triggers (e.g., market, technological, strategic, relational). The analysis focused exclusively on identifying stimuli that initiated capability change and managerial responses to them, rather than modelling the full formation process. Within-case analyses were followed by a cross-case comparison to identify recurring trigger patterns and differences across contexts (Eisenhardt, 1989).

3.4. Research scope and limitations

The study's scope is intentionally narrow, concentrating only on the triggers of dynamic capability formation, not on the complete lifecycle of capability development. While the in-depth, context-rich case design allows detailed insight, the limited number of cases restricts generalisability (Yin, 2018). Moreover, retrospective data rely partly on participants' recollections, which may involve interpretive bias. Nevertheless, triangulation of interview and documentary evidence and validation sessions enhanced reliability and credibility (Langley, 1999).

4. Discussion

The empirical analysis is based on four in-depth case studies of Hungarian startups (coded as P, Q, R, and S). While each organisation exhibited its own path of dynamic capability formation, several recurring mechanisms were observed across cases. The following discussion highlights those patterns that appeared in multiple organisations, while findings specific to a single firm are used to illustrate particular mechanisms or contextual nuances. The goal of this section is therefore not to describe each case individually, but to synthesise the common trigger dynamics that underpin capability formation in early-stage ventures.

The analysis revealed several interconnected findings:

- Dynamic capability formation unfolded as a continuous process, with multiple triggers emerging throughout the lifecycle of the same capability.
- Different types of triggers—constraint-based, opportunity-based, and interpersonal—appeared repeatedly and often interacted with each other.
- Triggers frequently accumulated or overlapped, creating compound effects that intensified learning and adaptation.
- The managerial interpretation of events determined which stimuli were recognised as triggers and how they shaped subsequent actions.
- Finally, triggers were observed to reappear over time, producing temporal layering and reflexive adaptation across development phases.

The subsequent subsections elaborate on these findings in detail, showing how triggers emerged, interacted, and recurred within the formation of dynamic capabilities across the studied organisations.

4.1. Continuous triggers throughout the formation process

The analysis shows that in each organisation the dynamic capabilities evolved through multiple waves of triggering events. In other words, capability formation was not a series of unrelated changes, but a single, ongoing developmental process in which several distinct triggers successively influenced the same capability.

In firm P the development of a technological integration capability began as a reaction to a partner's unexpected software requirement. However, once this new process was introduced, subsequent triggers—such as internal dissatisfaction with the team's coordination and the onboarding of a new developer—led to further refinement of the same capability.

Across cases, managers described these sequences as a continuous capability under construction, in which each new trigger acted as another impulse of the same developmental trajectory. This finding underscores that triggers are not discrete starting points but continuous activating forces that sustain the momentum of a single capability's evolution. The iterative, cumulative triggering pattern extends previous conceptual models that viewed triggers as initial events at the onset of capability building.

4.2. Typology of triggers

The data revealed three overarching categories of triggers:

- (1) Constraint-based triggers, arising from dissatisfaction or resource scarcity;
- (2) Opportunity-based triggers, linked to environmental change or innovation possibilities; and
- (3) Interpersonal triggers, originating in social or cognitive shifts within the team.

In firm R, an acute shortage of time and workforce resources triggered the introduction of digital management tools, representing a constraint-based trigger. In contrast, in firm S, an unexpected partnership proposal from a foreign collaborator created opportunity-based triggers, initiating the renewal of the firm's capabilities.

An illustrative case of interpersonal triggering occurred in firm P, where the arrival of a new senior developer fundamentally challenged the existing workflow logic. The newcomer's proposal to restructure how code documentation and testing were managed initially met resistance, but later proved pivotal in transforming the team's technological capability. Similarly, in firm R, interpersonal friction between two managers led to an informal reflection on collaboration methods, which in turn generated a more explicit project governance routine. These examples demonstrate that interpersonal interactions—whether cooperative or conflictual—can act as powerful stimuli for dynamic capability refinement. These categories frequently interacted in practice, as discussed in the following section.

4.3. Interaction and accumulation of triggers

Another significant finding is that triggers rarely acted in isolation. In each case, several stimuli interacted, reinforcing one another or creating tensions that required further adaptation. In company Q, for instance, a market feedback loop coincided with the CEO's personal drive to "prove the product's value to investors," resulting in a dual-source trigger (external and internal) that accelerated development.

Such interaction effects confirm that dynamic capability formation is cumulative and recursive. New triggers emerge as responses to earlier ones—each iteration generates new tensions, knowledge, and routines that, in turn, set the stage for further change. This continuous feedback process mirrors the path-dependent learning mechanisms described by Zollo & Winter (2002), but extends them by highlighting the multiplicity and simultaneity of triggers in practice.

4.4. Managerial interpretation and activation

The empirical data also emphasise that not every stimulus becomes a trigger. Across all four cases, managerial interpretation played a decisive role in transforming an event into a meaningful source of action (Pablo et al., 2007; Rindova & Taylor, 2002). In company S, the arrival of a new team member introduced fresh perspectives that were initially resisted. Only after the founder reframed the newcomer's suggestions as strategic opportunities did the team begin integrating them into its capability set. These examples illustrate how triggers depend on interpretation and agency—what one actor perceives as noise may become another's catalyst for change. This finding reinforces that triggers are not objective occurrences but socially constructed through managerial sense-making (Donada et al., 2016; Weick, 1995).

4.5. Temporal layering of triggers

The study also observed temporal layering, where triggers from earlier stages re-emerged later in modified forms. For example, in firm P, early dissatisfaction with knowledge sharing led to new documentation routines. Months later, as the company scaled, similar concerns resurfaced, now linked to inter-team coordination rather than individual practice. Such reactivation of earlier triggers suggests that capability development is not only iterative but also reflexive: previously addressed issues can evolve into new forms of tension as organisational complexity increases.

This temporal recurrence challenges linear models of dynamic capability evolution (Helfat & Peteraf, 2003) and supports a cyclical perspective (Cyfert et al. 2021), where each resolution generates the conditions for the next phase of capability adaptation.

5. Limitations and future research directions

This study, while providing valuable insights into the triggers of dynamic capability formation in start-ups, is subject to several limitations. First, the empirical evidence was derived from four cases, representing a specific sample of small, young Hungarian ventures. As such, the results primarily reflect the characteristics of these organisations and their contexts, and should not be generalised beyond them (Yin, 2018). The qualitative and retrospective nature of the data, which relied on participants' narratives, may also introduce interpretive bias. Moreover, the research was not longitudinal, limiting the ability to capture how triggers evolve and interact over extended periods.

A further limitation lies in the organisational characteristics of the sample: the studied firms were small and relatively early in their development, which implies that their dynamic routines were still emerging. To ensure analytical clarity, activities that recurred at least twice were treated as routines—an approach suitable for start-up settings, but less applicable to mature firms with more institutionalised processes. Despite these limitations, the study provides a solid basis for future empirical and theoretical work on the triggers underlying dynamic capability formation.

Future research could expand this work in several directions. Comparative studies in different organisational contexts—for example, in established firms or other industries—could test the transferability of the identified trigger patterns. In addition, longitudinal or quantitative studies could capture how multiple triggers interact and evolve over time. Finally, action research focusing on how dynamic capabilities can be deliberately facilitated in practice may help translate theoretical insights into managerial interventions.

6. Conclusion

This study contributes to the understanding of how dynamic capabilities emerge by demonstrating that their formation is not triggered by a single event but by a sequence of multiple, overlapping stimuli. Through four start-up case studies, it reveals that triggers act as continuous, interacting forces that shape the same capability over time. This perspective extends existing models that treat triggers as antecedent events and instead portrays them as enduring elements embedded in the process of capability building.

From a theoretical standpoint, the research advances the dynamic capabilities literature by highlighting the multi-trigger and recursive nature of capability formation and by emphasising the role of managerial sense-making in activating and sustaining these processes. The findings suggest that triggers should be conceptualised not as discrete moments, but as part of an ongoing pattern of renewal.

Managerially, the results indicate that leaders should pay close attention to both external and internal stimuli that may act as triggers for change, even when these appear minor or incidental. Recognising and interpreting such signals early can help firms sustain learning and renewal without waiting for crisis conditions. Encouraging open dialogue, reflection, and experimentation can enhance an organisation's ability to turn everyday challenges into developmental opportunities.

Overall, this research underscores that dynamic capabilities are built through continuity rather than disruption—through the repeated interpretation and activation of triggers that drive learning, adaptation, and renewal over time. This process perspective offers a more dynamic understanding of how capabilities evolve within entrepreneurial settings.

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Exploring Financial Literacy in Business and Organizations: A Bibliometric Perspective

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Abstract

This study reviews empirical research on financial literacy in business and organizational contexts from 2000 to 2025. Analysis of 120 articles, with 35 examined in detail, shows that financial literacy connects individual capabilities with organizational outcomes. The main argument is that financial literacy bridges personal knowledge and business practices, driving organizational performance.

The literature is organized into several thematic clusters. Core research explores links between financial literacy, digital banking, and microenterprise management, emphasizing its role in informed decision-making. Other strands focus on financial education and professional training, especially in employee development, retirement planning, and accounting. Additional clusters connect financial literacy to innovation, SMEs, and financial inclusion, highlighting its role in business resilience. Studies also examine gender, employment, and insurance, stressing their importance for equality and empowerment at work.

Cross-country patterns further reveal contextual specificities. In developed economies, research emphasizes workplace financial education, retirement planning, and the link between executive financial literacy and organizational innovation, reflecting a focus on performance optimization and long-term security. In contrast, studies in emerging economies highlight financial literacy as a tool for empowerment, poverty reduction, and resilience in times of crisis, with particular emphasis on women, microentrepreneurs, and rural communities. This lack of similarities across regions suggests that while financial literacy is universally recognized as a driver of well-being and business performance, its application is shaped by economic maturity, cultural values, and social priorities.

Overall, the findings suggest that financial literacy research extends beyond individual financial well-being, evolving into a multidisciplinary field that integrates economics, management,

education, and social sciences. Future research directions include consolidating digital financial literacy in corporate practices, expanding comparative cross-country studies, and embedding financial education into sustainable and inclusive business models.

Keywords: Financial Literacy, Financial Inclusion, Digital Transformation, Workplace, Training

JEL Classification: G53, D14, O33, G51, J24

1. Introduction

Financial literacy has emerged as a critical competency in both developed and developing economies, shaping not only individual financial decision-making but also organizational performance and resilience. Despite global recognition of its importance, levels of financial literacy remain low across countries (Lusardi, 2015). Individuals are increasingly responsible for managing their own financial well-being. Financial illiteracy carries implications that extend beyond personal finances, influencing social inequality and economic stability. The proliferation of digital payment technologies and alternative financial services has further amplified disparities in access, knowledge, and capability (Lusardi, 2019).

In organizational contexts, financial literacy plays a central role in improving decision-making, influencing financial behavior, and promoting long-term stability. Effective financial education programs that are tailored to the specific needs of employees and managers have been shown to enhance retirement planning, savings behavior, and investment decisions (Kadoya & Khan, 2018). Regular and active learning methods, such as short instructional videos or interactive workshops, often produce positive results in workplace environments. However, empirical evaluations of these interventions remain limited, particularly those conducted exclusively within organizational settings or focused on small and medium-sized enterprises (SMEs).

Recent systematic and bibliometric reviews (Goyal & Kumar, 2021; García & Pérez-Oleaga, 2025) indicate that, although financial literacy has been widely examined in educational and household contexts, empirical evidence within business and organizational environments is still scarce. These reviews highlight that the duration of financial training programs has little effect on outcomes. Instead, effectiveness depends on methodological quality and the use of diverse instructional approaches, including active learning techniques. Nevertheless, resource constraints, institutional inertia, and participant heterogeneity continue to pose challenges to the adoption of more dynamic and adaptive financial education strategies in organizations.

A deeper understanding of how financial literacy operates within organizational settings and shapes managerial practices, workforce behavior, and institutional performance represents a critical but still insufficiently examined dimension of financial research. Supporting empirical inquiry in this field can help bridge the gap between individual capability and institutional outcomes, contributing to more sustainable and inclusive financial practices in the workplace. Based on bibliometric

analysis, this study conducted a quantitative analysis of the literature on financial literacy in enterprises from 2000 to 2025 to reveal the current research status and development trend of financial literacy in organizations. The main contributions of the study include:

- 1) Provide a concise overview of the current empirical research on financial literacy in organizational contexts, evaluating the progress achieved in its application. This synthesis offers a valuable reference for advancing both academic inquiry and practical implementation of financial literacy initiatives in enterprises.
- 2) Using Bibliometrix and VOSviewer software, the study maps and visualizes publication trends, revealing the collaborative networks among leading research groups, including their geographical distribution, institutional affiliations, and patterns of international co-authorship.
- 3) Through keyword co-occurrence and cluster analysis, the study identifies key thematic areas, research priorities, and knowledge gaps in the field from 2000 to 2025, emphasizing current limitations and suggesting directions for future research on financial literacy development, training evaluation, and organizational learning.

2. Methodology

2.1. Data Collection

The Scopus database, a comprehensive global academic repository, was used as the primary data source for this study. Scopus provides extensive bibliometric information, including article titles, authors, institutional affiliations, countries, publication years, funding details, and keywords. The data retrieval covered the period from 2000 to 2025, and the search was conducted on August 18, 2025. The search strategy specifically targeted publications containing the following terms in their titles, abstracts, or keywords:

(("Financial literacy" OR "Financial capability" OR "Financial inclusion" OR "Financial well-being" OR "Financial education") AND ("Business Context" OR "Corporate" OR "Workplace" OR "Enterprise" OR "Organizational") AND ("Training" OR "Professional development" OR "Employee training" OR "Managerial training" OR "Staff training" OR "Capacity building" OR "Upskilling" OR "Financial training" OR "On-the-job training" OR "Executive education") AND ("Empirical study" OR "Quantitative" OR "Quasi-experiment" OR "Randomized controlled trial" OR "RCT" OR "Survey data" OR "Data analysis")).

Applying these search criteria yielded a total of 120 documents. The selection was limited to the following parameters:

Document type: Article

Subject areas: Economics, Econometrics and Finance; Business, Management and Accounting

Language: English

Source type: Journal

Time range: 2000 -2025

An accurate screening process was then undertaken to remove duplicates and irrelevant records, resulting in a final dataset of 35 valid research articles published between 2000 and 2025. The bibliometric analysis was performed using Bibliometrix (Aria & Cuccurullo, 2017) and VOSviewer (van Eck & Waltman, 2010).

2.2. *Visualization and Scientometric Analysis*

The primary objective of this study is to evaluate empirical research on financial education conducted within enterprise contexts, examining the evolution of these studies and identifying key themes in organizational settings. The analytical process involved the cooperation network maps of countries, institutions, and authors to visualize the global distribution and collaboration patterns of research groups in this domain. Then, a keyword co-occurrence analysis was conducted to provide a quantitative foundation for understanding research trends and thematic frontiers.

The overall technical framework of the study is presented in Figure 1. After selecting the keywords, a total of 120 empirical studies were identified. Following a thorough analysis and screening process, only those studies that were conducted in organizational settings were retained.

Quantitative analyses were carried out using the Bibliometrix package (R-based scientometric tool) to examine publication performance indicators, including annual publication trends, geographical and institutional contributions, author productivity, and high-frequency keyword distributions. The VOSviewer software was employed to construct and visualize the co-occurrence network of keywords, facilitating the identification of current research clusters, thematic structures, and potential future research directions.

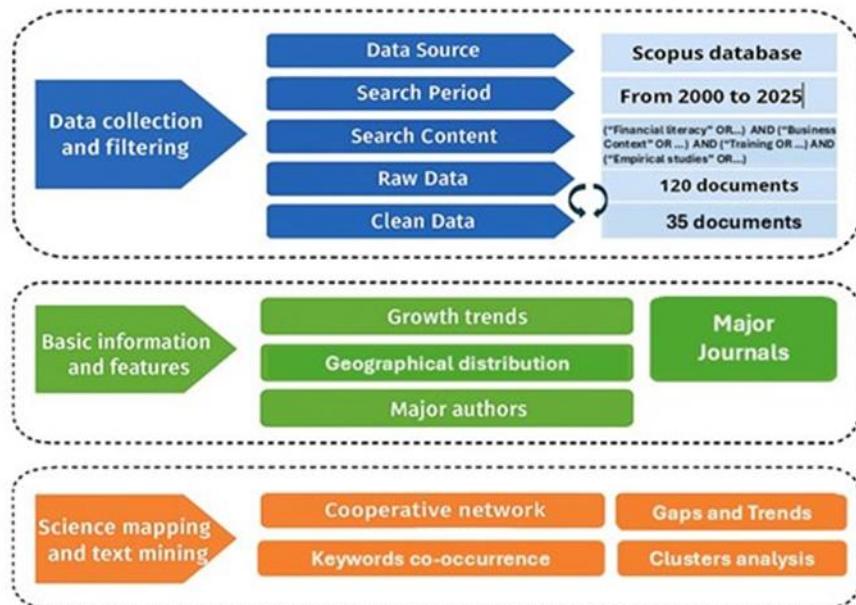


Figure 1. Flow Chart of Bibliometric Analysis

3. Results

3.1. Annual trends in publications

The publications were organized in Table 1 according to the authors, year of publication, journal, quartile ranking, h-index, and number of citations, as reported in the Scopus database. Data were obtained from the Scimago Journal & Country Rank (2025), which classifies journals into quartiles based on citation performance. The quartile ranking indicates the relative position of each journal within its field based on the distribution of impact factors, while the h-index represents a measure of both productivity and citation impact of the academic output authors. In addition to bibliometric indicators, further information was compiled on collaboration networks and the geographical distribution of research activity, allowing for a more comprehensive understanding of how academic partnerships and regional contexts influence the production of knowledge.

The descriptive analysis of the dataset demonstrates a notable annual growth rate of 12.2%, indicating increasing scholarly interest over time. The documents included in the sample have an average age of 3.92 years and receive, on average, 15.45

citations each, suggesting that the body of research is relatively recent yet steadily influential. With regard to the content of the dataset, it has been determined that there are 86 Keywords Plus and 225 author-provided keywords, which collectively reflect a diverse thematic structure. The authorship profile includes 296 contributing authors, 9.32 co-authors per article, and an international co-authorship rate of 15.79%. The classification of all documents in the dataset as articles serves to reinforce the empirical and peer-reviewed nature of the research landscape.

Table 1. Overview of Empirical Studies on Financial Literacy in Enterprises

Author	Year	Journal	Quartile	H-index	Citation /Scopus	Country	Sample
Zuhroh et al.	2025	<i>Journal of Open Innovation: Technology, Market, and Complexity</i>	Q1	63	5	Indonesia	234
Brimble et al.	2025	<i>Accounting and Finance</i>	Q2	70	0	Australia	592
Urmila et al.	2025	<i>Industrial and Commercial Training</i>	Q2	45	1	India	18
Rai et al.	2025	<i>International Journal of Law and Management</i>	Q3	36	3	India	719
Quarshie et al.	2025	<i>Quality & Quantity</i>	Q1	85	1	Ghana	350
Charisma et al.	2025	<i>Sustainability</i>	Q1	207	1	Indonesia	125
Peter et al.	2025	<i>Journal of the International Council for Small Business</i>	Q3	12	8	India	216
Rosso et al.	2024	<i>Human Resource Management Review</i>	Q1	132	4	Spain	136
Francisco	2024	<i>Cogent Business & Management</i>	Q2	56	0	Portugal	208
Sherwani et al.	2024	<i>Arab Gulf Journal of Scientific Research</i>	Q3	16	14	India	321
Karpacz & Wojcik-Karpacz	2024	<i>Central European Management Journal</i>	Q2	15	5	Poland	182

Ogundare et al.	2024	<i>Southern African Journal of Entrepreneurship and Small Business Management</i>	Q4	8	0	Nigeria	175
Goyal et al.	2024	<i>Global Business and Organizational Excellence</i>	Q1	32	5	India	132
Grobbelaar & Alsemgeest	2024	<i>Adult Learning</i>	Q2	27	1	South Africa	90
Rohatgi & Gera	2024	<i>International Journal of Bank Marketing</i>	Q1	113	0	India	482
Akinwale et al.	2024	<i>International Journal of Organizational Analysis</i>	Q2	47	2	Nigeria	644
Kumari et al.	2024	<i>Small Enterprises Development, Management & Extension Journal</i>	Q4	7	8	India	302
Rohatgi et al.	2024	<i>Journal of Management & Governance</i>	Q1	65	4	India	286
Rohatgi et al.	2023	<i>Gender in Management</i>	Q1	71	5	India	286
Kamaliah et al.	2023	<i>Cogent Business & Management</i>	Q2	56	1	Indonesia	150
Horani, Omar Mohammed Khatibi et al.	2023	<i>Interdisciplinary Journal of Information, Knowledge, and Management</i>	Q3	32	22	Jordan	307
Billari et al.	2023	<i>Journal of Banking & Finance</i>	Q1	211	11	Italy	1436
Arifin et al.	2022	<i>Economic Annals-XXI</i>	Q3	22	2	Indonesia	156
Munyuki & Jonah	2022	<i>Journal of Entrepreneurship in Emerging Economies</i>	Q1	41	26	South Africa	Case studies
Toth et al.	2022	<i>Risks</i>	Q2	38	21	Hungary	2.167 /3281

García-Pérez-de-Lema et al.	2021	<i>Technology in Society</i>	Q1	112	65	Spain	310
Buchdadi et al.	2020	<i>Academy of Accounting and Financial Studies Journal</i>	Q4	23	34	Indonesia	70
Purnamawati & Yuniarta	2020	<i>Management Science Letters</i>	Q4	43	14	Indonesia	246
Toosi et al.	2020	<i>Journal of Social Issues</i>	Q1	153	14	India, Bangladesh & Myanmar	1085/429
Eniola & Entebang	2017	<i>Global Business Review</i>	Q2	52	125	Nigeria	250
Frey et al.	2015	<i>Journal of Social Work Education</i>	Q2	68	16	USA	37
Seligman & Bose	2012	<i>Quarterly Review of Economics and Finance</i>	Q2	71	2	USA	11.191
Oehler & Werner	2008	<i>Journal of Consumer Policy</i>	Q2	63	47	Germany & UK	Case studies
Joo & Grable	2005	<i>Journal of Financial Counseling and Planning</i>	Q2	55	59	USA	751
Bernheim & Garrett	2003	<i>Journal of Public Economics</i>	Q1	184	368	USA	Case studies

Empirical research on financial literacy training within corporate contexts has gained notable prominence since 2019 and has grown in subsequent years. Increased academic interest in the subject and in the role that financial literacy plays in promoting sustainable economic behavior among employees has been observed. Among the most cited works, Bernheim & Garrett (2003), published in the *Journal of Public Economics* stand out for their contribution to workplace financial education and savings behavior. Subsequent research, such as Eniola & Entebang (2017) in the *Global Business Review* and García-Pérez-de-Lema et al. (2021) in *Technology in Society*, further expanded the discussion toward financial literacy in SMEs and innovation-driven contexts. Studies by Joo & Grable (2005) and Oehler & Werner (2008) also contributed to understanding financial behavior, counseling, and consumer policy. The most frequently cited studies are listed in Table 2.

Table 1. Most cited documents and Authors

Authors	Year	Journal	Citations
Bernheim & Garrett	2003	<i>Journal of Public Economics</i>	368
Eniola & Entebang	2017	<i>Global Business Review</i>	125
García-Pérez-de-Lema, Ruiz-Palomo, and Diéguez-Soto	2021	<i>Technology in Society</i>	65
Joo & Grable	2005	<i>Journal of Financial Counseling and Planning</i>	59
Oehler & Werner	2008	<i>Journal of Consumer Policy</i>	47

More recent publications continue to reinforce and diversify the impact on the field. Billari et al., (2023) in the Journal of Banking & Finance, present experimental evidence of the effects of financial and demographic education among workers, highlighting how structured training enhances retirement planning and long-term financial well-being. Charisma et al. (2025) in Sustainability explores the intersection of financial literacy and sustainable entrepreneurship, emphasizing the role of education in promoting environmentally responsible financial decisions. Rosso et al. (2024) in the Human Resource Management Review, examine the integration of financial literacy into human capital development strategies, showing its impact on employee performance and organizational commitment. Rohatgi & Gera (2025) in the International Journal of Bank Marketing, investigate the behavioral determinants of digital financial adoption, demonstrating how literacy mediates trust and engagement in financial technologies. Toosi et al. (2020) in the Journal of Social Issues broaden the debate by linking financial capability to social inclusion and well-being, underscoring the social dimensions of financial education

The journals with the highest academic reputation, including the Journal of Banking & Finance, Sustainability, and the Journal of Public Economics, all ranked in Q1 with H-index values above 100, confirm the field's interdisciplinary reach and growing methodological rigor. Leading universities such as Stanford University, Bocconi University, and the University of Oxford appear as central hubs of intellectual production, emphasizing quantitative rigor and policy relevance. Complementary research networks at the University of Málaga, Kansas State University, and the University of Georgia reinforce the applied dimension of financial literacy, particularly in human resource management and financial counseling. European institutions, such as the Toulouse School of Economics and the University of Essex, also play a significant role in advancing behavioral finance and economic education. Collectively, these results demonstrate that the empirical research of financial literacy has evolved from individual-level analysis to an institutionalized research domain, anchored in internationally recognized journals and supported by universities with strong research traditions. Table 3 identifies the leading journals in the field, ranked by publication volume, H-index, and citation impact.

Table 2. Top Journals by Citation Impact and Ranking Indicators

Journal	Quartile	H-index
Journal of Banking & Finance	Q1	211
Sustainability	Q1	207
Journal of Public Economics	Q1	184
Human Resource Management Review	Q1	132
Technology in Society	Q1	112
International Journal of Bank Marketing	Q1	113
Journal of Social Issues	Q1	153

The three-field plot clarifies the relationships among authors' countries (AU_CO), source journals (SO), and affiliated universities (AU_UN) as demonstrated in Figure 2. It highlights the distribution of scholarly production across geographic, editorial, and institutional domains.

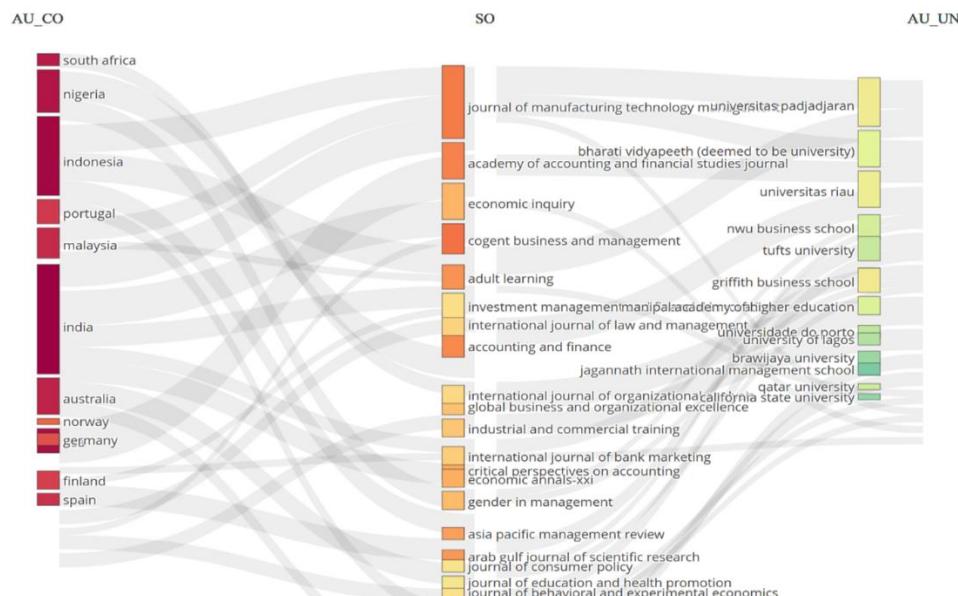


Figure 2. Three-field Plot Connection among Countries, Journals, and Institutions.

The visualization in Figure 2, reveals clusters in which countries such as India, Indonesia, and South Africa are strongly linked to various journals, indicating broad thematic engagement and dispersed publication. These journals, in turn, are affiliated with various universities, indicating a decentralized pattern of institutional

contributions to the field. The density and strength of the connections demonstrate that certain countries are prominent in the network, contributing substantially to publications across multiple outlets and institutions. Overall, the plot emphasizes the international and multi-institutional nature of the research landscape. It shows how academic output flows from specific national contexts through selected publication venues to a wide range of universities.

3.2 Geographical distribution

The number of empirical studies conducted, and their frequency of citation, reflect a country's overall research capacity and scientific influence. Between 2000 and 2025, 19 countries on five continents conducted studies on this topic. Figure 3 analyzes research collaboration among these countries. It illustrates the participation of different economies in the field, along with their connections. The network highlights both the geographical diversity of contributors and the strength of cross-national partnerships. Clusters of countries that frequently collaborate and influence the development of the field are revealed.

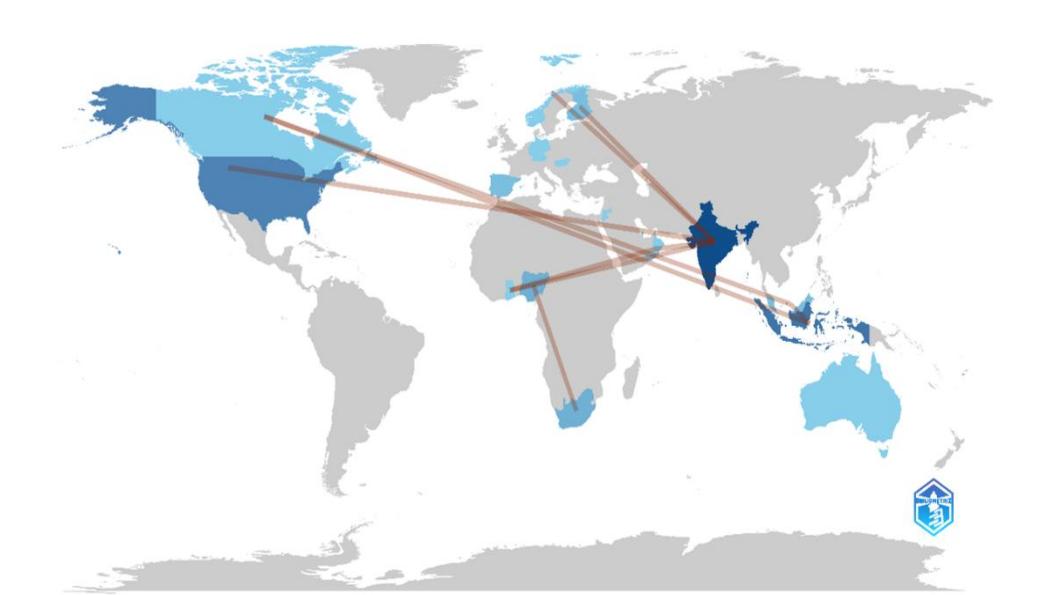


Figure 3. Country Collaboration Map of Cross-National Research Partnerships

The top five countries in terms of publication output were analyzed. Figure 4 illustrates the contributions of the United States, India, Indonesia, Nigeria, and South Africa, which represent the most productive nations in this field. The United States

demonstrates the highest frequency and performance in terms of citations, with over 500 citations among the analyzed studies. Moreover, the USA shows a consistent upward trend in publication development over the years.

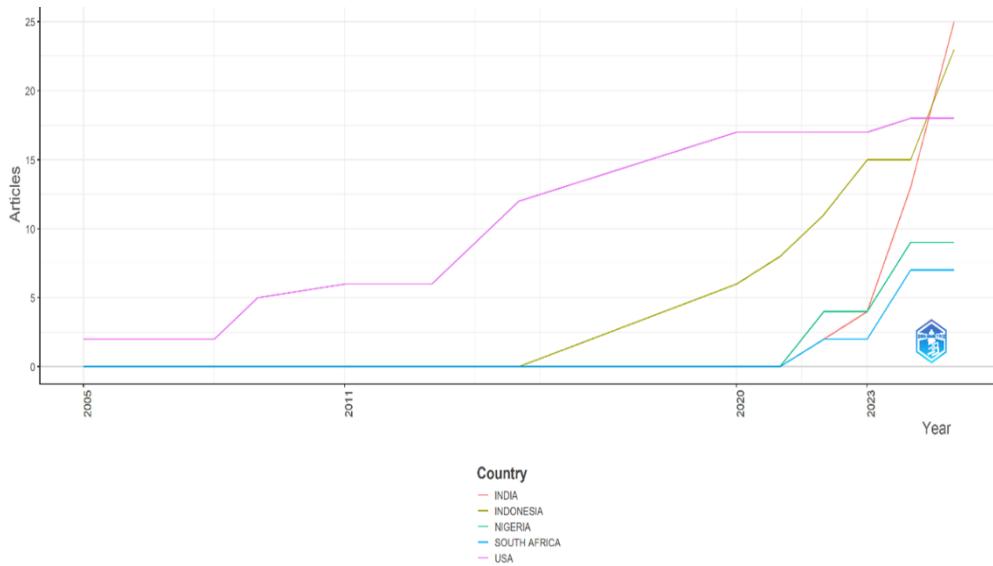


Figure 4. Top 5 Countries by Number of Empirical Studies on Financial Literacy in Organizations

We can highlight that in low- and middle-income economies, particularly in Asia and Africa, financial literacy is directly associated with economic stability, reduced vulnerability, and social empowerment. Initiatives focused on empowering women entrepreneurs in India and Indonesia stand out, reflecting priorities of inclusion and financial capacity building for women, rural entrepreneurs, and microbusiness owners (Purnamawati & Yuniarta, 2020; Sherwani et al., 2024).

Inclusive policy concerns are also evident, such as in a study conducted in Ghana on financial literacy training for managers with disabilities (Quarshie et al., 2025) and in Nigeria, where research indicates that financial well-being has a positive effect on quality of work life (Akinwale et al., 2024). In South Africa, financial literacy among young entrepreneurs increases business success. Overall, there is a broader focus on informal entrepreneurs, aiming to build their capacity and promote their inclusion through inclusive policies, particularly for women. Moreover, workplace financial literacy programs are linked to reduced stress and greater job satisfaction.

In contrast, studies in high-income economies such as the United States, Europe, and Australia show that financial literacy is more closely connected to organizational performance, retirement planning, innovation, and support for minority groups. In these contexts, the emphasis moves from essential inclusion to the enhancement of existing financial competencies and stimulating retirement plans. In the United States, studies show that workplace financial education is associated with higher savings rates

(Bernheim & Garrett, 2003; Joo & Grable, 2005). There is also a greater emphasis on training evaluation and employer-based financial education programs (Frey et al., 2015).

In Spain, researchers found that the financial literacy of CEOs directly influences the technological innovation of companies (García-Pérez-de-Lema et al., 2021). Studies in Portugal and Poland also show a strong connection between the financial literacy of managers and company performance (Francisco, 2024; Karpacz & Wojcik-Karpacz, 2024). García and Pérez-Oleaga (2025) note that gains in financial literacy often remain short-term and fail without ongoing reinforcement. Digital innovation and monetary incentives show limited impact, which highlights the importance of sustainable strategies to secure lasting results.

3.3 Key words Cluster analysis

The bibliometric analysis, conducted through keyword co-occurrence mapping, allowed the identification of five main clusters that structure the empirical literature on financial literacy within business and organizational contexts (Figure 5). These clusters represent distinct, nevertheless interconnected research domains, reflecting how financial literacy operates across individual, organizational, and social dimensions.

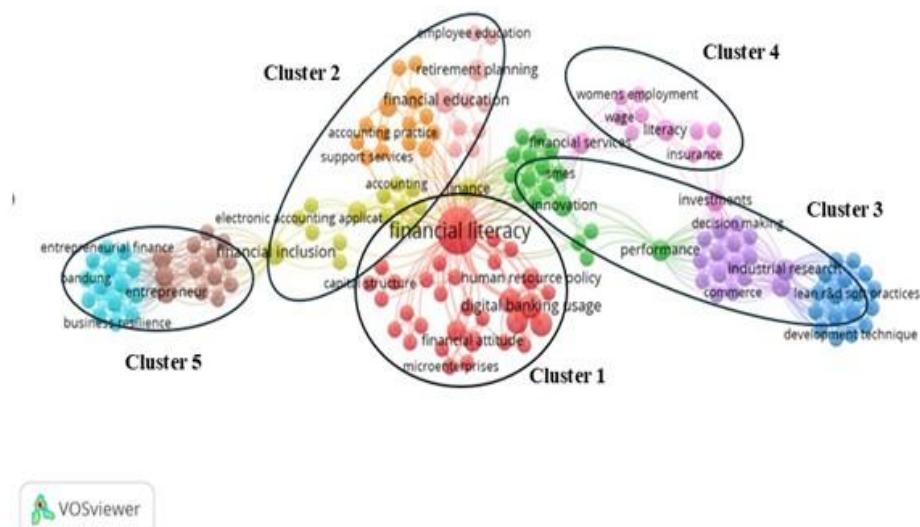


Figure 5. Network Visualization of Keywords Co-occurrence in Financial Literacy in Organizations

The first group in cluster 1 gathers the most cited and influential studies, emphasizing the connection between financial literacy, digital financial tools, and the financial attitudes of individuals. These investigations explore how digital accessibility,

financial behavior, and training initiatives for micro-entrepreneurs strengthen financial decision-making within organizations. They also point to the strategic role of human resource policies in encouraging workplace financial education as a means of improving performance and fostering inclusive financial practices. Another line of research concentrates on financial literacy in education and professional development, which is evidenced in cluster 2. Scholars in this group focus on financial training in organizational settings, particularly its influence on retirement planning, employee skill enhancement, and financial inclusion across social groups. These studies underscore how continuous financial learning supports personal empowerment while contributing to organizational sustainability.

A third area on cluster 3 connects financial literacy to innovation and technological development. Studies in this group analyze how financial competence promotes better investment decisions, facilitates innovation in financial services, and improves management practices, especially among SMEs. These findings suggest that financially literate managers are more capable of leveraging innovation to strengthen competitiveness. Research showing gender and social empowerment forms another significant dimension of the literature, analyzed in cluster 4. Investigations emphasize how women's access to financial knowledge enhances confidence, autonomy, and participation in entrepreneurship. They also consider the influence of age, employment security, and social protection, showing how these variables influence financial behavior and inclusion. In cluster 5, a substantial body of work examines the role of financial literacy in entrepreneurial success. The evidence consistently indicates that entrepreneurs with higher levels of financial understanding are better equipped to make informed decisions, manage risks, and achieve sustainable business growth. Financial literacy thus emerges as a crucial determinant of entrepreneurial resilience and long-term competitiveness.

Overall, the five clusters reflect the progressive evolution of financial literacy research. Over time, the field has expanded its analytical scope, integrating diverse perspectives from human resource management, entrepreneurship, digital finance, and gender studies. This multidimensional perspective positions financial literacy as a central construct that bridges individual competence, organizational performance, and social well-being, emphasizing its strategic relevance for practice and policy in organizational settings.

4. Conclusion, limitations, and future research

Through comprehensive analysis and graphical representation of data obtained from Scopus, significant findings include the average annual frequency of paper citations, geographical distribution, influential authors and journals, most cited

publications and development trends. The analysis of publication impact further supports these findings. Highly cited works such as Bernheim & Garrett (2003) in *Journal of Public Economics* and Joo & Grable (2005) in *Journal of Financial Counseling and Planning* established conceptual foundations for workplace financial education and savings behavior. More recent studies, including García-Pérez-de-Lema et al. (2021) in *Technology in Society*, extend this discussion toward technological innovation and managerial performance, while Eniola & Entebang (2017) and Oehler & Werner (2008) contribute to understanding the link between financial literacy, entrepreneurship, and consumer policy. These key studies represent some of the most recognized contributions in the field, illustrating how financial literacy research has expanded through applied investigations across diverse contexts and regions. Together, they reflect the growing body of empirical and practice-oriented studies conducted within organizational and business settings.

Geographically, the United States leads in publication volume and citation impact, reflecting its consolidated research tradition in workplace financial education. India and Indonesia follow, driven by studies emphasizing entrepreneurship and women's empowerment. In Africa, particularly in Nigeria, Ghana, and South Africa, research highlights the role of financial literacy in social inclusion, small business growth, and youth entrepreneurship. Meanwhile, several studies from Europe explore organizational and policy perspectives, linking financial literacy to innovation, retirement planning, and minority inclusion. These regional trends collectively reveal an increasing concern with gender equity and the financial empowerment of vulnerable groups, underscoring financial literacy as both an economic and social development tool.

The co-occurrence network of keywords, analyzed through VOSviewer and Bibliometrix, shows that the current state of research predominantly focuses on the connections between financial literacy, entrepreneurship, human resource management, innovation, and financial inclusion. These thematic intersections demonstrate the growing recognition of financial literacy as a strategic capability that enhances decision-making, work-life balance, and sustainable performance. They also reflect a broader concern with public policies that promote financial education among minority groups, women, and individuals with disabilities. At the same time, the literature emphasizes the need for inclusive and accessible financial training for marginalized populations, such as rural entrepreneurs and indigenous business owners. Another important aspect involves the development of financial literacy programs within organizations, aimed at planning retirement and at reducing financial stress, which remains a major factor affecting overall employee well-being and productivity.

Promising lines of future research include examining how emerging technologies can further enhance financial literacy initiatives within organizational settings. In particular, studies could explore the effectiveness of increasingly sophisticated gamified learning environments and interactive applications in promoting sustained engagement and personalized learning pathways. Another important avenue involves investigating how financial education programs can be designed to remain fully accessible to employees of varied socioeconomic backgrounds, ensuring equitable learning opportunities. Additionally, future research should focus on developing robust methodologies to track not only knowledge acquisition but also long-term behavioral changes and measurable financial outcomes. Such investigations would provide deeper insight into the mechanisms through which innovative, technology-driven financial education can contribute to improved financial well-being and organizational performance.

This study presents certain limitations. The analysis was conducted exclusively on the Scopus database. As a result, some relevant publications may have been excluded. Future bibliometric research should integrate multiple databases such as WOS, Google Scholar, Dimensions, and PubMed, and consider full-text analyses to ensure broader coverage and stronger theoretical support.

However, the growing body of work, the field still lacks sufficient empirical evidence on financial literacy within organizational environments. This study provides a quantitative foundation that is exclusively composed of empirical research, thereby establishing a basis for future meta-analytical studies, particularly if key variables are isolated and standardized across investigations. Additionally, the geographic analysis and co-occurrence mapping conducted in this study contribute valuable insights into prevailing trends and thematic gaps in the literature. Collectively, these analytical dimensions not only deepen the understanding of the current research landscape but also guide scholars toward emerging and underexplored areas that merit further investigation. Future studies should prioritize the development of more robust reviews, enabling comparative analyses, meta-analytical approaches, and longitudinal investigations that can strengthen both theoretical understanding and practical application.

Acknowledgements

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Zero-Waste, Zero Loss? An Econometric Test of Sustainable Packaging's Bottom Line

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Abstract

Sustainability, an imperative that is often confused to be a buzz word, is in fact a critical driver of long-term economic resilience, environmental stewardship and social equity. Utilizing econometric models, this research draws upon different analyses of results from a survey conducted under the ongoing EU-funded PRIMA project, EVOLVEPACK, which employs the triple bottom line framework through social and economic assessments of companies that produce sustainable food packaging. Combining a gender-based study with a cost/revenue one not only allows industry experts to look into adopting sustainable packaging but also inspires the academic world to explore the intersection of sustainability, economic viability as well as social inclusivity in packaging innovation. Thus, providing a holistic understanding of how the adoption of sustainable packaging impacts businesses across different dimensions—financial performance, environmental benefits, and gender-inclusive workforce dynamics. The findings' sole purpose is to bridge the existing gap between industry practices and academic research, proposing actionable insights for policymakers, corporate leaders, in addition to sustainability advocates seeking to balance profitability with planetary and social well-being.

Keywords: Sustainability, Packaging, Profitability, Life Cycle Costing, LCA.

JEL Classification: C50, C54, Q50, Q56, O32

1. Introduction

Econometrics, also known as the crossover of mathematics and statistics applied to economic theory (Gujarati & Porter, 2009), provides the rigorous framework to move forward and beyond theoretical assumptions and into the realm of quantifiable, causal and impactful insight. This research leverages this power to address a critical gap in the sustainable packaging sector; that of the lack of dynamic and accessible tools for holistic assessment. While Life Cycle Costing (LCC) and Social-Life Cycle Assessment (S-LCA) are recognized as vital for a complete sustainability picture, their traditional application is often static and complex.

This paper presents a novel methodology developed under the EU-funded PRIMA project, EVOLVEPACK, introducing two dedicated econometric models for real-time analysis. The first being an LCC model, designed to quantify the total economic and financial burden (costs) of packaging systems, from raw material costs to those related to end-of-life management. The second is an S-LCA model developed to evaluate a company's employability equity across the packaging value chain. The innovation of this research lies not only in these models alone but in their deployment. Through an engineered WordPress platform, data collected from a trans-Mediterranean survey is automatically fed into the pre-calibrated models, thus applying pre-estimated regression coefficients (β) to generate continuous, real-time results.

The objective of this integrated system has always been to bridge the chasm between static academic models and the dynamic needs of industry, policy as well as the environment. By providing a tool for live, comparative trans-Mediterranean analysis, this research empowers policymakers, corporate leaders and advocates alike, with both immediate and actionable insights. Its primary goal is to demonstrate that the true bottom line of sustainable packaging—encompassing cost, equity and environmental stewardship—can be measured not as a retrospective snapshot, but as a living, evolving dashboard for informed decision-making.

The research at hand reviews the literature behind the field of sustainable packaging's LCA assessments, specifically those in relation with LCC analyses and S-LCAs alike, presents and demonstrates the methodology as well as the two models, and finally presents a simulation of the models in addition to a suggested path forward.

2. Literature Review

From the literary point of view, the journey of sustainable packaging is one of expanding scope and deepening understanding. Its initial phase, dominant until the late 1990s, was characterized by a linear, end-of-pipe focus primarily on recyclability. In this paradigm, the environmental virtue of a package was nearly singularly judged

by its potential for post-consumer material recovery. This approach was successful in raising public awareness and establishing collection infrastructures, but it was also inherently limited. It risked "burden shifting", where optimizing for recyclability could lead to either increased energy consumption in production or the use of harmful additives, thereby solving one problem while exacerbating others (Guinée et al. 2011).

This recognition spurred quite the critical evolution toward a holistic life-cycle perspective. The field now operates on the fundamental principle that true sustainability must be assessed from raw material extraction (else known as "cradle") to end-of-life management ("grave" or back to "cradle"). This life-cycle or systems-thinking approach, which was formalized in Life Cycle Assessment (LCA) methodologies, evaluates a suite of environmental impacts; including carbon footprint, water usage as well as ecotoxicity, across all stages: sourcing, manufacturing, transport, use and disposal (Verghese et al., 2015).

This holistic environmental perspective naturally aligns with the Triple Bottom Line (TBL) framework, which posits that corporate performance should be measured through three interconnected lenses: Profit, Planet and People (Elkington, 1997). The TBL provides an extremely vital structure for moving beyond a purely ecological definition of sustainability into a more realistic one.

In packaging, however, this translates clearly:

- Profit involves analyzing the full economic / financial costs and benefits, from material sourcing or procurement and production efficiency to potential market advantages and brand value.
- Planet is addressed through the comprehensive life-cycle approach described above, which puts sustainability at the forefront, and rightfully so.
- People, the most nascent and complex pillar, encompasses both social and ethical dimensions, including consumer safety, community impact in addition to labor conditions throughout the value chain.

While the business case for the integration Planet and Profit has been increasingly documented, linking sustainability to efficiency and long-term resilience (Eccles et al., 2014), the People dimension has remained notably underdeveloped, often treated as a qualitative afterthought rather than a source of quantitative value.

Within the same pillar, People, of the TBL, one of the most potent yet overlooked metrics is gender equity. If we take the manufacturing and technology sectors for instances, their underpinning packaging innovation have historically displayed significant gender imbalances. However, a compelling body of research now indicates that gender-diverse teams are not merely an ethical imperative but a strategic one. They are statistically linked to enhanced innovation, with companies reporting up to 38% more revenue from new products and services when management diversity is above average (Dezsö & Ross, 2012; Lorenzo et al., 2017). This innovation boost is also

coupled with superior financial performance, including higher returns on assets and investments (Gomez & Bernet, 2019; Erhardt et al., 2003).

What is said above presents a critical and underexplored synergy. Companies that possess the strategic foresight to implement complex life-cycle analyses for environmental stewardship may also be more likely to cultivate inclusive cultures that leverage a diverse talent pool. The cognitive diversity inherent in a gender-balanced workforce, which, statistically, enhances creativity and improves risk assessment for complex problems (Crisp & Turner, 2011; Miller & Triana, 2009), is precisely the asset that is much needed to tackle the wicked problems of sustainable packaging design. Yet, this potential linkage remains largely theoretical, with the clear evidence for gender equity as a performance driver often residing in separate academic and operational silos from the environmental dimensions of sustainability.

This review of literature culminates in a clear and important gap. While the conceptual frameworks of life-cycle thinking and the TBL are well-established, their practical integration is fragmented. There is a conspicuous lack of quantitative, econometric research that simultaneously analyzes the interrelationships between the three pillars. Specifically, the field lacks models that can:

- Quantify the total economic cost (LCC) alongside economic impact.
- Integrate a measurable social variable, namely gender equity in employability (S-LCA), into this analysis.
- Empirically test the correlations and potential causalities between these dimensions.

Most studies address these elements in isolation, relying on case studies or descriptive statistics. The promise of the TBL, hereby, remains unfulfilled without a unified methodology capable of demonstrating, with statistical rigor, how investments in sustainable packaging correlate with both financial viability and social equity. This study aims to fill this void by developing and applying such an integrated econometric model.

While reviews such as Chitaga and Goga (2023) provide an invaluable map of the environmental LCA landscape, they simultaneously illuminate the uncharted territories by highlighting a consistent theme: the underdevelopment of the social dimension and the lack of integration with solid economic metrics. The authors confirm that social indicators are hardly ever operationalized in practice, a gap that aligns perfectly with the one identified in the present paper; the absence of integrated, econometric studies that analyze the Triple Bottom Line in unison. Where the same paper aforementioned detail the methodological struggle to quantify complex environmental impacts like marine litter, this research addresses an even more profound disconnect; the operational separation of planetary impact from economic cost and social equity.

Therefore, and in means of concluding this section of the article, this study does not seek to re-examine the environmental conclusions of prior LCA studies but to build upon them by introducing a unified framework. It directly responds to the call for more precise and actionable social metrics by incorporating Life Cycle Costing (LCC) with a specific, high-impact Social-Life Cycle Assessment (S-LCA) variable: gender balance as a measure of employability equity. Rather than attempting a broad but shallow S-LCA, a common pitfall, this research leverages econometrics to deeply investigate the correlation between sustainable packaging adoption and social inclusivity within a single, real-time analytical model. This targeted approach provides a quantifiable method to bridge the gap between the environmental pillar and the oft-neglected social and economic pillars of sustainability.

3. Methodology

The analysis is grounded in primary data collected through the survey. A structured digital platform was created initially to serve the purpose of collecting, analyzing and visualizing data collected from the survey, this platform was deployed to manufacturing and producing companies of sustainable packaging across a trans-Mediterranean cohort of seven countries: Morocco, Spain, Portugal, France, Slovenia, Croatia and Turkey. This strategic selection ensures a representative dataset capturing diverse economic and regulatory environments.

The survey in question was engineered to collect integrated data across the TBL, with three main specific sections dedicated to:

- Consumer Acceptance.
- Economic Impact: Understanding the challenges that the companies face when it comes to packaging and quantifying lifecycle costs, for various packaging types (e.g. cellulose-based, bio-based).
- Social Impact: Evaluating social equity, with a focus on gender disparities in employment, compensation and career advancement.

The core innovation of the research presented by the paper lies in the enhancement of the WP Forms platform from a data collection tool into a live analytical engine. The platform was subsequently enhanced to automatically feed new survey responses into these pre-calibrated models, enabling the continuous, real-time generation of results. A validation simulation using a subset of completed responses was conducted in order to ensure the integrity of the entire data processing pipeline, from input to calculation and output generation.

The platform's backend provides two distinct types of automated outputs:

- Descriptive Dashboards: Raw data from the Economic and Social Impact Assessment sections is automatically aggregated and visualized in charts and graphs for preliminary results.
- Econometric Model Outputs: The platform functions as an interactive tool where users can input their own data to generate processed results. While the Life Cycle Cost (LCC) Output produces a quantitative result in monetary terms, providing a straightforward financial assessment, the Social-Life Cycle Assessment (S-LCA) Output generates a semi-quantitative score. The score last mentioned is achieved by converting qualitative survey responses into a standardized point system via a predefined Likert scale (e.g., scoring gender distribution within the workplace from 0 to 10 points), which is then processed by the platform's econometric coefficients.

And in means of guaranteeing flexibility and long-term accuracy, the platform offers a decision-based approach; users can either apply the platform's periodically updated coefficients, refined as the survey dataset expands, or input their own. This design serves the sole purpose of enhancing the models' relevance and providing a more dynamic tool for real-time, comparative trans-Mediterranean analyses.

In terms of the two econometric dedicated models aforementioned, they were developed to utilize the data, both of which were automated within the online platform for real-time analysis.

The first, is the predictive LCC model. This model was designed as a predictive and benchmarking tool to estimate the total economic burden of packaging systems based on a company's cost profile. The final and refined specification identifies how different cost categories associate with the total LCC based on industry-wide data.

$$\begin{aligned}
 LCC_{it} = & \beta_0 + \\
 \beta_1 C \text{ Raw Materials}_{it} + & \beta_2 C \text{ R&D}_{it} + \beta_3 C \text{ Waste Management}_{it} + \\
 \beta_4 C \text{ Marketing}_{it} + & \beta_5 C \text{ Operational}_{it} + \beta_6 C \text{ Taxes \& Licensing Fees}_{it} + \\
 \varepsilon_t
 \end{aligned}
 \tag{1}$$

Where: LCC_{it} : Life Cycle Cost total for entity i at time t

- β_0 (Intercept): Represents the fixed baseline costs not captured by the other variables (e.g. / i.e., initial capital investment, general overhead).
- Raw Materials ($C \text{ Raw Materials}_{it}$): Biomass acquisition (e.g. / i.e., transport and handling costs) - Marine byproducts, cellulose, starch, and other inputs - Coating materials (gelatin, chitosan, bioactives).
- Research & Development ($C \text{ R&D}_{it}$): Process Optimization and Testing: Costs associated with optimizing the process, testing product properties (i.e.

biodegradability) and quality assurance procedures to meet performance standards.

- Waste Management (C Waste Management _{it})
- Marketing (C Marketing _{it}): A crucial addition accounting for the cost of bringing the product to market, including market research, advertising, branding and promotion to remain commercially viable.
- Operational Costs (C Operational Costs _{it}): Utilities (electricity, water) - General maintenance of facilities and machinery
- Taxes & Licensing Fees (C Taxes & Licensing Fees _{it}): This new variable was a critical improvement due to its often-overlooked character as well as regulatory compliance costs.
- ε_t (Error Term): Serves the purpose of capturing any random variation and / or unmeasured factors affecting the total LCC.

The second model is the gender-inclusive workforce S-LCA model, which analyzes the correlation between a company's sustainable packaging focus and its social performance, specifically through the lens of employability equity.

$$S-LCA_{it} = \beta_0 + \beta_1 WF_{it} + \beta_2 EDS_{it} + \beta_3 WC_{it} + \beta_4 C_{it} + \beta_5 PDO_{it} + \beta_6 RQ_{it} + \beta_7 M_{it} + \varepsilon_{it} \quad (2)$$

Where: S-LCA _{it}: Employability score for entity i at time t

- β_0 (Intercept): β_0 is the baseline or default employability score. It represents the expected value of the S-LCA score (the employability level) for a hypothetical company or entity when all the independent variables are zero.
- WF _{it}: Workforce and job breakdown (e.g. / i.e., gender distribution)
- EDS _{it}: Employment duration and stability
- WC _{it}: Working Conditions (health & safety, job security)
- C _{it}: Compensation (wage parity, benefits)
- PDO _{it}: Professional development opportunities
- RQ _{it}: Required qualifications and training
- M _{it}: Mediating influence of market changes
- ε_{it} (Error Term): Serves the purpose of capturing any random variation and / or unmeasured factors affecting the S-LCA score.

The WP Forms platform was enhanced from a data collection tool, its initial purpose, to an analytical engine, and is currently being developed to add a profitability automated model for all companies partaking in the study through the survey. It automatically feeds new survey data into the pre-calibrated econometric models,

applying pre-estimated regression coefficients (β) derived from the initial dataset. This allows the continuous generation of correct and updated LCC and S-LCA results in real-time

For the LCC model, this automated approach provides companies with an immediate and data-driven benchmarking tool; A user inputs their costs data, the platform utilizes the dataset, and returns a predicted total LCC based on the patterns learned from the broader industry survey. As for the S-LCA model, following the same approach and structure, the regression coefficients are automatically calculated through dataset. The platform's use of periodically updated coefficients, refined as more data is collected, ensures the model's accuracy and relevance remain current, providing a dynamic tool for trans-Mediterranean comparative analysis.

4. Results & Discussion

4.1. Economic and Social Model Findings

4.1.1. The Predictive LCC Model: Redefining Cost Drivers

The estimated coefficients for the predictive LCC model reveal a nuanced cost structure for sustainable packaging systems as it is shown in Table 1.

Table 1. LCC Model Regression Results as of November 8th, 2025. (source: the evolvepackstudysurvey.ma platform)

Cost Driver	Coefficient (β)	p-value	Interpretation
Constant	-7.94	-	Baseline LCC (when all variables are zero)
Raw Materials	0.24	< 0.01	Cost Driver: Directly increases total LCC
R&D	-0.09	< 0.10	Efficiency Marker: Associated with lower total LCC
Waste Management	-0.13	< 0.10	Efficiency Marker: Associated with lower total LCC
Marketing	-0.20	< 0.05	Efficiency Marker: Associated with lower total LCC
Operational Costs	0.29	< 0.01	Primary Cost Driver: Largest positive impact on LCC
Taxes & Licensing	0.10	< 0.05	Cost Driver: Directly increases total LCC
Model Statistics			
R-squared	0.85		Model explains 85% of LCC variance

The results show that Operational Costs are the largest positive driver of the total life cycle cost ($\beta = 0.29$, $p < 0.01$). Crucially, Marketing ($\beta = -0.20$, $p < 0.05$), Waste Management ($\beta = -0.13$, $p < 0.1$) and R&D ($\beta = -0.09$, $p < 0.1$) exhibit negative coefficients. This indicates that companies reporting higher expenditures in these categories are associated with a lower overall total lifecycle cost, suggesting that these

are not mere expenses but strategic investments or even markers of operational efficiency. For instance, the negative coefficient for R&D implies that innovation investment is linked to process or material efficiencies that reduce lifecycle costs.

4.1.2. The S-LCA Model: Unlocking the Social Dividend

Concurrently, the S-LCA model identified the key drivers of employability equity as it is shown in Table 2. The most powerful positive predictors of a high S-LCA score were Employment Duration and Stability ($\beta = 0.31$, $p < 0.01$) and Compensation Equity ($\beta = 0.22$, $p < 0.01$). This model also helps isolate a key disparity: while gender balance in the general workforce is significant ($\beta = 0.14$), its smaller coefficient suggests that achieving representation is only a first step; without equitable compensation and job security, the full "social dividend" of a diverse workforce cannot be realized.

Table 2. S-LCA Model Regression Results as of November 8th, 2025. (source: the evolvepackstudysurvey.ma platform)

Variable	Coefficient (β)	p-value	Interpretation
Constant	7.20	[value]	Baseline employability equity score
Sustainable Packaging Index	0.27	< 0.05	Key Driver: A focus on sustainable packaging predicts higher social equity
Workforce Gender Balance	0.14	< 0.05	Positive Contributor: Gender diversity improves the S-LCA score
Employment Duration and Stability	0.31	< 0.01	Primary Driver: Job security is the strongest predictor of social equity
Compensation	0.22	< 0.01	Major Driver: Equitable pay and benefits significantly boost the score
Model Statistics			
R-squared	0.78		Model explains 78% of variance in employability equity

The core finding of this research emerges from the interaction of both models. Although they are separate tools, their strategic integration is highly efficient. The economic model achieves a lower predicted Life Cycle Cost, whereas the social model consistently generates a higher S-LCA equity score—a metric derived from converting qualitative social data (namely, gender balance) into a standardized value. The platform's synergy allows us to leverage both outcomes without relying on a correlation between them, permitting companies to choose whichever focus they have; costs or social equity, or even both.

4.2. Interpreting the Bottom Line for a Sustainable Future

4.2.1. Challenging Conventional Wisdom: From Cost Burden to Strategic Profile

The predictive LCC model fundamentally reframes the “sustainability is too expensive” narrative, not only because it allows you to clearly visualize the estimated costs from sustainable packaging but also because the negative coefficients for R&D, Marketing and Waste Management demonstrate that these expenditures are characteristics of a strategically efficient operational profile. This positions innovation and market development not as a burden, but as components of a business model that achieves cost efficiency at the life-cycle level. The model in question shifts the debate from simple cost minimization to strategic investment allocation.

4.2.2. The Virtuous Cycle: A Theory Modeled in Data

Together, the models support a data-backed theory a virtuous cycle:

- Strategic Investment in Sustainability prioritizes areas like R&D and waste management, which the LCC identifies as markers of a lower total cost profile.
- This innovation-centric posture attracts diverse talent and fosters a culture that values fair compensation and stability.
- This diverse and inclusive workforce, statistically proven to enhance innovation capacity, reinforcing the R&D driven efficiencies and enabling successful market development.
- The resulting improved efficiency and profitability free up capital, which enables further strategic investment in both sustainability R&D and social equity, thus reinforcing the cycle.

4.3. Implications for the UN Sustainable Development Goals (SDGs)

The models provide a quantitative basis for policy and corporate strategy, notably in the following SDGs.

- SDG 9 (Industry & Innovation): Support for R&D is an investment in cost-efficient operations, as shown by its association with a lower life-cycle cost burden.
- SDG 12 (Responsible Consumption): Investment in advanced waste management is demonstrated to be part of a superior economic and environmental profile.
- SDG 8 (Decent Work) & SDG 5 (Gender Equality): The S-LCA provides a clear measurement tool, showing that promotion equality in the workplace requires addressing core issues like Compensation ($\beta = 0.22$) and job security ($\beta = 0.31$). The integration findings suggest that policies supporting the virtuous cycle between sustainability innovation and social equity will be the most effective.

5. Conclusion

This research set out to bridge a gap between the theoretical promise of the Triple Bottom Line and its practical application in the sector of sustainable packaging. Through the development and deployment of two integrated econometric models; the Life Cycle Costing (LCC) model and the Social-Life Cycle Assessment (S-LCA) model, we have moved beyond static, siloed assessments to create a dynamic, real-time analytical platform.

The findings of this research challenge entrenched narratives, revealing a more optimistic, synergistic reality. The LCC model demonstrates that strategic expenditures in R&D, Marketing and Waste Management are not merely costs but are, in fact, markers of a more efficient operational profile, associated with a lower total LCC. Simultaneously, the S-LCA model provides a rigorous, quantitative method for evaluating social equity, identifying Employment Stability and fair Compensation as the primary drivers of a positive social performance in the context of the industry. Most significantly, the integrated analyses truly represent the true core of the virtuous cycle of sustainable packaging; companies that invest strategically tend to build more equitable workplaces, and this combination is linked to a more resilient as well as, potentially, a more profitable business model.

The contribution of this first step of a body of work is twofold. For academia, it provides a novel and econometric methodology that quantitatively links the three pillars of sustainability, offering a new lens through which to study corporate performance. For industry, policymakers, and sustainability advocates, the platform transforms this methodology into an actionable decision-support tool. It demystifies sustainability metrics, allowing users to benchmark their performance, simulate scenarios and make data-driven decisions that align planetary health with social equity and economic viability.

Looking forward, the continuously evolving nature of the platform, alongside its periodically updated coefficients and expanding dataset, ensure that its insights will only grow more precise. Future research will focus on integrating a direct profitability model, deepening the causal understanding of the linkages we have identified as well as an inter-model combining both the LCC and the S-LCA models. In demonstrating that the pursuit of zero-waste need not result in a net loss, but can instead catalyze a cycle of innovation, inclusion and efficiency, this research a data-backed, novel, blueprint for building a truly sustainable future.

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AI-TAMME: Artificial Intelligence – Technology Acceptance Model for Marketing Effectiveness – A Conceptual Model of Decision-Making Quality across Marketing Cycle

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Abstract

Despite rapid adoption of artificial intelligence (AI), many organizations still struggle to turn new capabilities into sustained gains in marketing effectiveness - higher return on marketing investment, stronger retention and customer lifetime value, and healthier brand outcomes. Prior studies tend to focus either on getting technologies adopted or on measuring isolated pieces of the process, but it rarely specifies the decision pathway that links AI to results across planning, analysis, execution, and evaluation. What is missing is a clear, full-cycle framework for how AI improves decisions-making and, through them, marketing effectiveness.

This article introduces the Artificial Intelligence - Technology Acceptance Model for Marketing Effectiveness (AI-TAMME) a conceptual, multi-level model that places decision-making quality at the center, defined by four facets: accuracy, speed, consistency, and explainability. AI-TAMME structures marketing work into four linked stages - planning, analysis, execution, and evaluation; and explains where and how AI contributes to higher decision-making quality at each stage. Evaluation concludes the cycle, after which the process restarts. The model is grounded in established research on technology acceptance and use, organizational adaptation, and marketing decision support, providing a coherent logic for connecting AI use to marketing effectiveness. The study presents and defines the model's constructs, states testable propositions linking AI use, decision-making quality, and marketing effectiveness, and outlines a staged plan for future validation: develop a measurement instrument, assess it with experts, and then test it quantitatively.

Keywords: artificial intelligence; decision-making quality; marketing effectiveness; conceptual model

JEL Classification: M31, M15, C55, C44, 033

1. Introduction

Core marketing decisions - who to target, what to offer, how much to invest, and where to deliver value - are increasingly mediated by artificial intelligence (AI) across the planning-analysis-execution-evaluation cycle. AI now supports forecasting, segmentation, personalization, pacing control, and post-campaign attribution (Herhausen et al., 2024; Huang and Rust 2021). Adoption has expanded around industries, yet gains in marketing effectiveness - measured through ROMI/ROI, retention and customer lifetime value, or brand-based outcomes - remain inconsistent in the organisations and contexts (Gupta et al., 2021; Ruiz-Real et al., 2021). Cross-national and organizational conditions, together with privacy and ethics constraints, further shape results, suggesting the need for fit-for-context decision designs rather than tool inventories alone (Kopalle et al., 2022; Hermann, 2022).

Existing research typically addresses either adoption/acceptance or tool-specific analytics, but seldom clarifies the decision pathway that links AI use to measurable results across the full cycle (Volkmar et al., 2022; Herhausen et al., 2024). Exemplars show the potential where tasks and criteria are explicit - for instance, uplift modeling for retention decisions during analysis or validated marketing-mix models for attribution during evaluation (De Caigny et al., 2021; Estevez et al., 2025a). Information-systems design studies emphasize that performance improves when AI is embedded in workflows that define human-AI roles, ensure traceability, and align problems with appropriate methods (Pathirannehelage et al., 2025; Sobocińska, 2021). B2B syntheses similarly show that AI innovation emerges from coordinated actors and knowledge exchanges rather than isolated tools (Petrescu et al., 2022; van Doorn et al., 2023).

Object and aim

The object of this study is the impact of AI on the effectiveness of marketing activities, with emphasis on its influence on managerial decision-making and performance evaluation across the full cycle. The aim is to develop a conceptual model that links AI use to decision-making quality - accuracy, speed, consistency, and explainability - and, through that mechanism, to marketing effectiveness.

Conceptual contribution

This article introduces AI-TAMME (Artificial Intelligence–Technology Acceptance Model for Marketing Effectiveness), a multi-level model that positions decision-making quality as the point at which AI use becomes consequential for marketing

outcomes. The model breaks the marketing process into four linked stages - planning, analysis, execution, and evaluation and clarifies how AI supports the work carried out in each stage. The staging reflects contemporary accounts of how consumers, autonomous technologies, and employees interact within organisational frontlines, and it is consistent with evaluation practices that require decision paths to be explicit, auditable, and tied to incremental effects. By focusing on the quality of the decisions made with AI rather than on technology adoption alone, the model provides a clearer explanation of how and where AI can strengthen marketing effectiveness.

Planned validation

Although this article develops a conceptual model, a staged plan for empirical validation is outlined. First, content validity of stage practices and decision-quality facets can be assessed through expert elicitation (e.g., Delphi rounds) (Nesterenko and Olefirenko 2023; Volkmar et al., 2022). Second, multi-criteria prioritization tools may be applied to weight indicators by managerial relevance (Lam et al., 2024). Third, survey-archival designs can test the mediated pathway - AI use by stage → decision-quality → marketing effectiveness - using structural models and objective indicators (Chatterjee et al., 2021; Mishra et al., 2022). Finally, evaluation-practice quality can be benchmarked using transparent diagnostics in modern marketing-mix models (Estevez et al., 2025a).

Scientific and practical value

Scientifically, AI-TAMME advances a testable mechanism - AI use → decision-making quality → marketing effectiveness - grounded in evidence on AI-supported decision processes and contemporary evaluation practice. Practically, it offers a decision-oriented blueprint for aligning AI tools with stage-specific choices and auditable outcome metrics.

2. Literature Review

Marketing decisions such as targeting, offering design, budget allocation, and channel choice are increasingly mediated by artificial intelligence across the planning–analysis–execution–evaluation cycle. Despite this diffusion, reported gains in marketing effectiveness remain uneven across organisations and contexts (Gupta et al., 2021; Huang and Rust 2021; Mishra et al., 2022). A consistent theme in recent work is that these differences stem less from the availability of tools and more from how decision tasks are specified, governed, and evaluated within broader socio-technical systems (Urbani et al., 2024; van Doorn et al., 2023).

Evidence from specific stages of the cycle illustrates this point. Performance tends to improve when decision objectives and evaluation criteria are defined in advance, for example, when uplift modelling is used for retention decisions or when validated marketing-mix models are applied for attribution (De Caigny et al., 2021; Estevez et

al., 2025a). Reviews of machine learning in marketing similarly emphasise that analytical methods must be matched to the decision at hand and that transparent reporting is required to convert predictive output into reliable managerial action (Herhausen et al., 2024; Huang and Rust 2021).

Research on information systems design adds that decisions improve when human roles, interaction steps, and audit trails are clearly articulated, and when data and model risks are actively managed through organisational capabilities (Pathirannehelage et al., 2025; Akter et al., 2023; Sobocińska, 2021). In business-to-business contexts, capability studies show that AI generates value only when supported by well-structured competencies and complementary marketing capabilities (Mikalef et al., 2023; Mishra et al., 2022).

At the consumer interface, AI assistance can reduce search effort but may also alter perceived control, with implications for satisfaction and behavioural intention (Liu et al., 2025; Rohden and Espartel 2024; Akdemir and Bulut 2024). These dynamics underscore the need to specify decision pathways rather than assume uniform tool effects. In more complex decisions, such as partner or key-opinion-leader selection - formal multi-criteria decision-aid approaches improve transparency and quality by making criteria and trade-offs explicit (Lam et al., 2024; Gupta et al., 2021).

2.1. Definitions and scope

Marketing effectiveness

In this study, *marketing effectiveness* refers to measurable improvements in return on marketing investment (ROMI/ROI), customer retention, customer lifetime value (CLV), and market-based assets such as brand and customer equity (Gupta et al., 2021). Firm-level studies consistently show that data-driven decision processes support gains in profitability and efficiency, but also that outcomes vary widely across organisations. This variation highlights the need for disciplined and auditable measurement practices (Mishra et al., 2022; Gupta et al., 2021). Research at the consumer level further indicates that artificial intelligence can increase attention, engagement, and intention formation, making it important to specify not only the outcomes to be measured but also the procedures used to evaluate them (Liu et al., 2025; Akdemir and Bulut 2024; Rohden and Espartel 2024).

AI use in marketing (cycle view)

Artificial intelligence operates within socio-technical systems in which consumers, technologies, and employees jointly produce outcomes across the planning–analysis–execution–evaluation cycle (Liu et al., 2025; van Doorn et al., 2023). Within this cycle, AI contributes to goal setting and budget formulation in *planning*; segmentation, modelling, and response estimation in *analysis*; workflow routing, pacing, and exception handling in *execution*; and attribution and incrementality assessment in

evaluation (Huang and Rust 2021; Hao and Liu 2024). Reviews of interactive and B2B applications emphasise defining AI use around specific decision tasks and managerial goals rather than around tool lists. Such task-based definitions allow stronger alignment between use, governance requirements, and measurement practices (Mikalef et al., 2023; Urbani et al., 2024).

Decision-making quality (mechanism)

To explain how AI use produces results, this study adopts **decision-making quality** as the central mechanism. It comprises four facets - accuracy, speed, consistency, and explainability, each shaped by how AI-supported decision processes are designed (Pathirannehelage et al., 2025). Design decisions such as feature choice, evidence presentation, human oversight, and traceability influence whether model outputs are actionable and whether downstream decisions are reliable (Akter et al., 2023; Sobocińska, 2021). Because biases can emerge in data, modelling, and implementation, contemporary studies also underline the need for explicit bias-mitigation practices to support stable and defensible decisions (van Giffen et al., 2022; Soleimani et al., 2025).

Illustrative cases (operational clarity)

In the analysis stage, uplift modelling identifies customers most likely to change their behaviour due to an intervention. This helps firms direct treatments where they are most effective, assuming the available data are reliable and the underlying segment structure is stable (De Caigny et al., 2021). In the evaluation stage, modern AI-enabled marketing-mix models place strong emphasis on validation, diagnostics, and transparent reporting so that budget recommendations reflect true incremental effects rather than artefacts of model design (Estevez et al., 2025a). Broader reviews of machine learning applications in marketing similarly call for linking each analytical method to the specific decision it is intended to support and documenting key assumptions that influence inference and actionability (Herhausen et al., 2024; Koçoglu and Esnaf 2022).

Positioning within managerial scope

Recent reviews converge on the view that AI should be understood as part of a *managerial decision system* rather than as a catalogue of tools. This perspective clarifies which decisions are in scope, which controls are required, and how effectiveness should be evaluated (Kopalle et al., 2022; Hao and Liu 2024). In B2B contexts, studies similarly show that framing AI as a means to structure and execute marketing decisions, rather than as standalone technology adoption, helps identify clear use-cases and the evidence required to demonstrate performance effects (Mikalef et al., 2021; Petrescu et al., 2022; Keegan et al., 2023).

2.2. Adoption and Acceptance (TAM/UTAUT and extensions)

Research grounded in the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT) shows that intention to use and continued use are shaped by perceived usefulness, ease of use, social influence, and facilitating conditions. In artificial intelligence (AI) settings, these classical determinants remain relevant but are insufficient on their own. Additional factors - trust, perceived transparency, and perceived control become central because users must interpret and evaluate outputs that are often opaque or probabilistic (Urbani et al., 2024; Volkmar et al., 2022). Evidence from service interactions further demonstrates that perceived reliability and emotional reassurance influence whether users maintain trust in AI-enabled systems, extending traditional TAM/UTAUT beliefs toward more experiential and affective dimensions (Hermann et al., 2024; Sobocińska, 2021).

Conversational systems illustrate these extensions clearly. Acceptance depends not only on usefulness and ease of use but also on trust in the conversational agent, perceived reliability during interaction, and system–task fit (Urbani et al., 2024; Akdemir and Bulut 2024). Satisfaction with the interaction shapes intention to reuse and affects downstream behavioural outcomes, reflecting the importance of experiential quality as an antecedent to acceptance beyond classical TAM variables (Akdemir and Bulut 2024).

At the consumer interface, AI-driven recommendation agents can simplify choice processes but also introduce uncertainty when they reduce perceived autonomy. Such reductions in perceived control weaken satisfaction and purchase intention, underscoring the need to incorporate perceived agency and choice assurance into AI-specific acceptance models (Rohden and Espartel 2024). These effects differ across individuals: expectations, self-efficacy, and contextual cues, including anthropomorphic design shape whether AI is interpreted as helpful or intrusive (Gomes et al., 2025; Rohden and Espartel 2024). These findings extend TAM/UTAUT by emphasising the psychological dynamics of control, competence, and relational cues during AI-mediated decisions.

Trust plays an especially critical role in high-stakes or low-transparency settings. In response, third-party certification has been proposed as a means to signal competence and fairness, though its effectiveness varies by domain and perceived expertise of the certifying entity (Blösser and Weihrauch 2024; Liu et al., 2025). This adds an external governance component to acceptance models: adoption is shaped not only by internal user beliefs but also by institutional and legitimacy cues.

Managerial adoption in business-to-business (B2B) contexts exhibits its own extensions. AI systems are more likely to be taken up when they support knowledge creation, align with decision processes, and integrate into established workflows (Bag

et al., 2021; Chatterjee et al., 2021; Keegan, Iredale and Naudé 2023). Capability-based studies show that well-developed AI competencies strengthen marketing capabilities and enhance performance, indicating that organisational readiness and complementarity play a central role (Mikalef et al., 2023). Design-oriented research further shows that explicit problem framing, human-in-the-loop configurations, and traceable learning cycles strengthen user trust and enable more effective use (Pathirannehelage et al., 2025; Sobocińska, 2021). At the organisational level, firms increasingly rely on bias-management routines, documentation standards, and audit practices, which enhance both internal reliance and external legitimacy (Nesterenko and Olefirenko 2023; Akter et al., 2023; van Giffen et al., 2022).

Taken together, this literature suggests that acceptance in AI-TAMME is shaped by four interacting components:

- (i) **core TAM/UTAUT beliefs** (usefulness, ease of use, social influence, facilitating conditions);
- (ii) **AI-specific experiential factors** (perceived control, trust, transparency, uncertainty);
- (iii) **external assurance signals** (certification, governance cues, institutional trust); and
- (iv) **organisational design choices** that make human–AI interaction intelligible and auditable (Urbani et al., 2024; Blösser and Weihrauch, 2024; Pathirannehelage et al., 2025; Sobocińska, 2021).

This layered view aligns with frontlines research demonstrating that acceptance in AI-supported environments emerges from the combined influence of economic utility, governance signals, and socio-cognitive responses within consumer–worker–technology constellations (Liu et al., 2025; Kopalle et al., 2022).

2.3. Decision support and human–AI interaction: designing for decision-making quality

Research in information systems shows that artificial intelligence (AI) enhances managerial decision processes when it is embedded in well-structured workflows: problems must be clearly framed, feature selection and model updates must be traceable, and human oversight needs to be explicit so that outputs remain interpretable and actionable (Pathirannehelage et al., 2025; Sobocińska, 2021). Studies of frontline and customer-service operations echo this view, highlighting the importance of linking AI tools to concrete workflows, control points, and audit trails so that recommendations can be evaluated and implemented within existing

procedures (Urbani et al., 2024; van Doorn et al., 2023). Evidence from B2B environments similarly emphasises that AI creates value when it supports knowledge-creation routines - such as codifying domain rules and making tacit criteria explicit, and when its outputs are compatible with the organisation's decision logic and governance structures (Bag et al., 2021; Mikalef et al., 2021; Petrescu et al., 2022). Service research further recommends deploying AI where task boundaries, escalation rules, and feedback loops can be specified in advance, ensuring a clear link between analytical outputs and the decisions that managers ultimately take (Huang and Rust 2021; Cherkaoui et al., 2024).

Across these streams, a consistent conclusion emerges: the pathway from AI use to performance runs through **decision-making quality**, defined here through four facets - accuracy, speed, consistency, and explainability (Pathirannehelage et al., 2025). Each facet is shaped by specific design choices. **Accuracy** improves when model objectives and validation procedures match the decision context, for example when uplift modelling is used for selective interventions or when deployment-consistent checks are applied to predictive models (Herhausen et al., 2024; De Caigny et al., 2021). **Speed** depends on data pipelines and interfaces that minimise latency and enable timely operational responses (Hao and Liu 2024; Hornik et al., 2025). **Consistency** is strengthened by standard operating procedures, routing logic, and monitoring dashboards that stabilise decisions across similar cases (Urbani et al., 2024; van Doorn et al., 2023). **Explainability** is enhanced through clear documentation of inputs, assumptions, and rationale summaries, supported by interpretability techniques that allow users to interrogate outputs (Akter et al., 2023; Blösser and Weihrauch 2024).

Bias-arising from data, modelling, or deployment-presents an additional challenge. Marketing studies therefore advocate explicit bias-management capabilities, including dataset audits, stability checks, challenger models, and counterfactual assessments, as part of routine decision support rather than optional safeguards (van Giffen et al., 2022; Soleimani et al., 2025). Research in advertising and ethics reinforces this need by showing that transparency, clarity of purpose, and relevance constraints contribute to perceived fairness and mitigate concerns about manipulation (Rodgers and Nguyen 2022; Hermann, 2022).

User-experience research adds further nuance: perceived control, access to clear rationale displays, and reversibility of actions all influence users' readiness to rely on AI outputs (Rohden and Espartel 2024; Akdemir and Bulut, 2024). Case studies in procurement and sourcing show how codified criteria, scenario tests, and structured exception management translate model outputs into defensible and consistent award decisions (Allal-Chérif et al., 2021). In precision-marketing contexts, formalising segmentation logic, trigger rules, and content policies improves scalability and traceability (Yang et al., 2021). Studies of customer engagement and B2B innovation

further stress the importance of instrumenting touchpoints to capture feedback and close the loop between recommendation quality and realised outcomes (Bag et al., 2022; Petrescu et al., 2022).

Synthesis. The literature therefore supports treating “AI use” not as the deployment of isolated tools but as a set of structured AI-supported decision practices - observable routines that explicitly target accuracy, speed, consistency, and explainability. This perspective provides the conceptual foundation for the AI-TAMME model, which positions decision-making quality as the key mechanism linking AI use to marketing effectiveness.

2.4. AI across the planning–analysis–execution–evaluation cycle

2.4.1. Planning

In the planning stage, artificial intelligence supports activities such as forecasting, scenario analysis, and the formulation of initial budget allocations. Prior studies emphasise that the value of these tools depends on aligning model objectives, validation procedures, and diagnostic checks with the specific managerial decisions they are intended to inform (Herhausen et al., 2024; Huang and Rust 2021; Volkmar et al., 2022). Recent work also shows that generative-AI systems can broaden the range of potential scenarios or strategic options during market research and evidence synthesis, but their outputs require clear constraints and expert oversight to avoid unreliable or misleading inferences (Estevez et al., 2025b; Fayed, 2021).

In parallel, planning benefits from structured decision aids that help teams formalise assumptions and articulate trade-offs in early-stage allocation choices, improving transparency and repeatability (Lam et al., 2024). More broadly, reviews highlight the need to document data sources, feature definitions, and governance rules at the outset so that subsequent evaluation can trace decisions back to their underlying assumptions and inputs (Hao and Liu 2024; Kopalle et al., 2022; Volkmar et al., 2022).

2.4.2. Analysis

In the analysis stage, firms translate planning assumptions into operational rules for selection, timing, and offer design. Prescriptive approaches such as uplift modelling help identify individuals who are likely to change their behaviour when targeted, rather than simply those at high risk, and can therefore improve intervention efficiency when the underlying data are reliable and segment structures remain stable (De Caigny et al., 2021). Operational classifiers used in campaign execution, such as tele-marketing response models, produce more dependable guidance when they are assessed with deployment-consistent metrics and appropriate handling of class imbalance, rather than relying solely on generic accuracy indicators (Koçoglu and Esnaf 2022).

Domain-specific segmentation tasks, including the identification of potential electric-vehicle buyers, demonstrate how feature engineering and imbalance remedies directly influence model performance and the quality of subsequent marketing actions (Bas et al., 2021). Evidence from neuromarketing further shows that emotional and memory-related processes shape attention and choice, clarifying the conditions under which algorithmic recommendations are likely to be followed in practice (Beyari et al., 2024).

At the organisational level, firms with stronger data integration and more mature analytics routines tend to obtain greater benefits from analysis-driven decisions, underscoring the importance of data maturity as an enabling condition (Gupta et al., 2021). In digital advertising contexts, AI-based targeting and creative optimisation are associated with higher engagement when the design of the task and the timing of measurement align with the cadence of decision-making in the channel (Xu, Li and Donta 2024).

2.4.3. Execution

In the execution stage, outcomes arise from interactions among customers, frontline employees, and autonomous technologies. Research on organisational frontlines shows that routing rules, escalation procedures, and monitoring practices strongly influence whether analytical recommendations are implemented as intended (van Doorn et al., 2023). Managerial frameworks for AI-enabled service tools, such as chatbots - highlight the importance of task-technology fit, clearly defined handoff criteria, and KPI-linked dashboards to maintain consistent decisions across comparable cases (Urbani et al., 2024).

In settings that demand low response latency, such as dynamic offers or anomaly detection, fog and edge architectures help reduce delays and synchronise model outputs with the pace of frontline activity (Hornik et al., 2024; Hornik et al., 2025). Certain domains introduce additional operational risks. For example, live-streaming commerce is vulnerable to information asymmetries and manipulation, making structured risk assessment and control procedures necessary to ensure credible and repeatable outcomes (Zhang et al., 2025).

More generally, studies caution against deploying algorithms without appropriate oversight. Recommended safeguards include guardrails, stress testing, and the possibility of human override to prevent error cascades in high-velocity environments (van Giffen et al., 2022). Platform-specific analyses also advise piloting and staged implementation before full automation, particularly in contexts where brand exposure and reputational risks are concentrated (Xu et al., 2024).

2.4.4. Evaluation

In the evaluation stage, recent work on AI-enabled marketing-mix models emphasises the need for out-of-sample validation, planned holdouts, and transparent reporting to ensure that budget recommendations reflect genuine incremental effects rather than artefacts of model specification (Estevez et al., 2025a). Because models

may drift over time or embed structural biases, marketing research recommends incorporating bias diagnostics and challenger-model comparisons into routine performance review (Akter et al., 2022; van Giffen et al., 2022).

To support credible evaluation, organisations are encouraged to develop robust bias-management capabilities, including data audits, systematic documentation, and counterfactual testing. These practices strengthen external legitimacy and reinforce internal confidence in AI-generated insights (Nesterenko and Olefirenko 2023; Akter et al., 2023). In addition to short-term performance metrics, evaluation frameworks should incorporate downstream behavioural indicators, such as repurchase intentions - to capture longer-horizon effects that are not observable in immediate conversion outcomes (Alkaied et al., 2024).

Research on corporate responsibility adds that transparent governance processes and ethical safeguards can enhance stakeholder trust and, in turn, the perceived credibility of reported marketing results (Bag et al., 2024; Behera et al., 2022). At the firm level, empirical evidence shows that AI-enhanced CRM practices contribute to organisational performance when evaluation practices are aligned with strategic objectives and auditable performance indicators (Chatterjee et al., 2021).

2.5. Contextual conditions shaping AI-effectiveness relationships

The relationship between artificial intelligence (AI) use and marketing effectiveness is contingent on organisational and environmental conditions that enable or constrain decision quality across the planning–analysis–execution–evaluation cycle. **First**, partner ecosystems and co-creation matter: industrial studies show that value is realised when suppliers, customers, and technology providers co-define objectives, data standards, and governance, linking analytical outputs to shared processes (Li et al., 2021). **Second**, industry readiness and interface maturity condition adoption and outcomes; in emerging environments such as the metaverse, B2B workflows require standards for identity, data interchange, and measurement before AI-supported decisions can scale credibly (Bakeshloo et al., 2025). **Third**, asset and data specificity shape feasible methods and evaluation; domain work in real estate highlights data quality, timeliness, and integration as prerequisites for trustworthy inference and attribution, data maturity (de la Cal et al., 2025).

Macro-level technological change and organisational adaptation also moderate results. Analyses of computer-enabled transformation document how shifts in infrastructure, interfaces, and work routines alter decision cadences and the cost of errors, implying that identical models may yield different payoffs under different operating regimes (Rockel et al., 2024). Cross-country marketing work similarly notes that infrastructure, policy environments, and skills ecosystems influence how quickly firms absorb AI into managerial routines, affecting both the speed and stability of

decisions (Kopalle et al., 2022). Inside firms, power and negotiation dynamics shape whether analytical recommendations translate into action; when decision rights, incentives, and escalation paths are unclear, managers discount model advice even when predictive accuracy is high (Keegan et al., 2022).

At the strategy layer, **AI focus** - the explicit prioritisation of AI initiatives and their alignment with business goals - amplifies realised performance, suggesting that leadership intent and portfolio discipline condition effect sizes (Mishra et al., 2022). Parallel bibliometric evidence in business and economics underscores that expectations surrounding responsible deployment and documentation affect legitimacy and the credibility of reported performance, shaping internal and external acceptance of gains (Ruiz-Real et al., 2021). Complementary findings indicate that capability endowments and analytics orientation strengthen returns from AI-supported decisions, reinforcing the enabling role of organisational competencies and data maturity (Gupta et al., 2021; Mikalef et al., 2023).

These conditions explain why similar AI toolsets yield divergent outcomes in the organisations and industries: effect sizes are contingent on co-creation with partners, interface and data maturity, macro infrastructure and skill bases, intra-organisational power structures, and strategic focus on each acting on the accuracy, speed, consistency, and explainability of decisions at the marketing cycle (Li et al., 2021; Bakeshloo et al., 2025; de la Cal et al., 2025; Keegan et al., 2022; Mishra et al., 2022).

3. Methodology

This study develops AI-TAMME as a conceptual model in which AI-supported decision practices shape decision-making quality and, through that mechanism, marketing effectiveness. The methodological aim is to integrate recent evidence on AI-enabled decision processes into a coherent structure of constructs that can underpin theoretically grounded propositions and future empirical validation.

Model development followed a structured review of peer-reviewed studies published between 2021 and 2025. Inclusion criteria focused on research that (i) specifies marketing decision tasks across planning, analysis, execution, or evaluation; (ii) links analytical methods to attribution, bias control, or validation standards; or (iii) examines organisational capabilities relevant to AI-enabled decision support. Representative streams included work on consumer-technology-worker configurations (van Doorn et al., 2023; Urbani et al., 2024); prescriptive modelling and analytics standards (De Caigny et al., 2021; Estevez et al., 2025a); and organisational readiness and capability formation (Mikalef et al., 2023; Rahman et al., 2023).

All evidence was coded according to the marketing decision cycle - planning, analysis, execution, and evaluation with particular attention to how stage-specific practices influence four facets of decision-making quality: accuracy, speed,

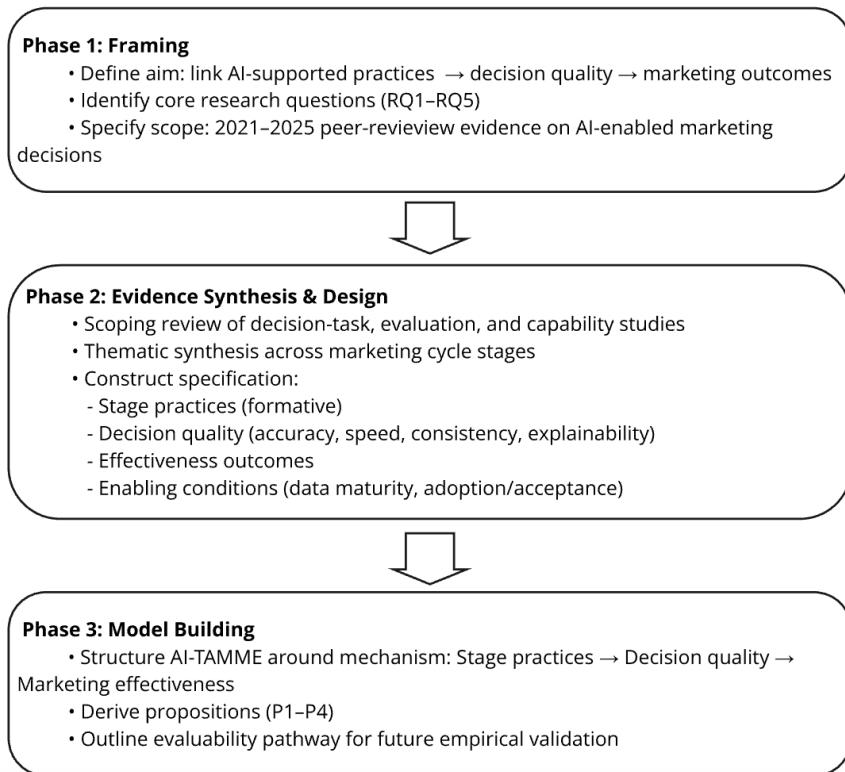
consistency, and explainability (Pathirannehelage et al., 2025; Lam et al., 2024). Through this synthesis, stage practices were conceptualised as formative indicators of enactment quality in the each phase, whereas decision-making quality was specified as a second-order construct reflecting the four facets. Marketing effectiveness was defined through established indicators - ROMI/ROI, retention and customer lifetime value, and brand or customer equity - consistent with analytics research emphasising incremental effects and auditable evaluation (Gupta et al., 2021; Mishra et al., 2022).

The review also identified two cross-cutting enabling conditions: data maturity and adoption/acceptance. These conditions moderate how stage practices translate into decision quality and outcomes, drawing on evidence concerning organisational readiness, trust, perceived control, and analytics capability (Volkmar et al., 2022; Urbani et al., 2024; Akter et al., 2023). This ensures that AI is conceptualised not as a standalone technology but as part of a socio-technical decision system.

The resulting model therefore represents AI use as a set of observable decision routines embedded in managerial workflows, rather than as the presence of particular tools. From this structure, propositions follow logically, and an initial validation pathway is outlined. This includes expert content assessment (e.g., Delphi review) and subsequent structural modelling using multi-role data and archival indicators, consistent with recommended practice in marketing analytics and information-systems design (Estevez et al., 2025a; Pathirannehelage et al., 2025; Hornik et al., 2025).

Figure 1 summarises the methodological logic, depicting the three-phase process used to construct AI-TAMME: research framing, evidence synthesis, and model specification.

Figure 1. Methodology phases



4. Conceptual model development (AI-TAMME)

Research on artificial intelligence (AI) in marketing has largely examined whether systems are adopted and used, yet this line of inquiry offers limited insight into how AI alters the quality of managerial decisions. Adoption-oriented studies clarify antecedents of use but not whether use materially improves allocation, targeting, or evaluation outcomes. A growing body of decision-focused work instead situates AI within managerial routines that structure problem formulation, option generation, criteria application, and justification, thereby offering a tractable pathway from use to performance (Huang and Rust 2021; Herhausen et al., 2024; Estevez et al., 2025a). In business-to-business settings, similar arguments emphasise AI's value when it supports knowledge creation, disciplined decision trails, and governance structures that fit organisational logic (Bag et al., 2021; Mikalef, Conboy and Krogstie 2021; Petrescu et al., 2022). Evidence converges on a central point: performance gains depend less on access to advanced tools and more on aligning problem definition,

data design, and validation criteria with the specific managerial decision at hand (Hao and Liu 2024; Volkmar et al., 2022, Keegan, Iredale and Naudé 2023).

At this perspective, AI-TAMME positions **decision-making quality** as the mechanism through which AI-supported practices influence marketing effectiveness. The model specifies four facets - **accuracy, speed, consistency, and explainability** - that determine whether analytical recommendations can be trusted, enacted, and audited. These facets link AI use to evaluation practice through alignment with credible attribution logic (e.g., validated marketing-mix models) and to organisational acceptance through documentation and rationale that withstand scrutiny (Estevez et al., 2025a; Urbani et al., 2024; van Giffen et al., 2022; Akter et al., 2023).

The strength of these effects is contingent on boundary conditions. **Data maturity** - quality, timeliness, integration sets upper limits on attainable accuracy and stability in analysis and evaluation (Gupta et al., 2021; Herhausen et al., 2024). **Organisational readiness** - workflow fit, competencies, and facilitation structures determines whether AI recommendations can be executed at the required cadence and with procedural consistency (Mikalef et al., 2023; Chatterjee et al., 2021; Volkmar et al., 2022). **Co-creation** with partners and clients influences explainability and acceptance by establishing shared objectives, interfaces, and governance (Li et al., 2021 [36]). **Strategic AI focus** amplifies realised gains when investment and prioritisation align with decision improvements (Mishra et al., 2022). Ethical and legitimacy expectations in advertising and customer treatment impose further constraints that shape decision design and reporting (Hermann, 2022; Rodgers and Nguyen 2022). Domain specificity sectoral data regimes and asset characteristics conditions feasible methods and the credibility of attribution (de la Cal et al., 2025), while macro-level infrastructure and skill ecosystems shape absorptive capacity and decision stability (Kopalle et al., 2022; Rockel et al., 2024).

These elements position AI-TAMME as a mechanism-based explanation of how AI-supported practices translate into marketing effectiveness. The model accounts for why similar technologies produce divergent outcomes across organisations and industries: gains materialise only when stage-level practices enhance the quality of decisions and when enabling conditions support their enactment (Mikalef, Conboy and Krogstie 2021; Estevez et al., 2025b).

4.1. Introduction to the Conceptual Model

Drawing on the evidence synthesised in Section 2 and the methodological approach in Section 3, this chapter formalises the Artificial Intelligence–Technology Acceptance Model for Marketing Effectiveness (AI-TAMME). The model integrates stage-based marketing processes, AI-enabled decision routines, the four facets of decision-making quality, and enabling organisational conditions into a coherent explanatory structure. Section 4.2 elaborates the cycle and its internal logic, and Section 4.3 outlines propositions that render the model empirically testable. Together,

these components specify how AI becomes consequential not merely by being adopted but by altering the quality of decisions in the marketing cycle.

4.2. Model Composition and Flow

AI-TAMME conceptualises AI use as embedded in the a four-stage managerial cycle - **planning, analysis, execution, and evaluation**, followed by iterative return to planning. In the each stage, AI supports specific decision routines whose effects materialise through the four facets of decision-making quality. Two cross-cutting conditions - **data maturity** and **adoption/acceptance**, shape the strength of these relationships by influencing what can be modelled, how reliably outputs can be enacted, and how readily users trust and apply recommendations. This formulation aligns with contemporary accounts of marketing and service processes as sequential, interdependent, and feedback-driven (van Doorn et al., 2023; Huang and Rust 2021; Herhausen et al., 2024) and with design research emphasising task specification, governance, and traceability in AI-enabled environments (Pathirannehelage et al., 2025; Akter et al., 2023).

Planning

Planning establishes objectives, constraints, target audiences, and baseline allocation principles. AI supports this work through forecasting, scenario generation, audience sizing, allocation simulations, and structured partner/KOL selection (Lam et al., 2024; Estevez et al., 2025a). Effective planning requires alignment between model objectives and managerial intent and depends on explicit documentation of assumptions, data sources, and evaluation rules to support later interpretation (Huang and Rust 2021; Herhausen et al., 2024). Generative-AI systems may broaden alternative development but require disciplined prompting and expert oversight to avoid unreliable inference (Estevez et al., 2025b; Nesterenko and Olefirenko 2023; Fayed, 2021).

Analysis

Analysis converts planning assumptions into operational rules, such as whom to target, when to intervene, and what to offer. Activities include segmentation, propensity and uplift modelling, dynamic pricing and offer rules, and creative or variant selection (De Caigny et al., 2021; Bas et al., 2021). Evidence shows that prescriptive approaches improve intervention efficiency when grounded in incremental-effect logic, and that operational classifiers require deployment-consistent metrics and stability checks to ensure reliable performance (Koçoglu and Esnaf 2022). Neuromarketing research highlights how cognitive and emotional mechanisms shape whether algorithmically generated recommendations translate into behaviour (Beyari et al., 2024). The outputs of analysis form the decision rules enacted in the next stage.

Execution

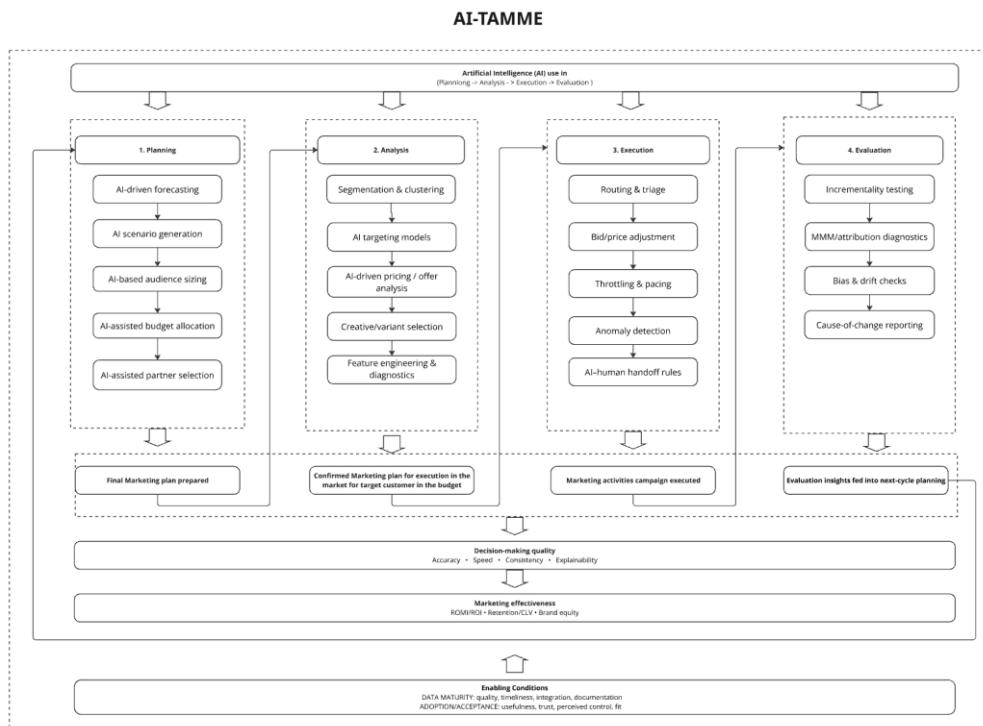
Execution enacts analytical recommendations in interactions among customers, employees, and autonomous technologies. AI supports routing, triage, pacing, bid/price adjustments, anomaly detection, and human–AI handoff logic (Urbani et al., 2024; van Doorn et al., 2023; Sobocińska, 2021). Execution quality hinges on latency management, escalation protocols, exception handling, and operator-readable explanation formats. High-velocity contexts, such as live-streaming commerce introduce distinct operational and ethical risks that require formal safeguards, monitoring, and override capacity (Zhang et al., 2025; van Giffen et al., 2022). Execution outcomes then supply the empirical basis for evaluation.

Evaluation

Evaluation reconciles planned and realised outcomes and informs adjustments to objectives and allocations. AI-enabled capabilities include incrementality tests, modern MMM with transparent diagnostics, drift and bias assessments, retention/CLV updates, and cause-of-change analyses (Estevez et al., 2025a; Akter et al., 2022). Credible evaluation requires counterfactual designs, systematic diagnostics, and high-quality reporting. Organisations with established bias-management practices - audits, challenger models, documentation tend to sustain more reliable performance and greater internal legitimacy (Akter et al., 2023; van Giffen et al., 2022). Incorporating longer-horizon behavioural metrics, such as repurchase intentions, provides a more comprehensive view of marketing outcomes (Alkaied et al., 2024).

Evaluation results feed back into planning and contribute to iterative refinement of assumptions, objectives, and model configurations. As represented in **Figure 2**, stage-level AI-supported practices influence marketing effectiveness - ROMI/ROI, retention and CLV, and brand and customer equity through their cumulative effects on decision-making quality, moderated by data maturity and adoption/acceptance (Gupta et al., 2021; Mikalef et al., 2023; Blösser and Weihrauch 2024).

Figure 2. AI-TAMME Model visualisation



4.3. Propositions

The AI-TAMME model translates the conceptual logic developed in Sections 2-4 into a set of empirically testable propositions. These propositions derive directly from evidence that stage-specific decision practices improve the quality of managerial judgements (Pathirannehelage et al., 2025; Nesterenko and Olefirenko 2023; De Caigny et al., 2021), that decision quality predicts marketing outcomes (Gupta et al., 2021; Mishra et al., 2022), and that organisational conditions shape whether such improvements materialise (Mikalef et al., 2023; Urbani et al., 2024). Formalising these relationships provides a basis for future empirical assessment using structural modelling and stage-level measurement instruments.

P1. Stage-specific AI-supported decision practices are positively associated with decision-making quality.

Research shows that decision routines aligned with task requirements, such as validated forecasting in planning, treatment-effect modelling in analysis, latency-controlled routing in execution, and transparent diagnostics in evaluation improve

accuracy, speed, consistency, and explainability (Herhausen et al., 2024; van Doorn et al., 2023).

P2. Higher decision-making quality is positively associated with marketing effectiveness.

Evidence from analytics, CRM, and capability studies indicates that improved accuracy, faster and more stable decisions, and clearer rationales contribute to higher ROMI/ROI, stronger retention and CLV, and gains in brand or customer equity (Gupta et al., 2021; Chatterjee et al., 2021).

P3. Decision-making quality mediates the relationship between AI-supported stage practices and marketing effectiveness.

Findings across modelling, service, and organisational research suggest that the effects of AI arise not from adoption per se, but from how AI changes the quality of decisions embedded in workflows (Huang and Rust 2021; Estevez et al., 2025a). This implies a mediated pathway from stage practices → decision quality → effectiveness.

P4. Data maturity and adoption/acceptance conditions moderate the effects of stage practices on decision-making quality and marketing effectiveness.

High-quality, timely, and integrated data strengthen the reliability and stability of decisions (Gupta et al., 2021; de la Cal et al., 2025), while favourable acceptance conditions - trust, perceived control, usefulness, and task-technology fit support the effective enactment of AI-assisted routines (Urbani et al., 2024; Volkmar et al., 2022). These enabling conditions therefore amplify the effects articulated in P1–P3.

Together, these propositions establish a coherent empirical agenda for assessing AI-TAMME. They reflect the view, consistent in the reviewed literature, that the performance impact of AI in marketing originates not from the presence of algorithms but from the quality of decisions that organisations are able to make with them.

5. Discussion

This study reframes the role of artificial intelligence in marketing by shifting the focus from technology adoption to the **decision practices** through which AI affects performance. AI-TAMME conceptualises AI use as embedded in the planning–analysis–execution–evaluation cycle and identifies **decision-making quality** - accuracy, speed, consistency, and explainability, as the mechanism through which stage-specific practices translate into marketing effectiveness. This mechanism-oriented view advances prior work by specifying not only whether AI is used but how it modifies managerial routines, the points in the cycle where such modifications occur, and the evaluative conditions under which these changes produce measurable gains.

The model contributes theoretically by integrating insights from prescriptive analytics, frontline service research on human–technology configurations, and

contemporary evaluation practice into a unified, cycle-based explanation of AI effects. It clarifies the distinction between stage practices (the concrete routines through which AI is operationalised), the mechanism (decision-making quality), and the enabling conditions (data maturity and adoption/acceptance). By organising these elements into a coherent structure, AI-TAMME supports a testable pathway linking AI-supported decisions to ROMI/ROI, retention and CLV, and customer or brand equity.

For practitioners, the framework offers directly actionable guidance. Effective planning requires explicit objectives, constraints, and documentation so that later evaluation is auditable. Analysis benefits from using models aligned with the decision intent (e.g., uplift for selective interventions) and maintaining diagnostics and rationales that justify thresholds and selections. Execution requires routing logic, hand-off rules, latency targets, and monitoring to ensure timely, consistent delivery of decisions in the frontline contexts. Evaluation demands credible counterfactuals or validated MMM with transparent diagnostics to inform resource reallocation. Two cross-cutting enablers - **data maturity** and **acceptance conditions** (task-technology fit, trust, perceived control) - reinforce the translation of stage practices into decision quality.

Methodologically, the study advances a structured empirical pathway by proposing formative indices of stage practices and a second-order reflective construct for decision-making quality. This encourages multi-source measurement, the incorporation of archival performance data, and the elevation of evaluation standards (e.g., holdouts, bias diagnostics) from technical details to core components of marketing decision research.

Finally, the model's scope is bounded by contextual conditions. Gains from AI-supported decisions depend on data quality, organisational readiness, and partner co-creation; in environments characterised by low data maturity, unclear decision rights, or high-latency operations, improvements may be attenuated despite advanced models. AI-TAMME therefore applies most strongly to organisations capable of defining decision rules, instrumenting outcomes, and conducting transparent evaluation, while still offering a structured blueprint for those seeking to move toward such capacity.

6. Conclusion

This article develops AI-TAMME, a mechanism-focused conceptual model explaining how artificial intelligence influences marketing effectiveness through its impact on decision-making quality across the planning–analysis–execution–evaluation cycle. By shifting attention from adoption to decision practice, the model clarifies the organisational routines through which AI becomes consequential for performance. It shows that AI improves outcomes when embedded in well-specified decision processes, when evaluation procedures are credible and transparent, and when data and organisational conditions support accuracy, speed, consistency, and explainability.

The study offers three main contributions. Theoretically, it integrates marketing analytics, human–AI interaction, and organisational readiness literatures into a coherent, decision-centred explanation of AI's performance effects. Managerially, it provides a structured blueprint for designing and governing AI-supported decisions in ways that reduce variance and improve impact. Methodologically, it outlines a basis for evaluating AI-TAMME empirically through content validation, multi-criteria assessment, and structural modelling linking stage practices, decision quality, and marketing effectiveness.

Future research can extend the model by testing it across industries with different data regimes, by examining temporal effects in sequential decisions, and by evaluating how human–AI collaboration patterns evolve as organisations mature. As AI becomes more deeply embedded in marketing work, understanding the mechanisms through which it shapes decision quality, and the conditions under which these mechanisms operate - will be essential for both scholarship and practice.

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Sustainable Entrepreneurship in Türkiye: Mapping the Contemporary Business Landscape

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Abstract

While sustainable entrepreneurship is a global phenomenon, its manifestation varies significantly across different institutional and economic landscapes. Challenging the notion of a uniform global model, this study provides the first systematic evidence on how ventures in a pivotal emerging economy align with the United Nations Sustainable Development Goals (SDGs). Using Türkiye as a critical case, we analyze 270 startups and find a distinct pattern of activity: venturing is highly concentrated in SDG 12 (Responsible Consumption and Production, 20.82%) and SDG 9 (Industry, Innovation, and Infrastructure, 12.59%), while social equity goals like SDG 5 (Gender Equality) and SDG 16 (Peace and Justice) are systematically overlooked. We argue that this evidence suggests a "developmental" model of sustainable entrepreneurship, primarily driven by opportunities in industrial modernization and resource efficiency, which contrasts sharply with prevailing trends in developed economies. This research offers a critical counterpoint to universalist entrepreneurship theories, demonstrating how an emerging market's institutional context filters global sustainability norms to produce a predictable, development-focused hierarchy of entrepreneurial action.

Keywords: Sustainable Development Goals (SDGs), emerging economy, entrepreneurial ecosystem, emerging economies, startup ecosystems, Turkish sustainability startups

JEL Classification: L26, Q01, O31, M13, Q56, O44

1. Introduction

The increasing socioeconomic activity of humans has surpassed the Earth's capacity to supply essential resources, making sustainable innovation vital for the global economic order, as macroecological evidence shows that rising population, accelerating resource extraction, and the overuse of finite ecological stocks have already pushed human systems beyond the planet's biophysical limits. (Burger et al., 2012). Building on this global imperative, sustainable innovation has emerged as an important approach integrating environmental, social, and economic considerations

into products, services, and processes (Zartha et al., 2024). Sustainable entrepreneurship has emerged as a transformative force in this transition, characterised not merely by ventures that create economic value while improving environmental outcomes, but by entrepreneurs who holistically integrate economic, social, and ecological goals to generate broader forms of sustainable wealth (Tilley & Young, 2006). These entrepreneurs play a pivotal role in translating sustainability-focused knowledge into innovative products, services, and business practices that can underpin large-scale shifts towards a more sustainable future (Krara, 2025; Pedreño Santos, 2025).

While this trend is global, its manifestation is shaped by local economic, political, and social contexts. Türkiye possesses a dynamic and rapidly growing entrepreneurial ecosystem, particularly in hubs such as Istanbul, Ankara, and İzmir. With increasing alignment with global sustainability frameworks, such as the European Green Deal, and a national push for innovation, Turkish startups are progressively integrating sustainability into their business models.

However, a significant research gap exists. While extensive reviews and theoretical models on sustainable entrepreneurship exist (Sarango-Lalangui et al., 2018; Cillo et al., 2019; Afeltra et al., 2023), there is a lack of empirical evidence detailing what these entrepreneurs actually do within specific national contexts. This study aims to fill that gap by providing a data-driven map of the Turkish sustainable entrepreneurship landscape, based on a comprehensive sample of 294 active startups.

It addresses two fundamental research questions:

1. What is the business coverage of sustainable entrepreneurship in Türkiye's contemporary startup landscape?
2. Which Sustainable Development Goals (SDGs) do Turkish sustainable entrepreneurs primarily serve?

By answering these questions, this paper offers a comprehensive overview of the current state of the ecosystem, identifying both its strengths and its critical gaps.

2. Theoretical Background

2.1. Defining Sustainable Entrepreneurship

This study defines sustainable entrepreneurship as the process through which entrepreneurs discover, evaluate, and exploit economic opportunities embedded in market failures that undermine sustainability (Dean & McMullen, 2007). It involves creating value from an economic, social, and ecological perspective simultaneously (Belz & Binder, 2017). The goal is the "preservation of nature, life support, and

community in the pursuit of perceived opportunities to bring into existence future products, processes, and services for gain" (Shepherd & Patzelt, 2011, p. 142).

2.2. *The Turkish Entrepreneurial Ecosystem*

The success of startups is significantly determined by the supportive conditions of a country's entrepreneurial ecosystem (Tiba et al., 2021). These ecosystems encompass a complex interplay of economic, social, and institutional factors that influence entrepreneurs' strategic choices, resource access, and even the spatial clustering of similar ventures (Autio et al., 2018). The authors further highlight that entrepreneurial ecosystems today are shaped not only by traditional spatial dynamics but also by digital affordances, which expand opportunity discovery, enable horizontal knowledge spillovers, and allow new ventures to experiment with innovative business models beyond industry boundaries. National policies and institutional settings—such as regulatory quality, innovation support mechanisms, and government programs—also play a substantial role in shaping ecosystem performance and fostering new venture creation (Acs et al., 2017). In Türkiye, these dynamics are reflected in government-supported entrepreneurship programs, expanding digital infrastructure, and the gradual development of a venture capital market, all of which shape the trajectory of sustainability-oriented startups. Building on this, the present study examines how such ecosystem conditions influence the development of sustainable ventures in the country.

2.3. *Entrepreneurship and the SDGs*

The UN's adoption of the Sustainable Development Goals in 2015 established a universal framework for addressing interconnected economic, social, and environmental challenges (UN General Assembly, 2015). This agenda intensified global attention toward sustainability-oriented innovation and expanded expectations for how the private sector contributes to long-term development priorities. Recent research shows that entrepreneurial activity is increasingly evaluated through the SDG framework, enabling scholars to identify the ways in which ventures support—or fail to support—specific goals (Tiba et al., 2021). Applying an SDG lens also reveals uneven patterns of engagement across goals and highlights gaps where entrepreneurial action remains limited (Filser et al., 2019). Despite growing interest in this area, evidence on how entrepreneurial initiatives directly advance the SDGs is still emerging, indicating a need for deeper empirical research into their actual contributions.

3. Materials and Methods

The initial dataset from startups.watch contained 294 startups tagged with sustainability and established in Türkiye. After removing ventures identified as inactive or discontinued, the final dataset consisted of 270 active startups. A systematic content analysis was performed to map each of these startups to the primary SDG(s) they serve. Following the procedure outlined by Tunçalp and Yıldırım (2022), each startup's official website and business description were manually coded based on its core products, services, and stated mission. To enhance the completeness and accuracy of the coding process, multiple publicly available information sources were systematically reviewed for each startup. These included LinkedIn company profiles, product and service descriptions, social media announcements, promotional materials, and, where accessible, registrations in relevant provincial chambers of industry or commerce. Together, these sources provided a consistent and multifaceted understanding of each startup's activities, market focus, and sustainability claims, thereby enabling a more robust and reliable classification.

4. Results

This section presents the findings from the analysis of 270 Turkish startups.

4.1. The Coverage of Sustainable Entrepreneurship in Türkiye

The keyword analysis reveals a mature landscape with six core clusters:

- Agritech & Food: Strong focus on precision agriculture, biotechnology, and food waste reduction.
- Circular Economy & Advanced Materials: Prominent activity in developing new sustainable materials and industrial-scale B2B circular economy platforms.
- Clean Energy & Mobility: Concentrated on energy efficiency, renewable energy, and EV charging infrastructure.
- Sustainable E-commerce & Fashion Tech: Significant emphasis on ethical marketplaces and innovations in textile recycling.
- Corporate Sustainability & ESG Tech: A defined cluster providing SaaS platforms for ESG data management and carbon accounting.
- Water Tech & Environmental Monitoring: An emerging cluster focused on water purification, efficient irrigation, and IoT-based environmental monitoring.

4.2. How Turkish Sustainable Entrepreneurship Serves the SDGs

The content analysis shows that entrepreneurial focus is concentrated on a few key developmental, industrial, and environmental goals. SDG 12 (Responsible Consumption and Production) (20.82%) and SDG 9 (Industry, Innovation, and

Infrastructure) (12.59%) are the dominant areas of focus. A strong second tier of activity is evident in environmental and health-related goals, including SDG 13 (Climate Action) (11.72%), SDG 15 (Life on Land) (10.21%), and SDG 3 (Good Health and Well-being) (9.61%). Goals related to energy, food, and water form a middle-low tier, including SDG 7 (Affordable and Clean Energy) (6.39%), SDG 2 (Zero Hunger) (5.79%), and SDG 6 (Clean Water and Sanitation) (5.16%). Critically, social equity and institutional goals remain systematically underserved, including SDG 5 (Gender Equality) (0.60%), SDG 16 (Peace, Justice & Strong Institutions) (0.60%), and SDG 8 (Decent Work & Economic Growth) (0.33%).

Table 1. Turkish Sustainable Entrepreneurs' Focus on SDGs (n = 270)

SDG	Title	Percentage
SDG 12	Responsible Consumption & Production	20.82%
SDG 9	Industry, Innovation & Infrastructure	12.59%
SDG 13	Climate Action	11.72%
SDG 15	Life on Land	10.21%
SDG 3	Good Health and Well-being	9.61%
SDG 7	Affordable and Clean Energy	6.39%
SDG 2	Zero Hunger	5.79%
SDG 6	Clean Water and Sanitation	5.16%
SDG 11	Sustainable Cities and Communities	4.99%
SDG 4	Quality Education	2.91%
SDG 17	Partnerships for the Goals	2.78%
SDG 14	Life Below Water	2.34%
SDG 10	Reduced Inequalities	2.14%
SDG 1	No Poverty	1.00%
SDG 5	Gender Equality	0.60%
SDG 16	Peace, Justice & Strong Institutions	0.60%
SDG 8	Decent Work & Economic Growth	0.33%
Total		100%

5. Discussion

The results from the dataset (n = 270) provide a nuanced understanding of the Turkish sustainable startup ecosystem.

The dominance of SDG 12 (20.82%) and SDG 9 (12.59%) reveals an ecosystem deeply connected to Türkiye's economic core: manufacturing and industry. Startups are clearly responding to the pressures and opportunities of the green transition,

focusing on industrial efficiency, new materials (SDG 9), and creating circular models for production and consumption (SDG 12).

The data highlights a strong focus on environmental and health goals. The high concentrations in SDG 13 (Climate Action) (11.72%), SDG 15 (Life on Land) (10.21%), and SDG 3 (Good Health) (9.61%), all ranking in the top five, suggest that these are key emerging specializations. The emergence of a Water Tech (SDG 6) cluster is also significant, reflecting a growing recognition of Türkiye's future water scarcity challenges. Likewise, the formalization of an ESG Tech cluster shows a maturing market where sustainability is moving from a niche concept to a core corporate compliance issue.

The fundamental gaps remain. The continued low focus on SDG 14 (Life below Water) (2.34%) is a central paradox for a maritime nation. The minimal activity in social and institutional goals like SDG 5 (Gender Equality) (0.60%), SDG 16 (Peace and Justice) (0.60%), and SDG 1 (No Poverty) (1.00%) suggests that the tech startup model in Türkiye has not yet been effectively leveraged to tackle these deep-seated societal challenges.

The findings present a clear call to action. Policymakers could develop targeted grants or incubators to stimulate innovation in underserved SDG areas, a strategy shown to be effective in enhancing entrepreneurial ecosystems. Impact investors have a clear roadmap to areas with high potential for impact and low market saturation.

5.1. Comparison with the Global SDG Landscape

Comparing the Turkish SDG distribution with the global landscape analyzed by Tunçalp and Yıldırım (2022) reveals how the Turkish ecosystem both aligns with and diverges from international trends.

The Turkish ecosystem is strongly aligned with global trends in its focus on industrial and consumption-related goals. SDG 12 (Responsible Consumption and Production) is a top-tier focus in both Türkiye (20.82%) and globally (33.0%), reflecting a worldwide, market-driven orientation toward responsible production and resource efficiency. Furthermore, the prominence of SDG 9 (Industry, Innovation, and Infrastructure) in Türkiye (12.59%) is almost identical to the global finding (12.3%). This confirms that, like their international peers, Turkish entrepreneurs prioritize opportunities in industrial modernization and innovation-oriented sectors..

The "deficient" SDGs in Türkiye are the same ones that are underserved globally. Goals such as SDG 14 (Life below Water), SDG 5 (Gender Equality), and SDG 1 (No Poverty) receive negligible entrepreneurial attention worldwide. This suggests that the difficulty in creating scalable, for-profit business models for these issues is a systemic global challenge, not a uniquely Turkish one.

A significant point of divergence is the specific combination of goals that comprise Türkiye's top tier. While the global study reveals a top five dominated by SDGs 12, 9, 7, 11, and 2, the Turkish ecosystem exhibits a distinct "developmental" profile. The focus is on industrialization (SDG 9) and consumption (SDG 12), as well as managing the consequences of development, specifically Climate Action (SDG 13), Life on Land (SDG 15), and Good Health (SDG 3). This suggests a model of sustainable entrepreneurship filtered through the lens of an emerging economy, one focused on industrial modernization and resource efficiency, while simultaneously addressing the clear environmental and health externalities of that development.

6. Conclusion

This study provides the first robust, empirical map of the active sustainable entrepreneurship landscape in Türkiye. Based on a sample of 270 operational startups, it identifies six key business clusters. It reveals a heavy concentration of activity around industrial and consumption-related SDGs (9 and 12), as well as environmental and health goals (13, 15, and 3). The findings suggest an ecosystem that is adept at addressing market-driven and technology-enabled challenges, but has yet to engage with more complex social and environmental issues effectively.

The primary limitation of this study is its reliance on a single database. Future research should triangulate this data with other sources and conduct qualitative case studies to understand the barriers and drivers for entrepreneurs in the underserved SDG areas. Ultimately, this research serves as a vital baseline for enabling a more diverse, resilient, and impactful sustainable entrepreneurship ecosystem in Türkiye.

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NECHAD, A., MAGHNI, A. & CERRATE, R. / *Rethinking the Balance: Durability and Employability in the Sustainable Food Packaging*

Rethinking the Balance: Durability and Employability in Sustainable Food Packaging

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Abstract

As companies face growing pressure to rethink consumption models, innovative packaging solutions offer a pathway to enhance competitiveness while addressing sustainability challenges. Although these innovations have broad environmental and economic implications, this study focuses on their social impacts, particularly employability and job creation. By analyzing how sustainable packaging influences employment dynamics, the research highlights regional disparities and emerging opportunities in the workforce. Thus, the research employs a Social Life Cycle Analysis (S-LCA) alongside a mixed-methods approach, combining quantitative data and qualitative insights to assess the social impacts of sustainable packaging. The results highlight the emergence of sustainable jobs linked to green packaging innovation, as well as notable disparities in employment opportunities and job quality between different countries. Hence, the study reveals key factors that enhance or hinder the positive social impacts of this transition and underscores the importance of aligning sustainability goals with employability strategies in the packaging sector. While eco-innovation fosters job growth, achieving inclusive workforce development requires targeted interventions from industry and policymakers. Therefore, the study's originality lies in applying S-LCA to the packaging sector, bridging a gap in social sustainability literature. Its mixed-methods framework provides actionable insights to maximize both environmental and social benefits, making it relevant for businesses, governments, and researchers advancing the circular economy.

Keywords: Durability, Employability, Sustainable Packaging, Social Life Cycle

JEL Classification: D23, J24, Q56

1. Introduction

In a global context increasingly shaped by environmental awareness, sustainability has emerged as a strategic priority across numerous economic sectors, influencing every link in the value chain. This pursuit of sustainability addresses the urgent need to mitigate environmental impacts while rethinking production and consumption patterns. Among the industries at the forefront of this transition, packaging plays a pivotal role, particularly in the development of sustainable packaging solutions for the food sector. These innovations aim to reduce ecological footprints and respond to increasing consumer and regulatory expectations for more environmentally friendly products.

Moreover, the shift toward sustainable food packaging is driving profound changes in the job market, creating new professional opportunities. However, these opportunities come with an increased demand for specialized skills, ranging from expertise in innovative technologies to a deep understanding of sustainability imperatives. This evolution raises a critical question: To what extent can the growth of the sustainable food packaging industry support sustainability goals while also influencing employability and creating new career prospects?

To address this question, the study will first define the key concepts of sustainability and employability, establishing a conceptual framework and situating the research within the existing scientific landscape. Next, the interplay between sustainability and employability will be explored within the context of sustainable food packaging. Finally, the methodology employed in this study will be detailed, explaining how both qualitative and quantitative approaches are used to address the research questions.

2. Conceptual Framework: Exploring the Concepts of Employability and Sustainability

Discussions around sustainability and employability have gained significant traction in recent years, with their interaction rooted in deep reflections on their definitions and practical implementation. It is therefore essential to clarify these concepts by drawing on pioneering and relevant works.

2.1. Initial Reflections on Sustainability and Employability

The concept of sustainability, as widely understood today, traces its origins to the 1960s and 1970s, a period marked by growing awareness of the ecological limits of our planet and the need for balanced development. Boulding, in his 1966 essay « The Economics of the Coming Spaceship Earth », likened Earth to a spaceship with finite resources, emphasizing the urgency of recognizing these limitations. His vision of a

cyclical ecological system foreshadowed the principles of the circular economy, which are now central to sustainable development.

The 1970s and 1980s saw further formalization of these ideas, notably through the « Limits to Growth» report by the Club of Rome in 1972. Using the World3 model, the report simulated the consequences of unchecked growth on a finite planetary system, warning that resource depletion could occur within a century if current trends continued. This marked a turning point in challenging the prevailing belief in unlimited economic growth.

The 1987 Brundtland Report, « Our Common Future », introduced the foundational definition of sustainable development as « development that meets the needs of the present without compromising the ability of future generations to meet their own. » (World Commission on Environment and Development, 1987, p. 26.). This report highlighted the interconnectedness of environmental, social, and economic dimensions, laying the groundwork for global sustainability initiatives such as Agenda 21 and international agreements like the Kyoto Protocol.

2.2. *Triple Bottom Line: The Three Pillars of Sustainability*

Building on these foundational ideas, John Elkington's Triple Bottom Line (TBL) framework, introduced in « Cannibals with Forks: The Triple Bottom Line of 21st Century Business » published in 1997 the concept of organizational performance beyond financial metrics to include three key dimensions: economic (Profit), environmental (Planet), and social (People).



Figure 1. The interconnection of the elements of the Triple Bottom Line concept. (Source: Dalibozhko, A., & Krakovetskaya, I. (2018). Youth entrepreneurial projects for the sustainable development of the global community: Evidence from the Enactus program)

- Economic Dimension (Profit): This pillar emphasizes long-term value creation and financial viability, advocating for ethical and responsible business practices that balance profitability with stakeholder engagement.

- Environmental Dimension (Planet): This dimension focuses on preserving ecosystems and reducing the negative impacts of human activities, promoting practices such as renewable energy use, sustainable water management, and material recycling.
- Social Dimension (People): This pillar underscores the importance of fair labor practices, human rights, and community inclusion, highlighting the role of businesses in reducing inequalities and fostering social well-being.

The TBL framework illustrates that true sustainability can only be achieved when these three dimensions are balanced and integrated, as represented by the intersection of three circles in Figure 1.

2.3. Employability: A Multifaceted Concept in Constant Evolution

The concept of employability has evolved over time, adapting to economic, technological, and social changes. It emerged in the 1990s as a response to labor market transformations, including rising unemployment, economic instability, and the rapid evolution of required skills. This led theorists to introduce the concept of individual employability, emphasizing workers' autonomy in shaping their professional trajectories.

Among these theorists, Alain Dubar, in his 1991 work « *La socialisation: Construction des identités sociales et professionnelles* », provided a sociological analysis of employability. He defined it as a dynamic and evolving capacity, dependent on both individual skills and structural conditions. Dubar highlighted the individualization of career paths, where employees can no longer rely on linear trajectories guaranteed by stable organizational structures but must continuously adapt to a changing environment. He also introduced key concepts such as professional transitions, which he described as critical moments when individuals move from one situation to another, such as from employment to unemployment or career change. Dubar examined the relationship between flexibility and precariousness, noting that while flexibility has become a growing demand for businesses, it often leads to instability for workers. This tension underscores the emerging challenges of employability, requiring individuals to balance personal and professional lives while adapting to fluctuating market demands. Finally, he emphasized the central role of public policies and training in strengthening employability, arguing that the rapid obsolescence of skills, accelerated by technological advancements, necessitates continuous renewal of knowledge and competencies to remain competitive in the labor market.

Similarly, Philippe Zarifian contributed to understanding the transformation of work and skills in the context of modernization and globalization through his 2001 book « *Objectif Compétence: Pour une nouvelle logique* ». He argued that competencies extend beyond formal qualifications or degrees, emphasizing their dynamic nature as abilities to be improved and adapted in various professional contexts. Unlike

qualifications, which are based on formal knowledge, competencies involve the active mobilization of knowledge, skills, and attitudes, integrating both theoretical understanding and practical application. Zarifian also highlighted the collective dimension of skill development, stressing that competencies often emerge in cooperative settings. Collaboration and exchange among workers become essential drivers of knowledge construction. He argued that the collective should not be seen as a mere complement but as a central vector in professional learning, particularly in complex and collaborative work environments. Furthermore, Zarifian emphasized the impact of new technologies on skills, noting that technological advancements not only transform tasks but also require constant adaptation of competencies. In response, he advocated for lifelong learning, where individuals continuously develop transferable skills to navigate their professional evolution.

In summary, sustainability, rooted in the recognition of ecological limits, has evolved through historical reflections such as those of Boulding and the Club of Rome, highlighting the interconnection between present and future needs. On the other hand, employability, as an ever-evolving concept, integrates individual competencies with collective dynamics and the demands of an unstable labor market, with a particular focus on adaptability and continuous learning. Together, these two axes underscore the importance of aligning with responsible and flexible practices to address contemporary challenges, fostering a sustainable balance between work and the environment.

3. Employability in the Sustainable Industry: The Case of Sustainable Food Packaging

The global economic landscape has been reshaped by growing environmental concerns, leading to the expansion of the sustainable industry and generating new opportunities for employability. However, thriving in this new environment requires a holistic approach that integrates ethics, innovation, sustainable practices, and specialized technical skills.

3.1. Employability and Sustainability: Between Industry Transformation and Challenges

Today, the sustainable industry stands out as a dynamic and rapidly expanding sector, offering exciting new avenues for employability. This evolution creates numerous opportunities for individuals seeking to contribute to a more environmentally friendly future, though it also presents certain challenges.

The growth of the sustainable industry has opened new pathways for employment, as highlighted in the International Renewable Energy Agency's (IRENA) 2021 report, «

Renewable Energy and Jobs – Annual Review 2021 ». The report revealed that approximately 12 million people were employed in renewable energy in 2020, with projections suggesting this number could reach 24 million by 2030 under robust growth scenarios. This underscores the sector's significant potential to drive global employment while supporting climate goals. Similarly, the International Labor Organization (ILO) forecasted in its 2018 report, « *World Employment Social Outlook 2018: Greening with Jobs* » that the transition to a green economy could generate up to 24 million additional jobs worldwide by 2030. The report emphasized that this growth spans various sectors, including renewable energy, waste management, and energy efficiency technologies, highlighting the importance of an integrated approach to addressing environmental challenges. These statistics demonstrate that the shift toward a sustainable economy is not only a moral and environmental imperative but also a significant opportunity to renew and diversify the labor market. The sustainable industry has the potential to create a variety of jobs, ranging from emerging roles to specialized training programs, contributing to broader efforts toward more responsible and sustainable development.

Furthermore, in response to growing demand, the concept of "green careers" has gained traction, as discussed by Rush and Cassio in their 2010 work « *Green Careers: Choosing Work for a Sustainable Future* ». Indeed, they defined these "green careers" as « *Green careers involve working in green jobs that are focused on sustainability and/or environmental protection and preservation.* » (Rush, A. & Cassio, J., 2010, p.01). In other words, these careers encompass professions that directly contribute to environmental protection and extend to diverse fields such as renewable energy and the circular economy. This creates a broad spectrum of opportunities for individuals seeking to align their work with ethical and strategic values. Rush and Cassio further explain that green jobs can be defined "either by the nature and purpose of the job or by the nature and purpose of the employer" (Rush & Cassio, 2010, p. 1). This means that a green career can be shaped by individual roles aimed at improving environmental conditions—such as waste management—or by the overall commitment of the organization, whether it is a sustainability-focused company or one integrating eco-friendly practices. Thus, this dual approach offers insights into the diversity of green careers and invites professionals to consider how their career choices may align with ecological and ethical considerations.

3.2. Sustainable food Packaging: A new horizon for Employability

As consumers, businesses, and governments increasingly support innovative and environmentally friendly solutions, the food packaging sector is undergoing rapid transformation. This shift is driving a growing demand for specialized skills, making employability a key consideration for professionals seeking green careers. In this context, employability offers fertile ground where expertise and social responsibility converge.

The sustainable packaging industry is increasingly recognized as a significant area of innovation, with potential to reduce environmental impacts and create jobs across various

fields. First, it is important to note that the food packaging sector is the largest consumer of plastics, accounting for approximately 40% of global usage. Similarly, according to PlasticsEurope's 2019 annual report, plastic packaging is responsible for about 60% of post-consumer plastic waste in the European Union, most of which is used only once before being discarded. While consumers are increasingly aware of the environmental damage caused by such packaging, they remain less informed about the ecological impact of microbial contamination. This has prompted the food industry to explore innovative, biodegradable, and recyclable packaging materials equipped with functionalities to prevent food spoilage without harming the environment. Moreover, research and development in eco-innovation, such as biomaterials, have proven to be an excellent foundation for creating functional packaging materials. Indeed, as highlighted in « *Application of immobilized enzymes in food industry* » (Yushkova, E. A., Reshetilov, A. N., Shumakovitch, G. P., Bayramov, T. D., & Yaropolov, A. I., 2019), by incorporating additives like antimicrobial agents, antioxidants, and nutrients, these materials enhance food quality and extend shelf life while limiting microbial proliferation and preventing environmental contamination.

In this context, job opportunities are multiplying due to the rising demand for specialized roles. Companies in this industry are increasingly seeking professionals with expertise in biotechnology, materials chemistry, and environmental engineering. This evolution directly impacts employability by opening new pathways for training and career development, albeit with specific challenges. According to a 2021 Mordor Intelligence report, the sustainable packaging market is projected to reach \$412 billion by 2027, with a compound annual growth rate (CAGR) of 7.7% between 2021 and 2026. This forecast points to a promising future for employability, as the rise of eco-friendly initiatives drives businesses to integrate sustainable practices into their models. This transition is creating new roles in diverse fields, from environmental engineering and resource management to the innovation of eco-friendly products. For example, companies committed to high environmental standards will need skilled professionals to develop less polluting production methods and design sustainable products. Additionally, the advancement of green technologies will increase demand for specialized labor, with skills in data analysis, software engineering for waste management systems, and sustainable product marketing becoming increasingly sought after.

In summary, the sustainable packaging industry is establishing itself as a catalyst for innovation and job creation, addressing contemporary environmental challenges. Growth projections in this sector highlight a rising demand for specialized skills, promising a future where sustainability and employment opportunities intersect. This transition toward a greener economy is often viewed as an ecological necessity and a potential contributor to sustainable prosperity for future generations.

4. Discussion and Analysis

Sustainability, both environmental and social, hinges on a deep understanding of the interplay between economic practices, professional opportunities, and community impacts. Tools such as Social Life Cycle Assessment (SLCA) prove essential in evaluating these impacts, particularly in the sustainable packaging sector. By focusing on employability, this methodology deciphers the relationships among various stakeholders throughout the process, offering a comprehensive view of the opportunities and challenges within this industry.

4.1. S - LCA: An Effective Tool for Identifying Social Impact on Employability

To better understand the social impact of sustainable food packaging on employability, this study draws on EVOLVEPACK, a project under the EU-supported PRIMA program, which focuses on sustainable and innovative strategies to combat food waste in the Mediterranean region. The project aims to develop new antimicrobial, compostable, and/or recyclable food packaging materials while integrating environmental, economic, and social impacts throughout the product lifecycle.

Using the S-LCA methodology, the study will examine the entire process—from raw material sourcing to end-of-life disposal—to derive insights into its impact on employability. It is important to note that there is currently no standardized methodology for measuring and evaluating social impacts due to the complexity of social issues. Therefore, it is crucial to adapt this method based on available data and the specific context in which it is applied. One of the primary objectives of this analysis is to develop a semi-standardized methodology for assessing the social impacts of eco-friendly food packaging, while identifying strategies to promote equitable job creation across genders. This gender-disaggregated approach will highlight disparities and identify opportunities to improve employability in the industry.

The analysis will focus on six key data categories: workforce composition and job distribution, required qualifications and employee training, job duration and stability, working conditions, employee compensation, and professional development opportunities. These data points will provide a comprehensive picture of the social impacts of eco-packaging and identify significant areas for improvement. Additionally, the data will be categorized into four job levels—strategic, expert, intermediate, and operational—to ensure more precise insights. Strategic roles include positions such as CEOs and operations directors, expert roles encompass biochemists and scientific analysts, intermediate roles involve production managers, and operational roles cover machine operators and maintenance staff.

This categorization will enable a more detailed analysis. For example, by examining the minimum qualifications required for expert roles, we can identify trends and expectations,

which will help assess their impact on employability. Similarly, analyzing the training required for specific roles will reveal the minimum standards expected by companies in this sector, providing valuable insights for individuals seeking to enter or advance in this industry.

Gender-disaggregated data at each stage of the process will play a crucial role in identifying disparities between men and women in the industry. For instance, by comparing compensation for expert roles, we can uncover existing or potential gender pay gaps. This analysis will help identify opportunities to reduce these disparities and explore their underlying causes, enabling the formulation of strategic recommendations to promote fairer compensation practices. Additionally, EVOLVEPACK aims to support female entrepreneurship in eco-packaging by providing funding, innovative technologies, and tools, thereby enhancing women's employability and addressing identified gaps through targeted recommendations.

Thus the analysis will be conducted in three Mediterranean countries—Morocco, Portugal, and Turkey—to enable a comparative study. By integrating data from diverse contexts, we can triangulate information to obtain more concrete insights into the social impact of this industry. While the same data categories will be used across countries, distinctions such as living standards will be factored in to ensure relevance, particularly in terms of salary ranges, and to provide a more comprehensive overview.

Finally, the collected data will be integrated into an econometric model to analyze the information in depth. This model will identify significant trends, establish averages, and produce quantifiable results, which will then be interpreted and explained. This will help uncover underlying patterns and potential relationships between the variables studied. Complementing this quantitative approach, qualitative methods such as interviews and surveys will be used to explore participants' perceptions, motivations, and experiences, enriching the understanding of the dynamics at play. By comparing qualitative and quantitative results, we can validate initial hypotheses and draw insightful comparisons, ensuring robust and holistic conclusions.

This mixed-method approach aims to strengthen the reliability of the findings and provide a nuanced perspective on the issues addressed. By combining numerical data with qualitative insights, we can better understand the complexities of the situation and formulate evidence-based recommendations to address the specific needs identified in the study.

4.2. Limitations of the Analysis and Future Proposals

However, this study faces several inherent challenges related to its design and analytical methods. First, the lack of a standardized methodology for measuring social impacts complicates the evaluation of results, making comparisons across regions and contexts

more difficult. Additionally, the variability in data collection systems across the three countries studied could compromise the reliability and comparability of the information gathered. These factors, combined with the diversity of socio-economic issues, raise questions about the actual impact of eco-packaging practices on employability and make it difficult to isolate specific effects related to this industry.

Furthermore, while gender-disaggregated data is relevant, it also presents challenges in terms of collection and analysis, particularly due to the underrepresentation of women in certain job categories, such as operational roles. Potential response biases in qualitative results may also affect the validity of conclusions drawn from interviews and surveys. Finally, it is important to note that the findings may not reflect long-term trends, given the rapid evolution of the sustainable packaging industry. Therefore, extended follow-up studies would be necessary to assess the real evolution of impacts and adapt recommendations accordingly.

To enhance the robustness of this study, several avenues for future research should be explored. First, expanding the literature on eco-friendly food packaging is crucial, as the current body of research remains limited. Collaborations with experts and academic institutions specializing in this field could facilitate the development of a more precise and standardized methodology for assessing social impacts across different cultural and economic contexts. Second, broadening the sample to include other Mediterranean or European countries would provide a more comprehensive comparative perspective, helping to identify region-specific trends and challenges. Finally, incorporating additional dimensions such as age, ethnicity, and socio-economic status would deepen the analysis, offering a more nuanced understanding of disparities and dynamics within the industry.

5. Conclusion and Synthesis

The sustainable food packaging industry is increasingly seen as an area of innovation, with potential to address environmental challenges and influence job creation. This study represents an ambitious effort to analyze the social impact of the sustainable food packaging industry on employability, employing the Social Life Cycle Assessment (SLCA) methodology. By examining the interactions among stakeholders throughout the lifecycle, it provides valuable insights into the economic, social, and professional dynamics within this rapidly growing industry.

The SLCA methodology proves to be a strategic tool for evaluating social impacts, particularly in terms of job creation, skill development, and improved working conditions. The study highlights essential criteria such as job distribution (strategic, expert, intermediate, operational) and gender-disaggregated data, offering a detailed analysis of opportunities and disparities within the industry. However, the research faces several challenges, including the absence of a standardized methodology for quantifying social

impacts and the variability in data collection systems across the countries studied (Morocco, Portugal, and Turkey), which complicates the comparability of results.

In conclusion, this study underscores the central role of the eco-packaging industry as a driver of innovation and professional opportunities in the transition to a greener and more sustainable economy. It also emphasizes the importance of integrating social dimensions into industrial strategies to maximize benefits for communities and ensure inclusive and equitable growth. While the path to sustainability is ambitious and involves significant challenges, it is often framed as both an ecological necessity and a potential contributor to long-term prosperity.

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Digital Infrastructure of Slovakia: Technical Analysis of Domains, Functional Websites, and Google Business Profiles

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Abstract

This paper maps Slovakia's digital infrastructure through a national-scale technical scan of the web ecosystem. We enumerated the population of registered domains, identified functional websites, and cataloged Google Business profiles to establish a comprehensive baseline of online presence. Custom Python pipelines profiled websites for content-management system (CMS) detectability, availability of technical metadata, and core operational characteristics relevant to stability and maintainability. The analysis shows a clear dominance of WordPress within the CMS landscape and a substantial long tail of undetected or custom solutions, indicating heterogeneous practices and lower degrees of standardization. We also observe a structural gap between the volume of registered domains and the share of robust, consistently configured websites, suggesting opportunities to strengthen configuration hygiene and technology transparency. Beyond descriptive results, the contribution of this work is methodological: a reproducible scanning and profiling approach that can be reapplied for longitudinal tracking, regional comparisons, or targeted audits. We outline practical implications for policymakers, hosting providers, and web operators—namely to improve technology identifiability, adopt consistent metadata and security headers, and monitor availability and performance at scale. The presented dataset and workflow provide a grounded basis for evidence-informed stewardship of Slovakia's web ecosystem and for future studies on resilience, security, and scalability.

Keywords: CMS, Digital Infrastructure, Domains, Google Business Profiles, Web Ecosystem

JEL Classification: O33, L86, M15, C88, D83

1. Introduction

The digital infrastructure of a country represents one of the fundamental determinants of its competitiveness, innovation potential and administrative efficiency. Within the European Union, Slovakia's progress in digital transformation

remains below the EU average across several dimensions, particularly in digital public services, advanced digital skills and the business integration of technologies such as cloud computing, big data and artificial intelligence (European Commission, 2024; OECD, 2025). While broadband coverage and network connectivity have reached satisfactory levels, the technical performance and online visibility of Slovak domains remain underexplored indicators of the nation's digital maturity.

Academic research has consistently shown that infrastructure alone does not ensure competitiveness without a functional and integrated online ecosystem that supports e-governance, education and business operations (Gong and Ribiere, 2021; Vaňová et al., 2025). The structure, accessibility and technical quality of national domain systems reflect how effectively institutions and enterprises integrate digital tools into their processes. From this perspective, the digital ecosystem composed of domains, websites and verified business profiles functions both as a mirror and as a driver of national digital transformation (Chupaň Kunertová and Strenitzerová, 2024).

Empirical evidence confirms that countries with cohesive and well-optimised web infrastructures achieve higher levels of digital competitiveness and public trust (Kő et al., 2022; Ondrušová, Šimák and Benko, 2023). A technically optimised and user-centred web ecosystem enhances the visibility of institutions, improves accessibility and strengthens communication efficiency across public and private sectors (Kraus et al., 2023; Miklosik and Evans, 2020). Within this framework, Google Business Profiles (GBP) have become crucial elements of local digital ecosystems by linking digital identity, geolocation and business services, yet their adoption in Slovakia remains inconsistent and regionally uneven (Ondrušová, Šimák and Benko, 2023).

Despite a growing number of strategic initiatives such as the *Digital Transformation Strategy of Slovakia 2030* and the *Digital Decade 2024* framework, empirical data-driven analyses of the technical quality and performance of Slovak web domains remain scarce. Most existing research focuses on policy frameworks or readiness indices rather than measurable indicators of digital performance (Vitálišová and Vaňová, 2023). This gap motivates the present study.

The main objective of this paper is to analyse Slovakia's digital infrastructure using large-scale technical data, with a focus on national domain activity, functional website availability and verified business profiles in Google services. The study aims to identify structural patterns in the Slovak digital ecosystem and to evaluate the relationship between digital presence, functionality and visibility across sectors. The research employs a hybrid methodological framework combining Python-based web scanning, Google API data collection and statistical evaluation of performance indicators. The analysis covers all registered Slovak domains and provides a data-driven perspective that complements existing policy-level assessments.

The contribution of this work lies in extending the understanding of digital maturity from theoretical and policy concepts to a measurable technical layer of the Slovak web ecosystem. By linking infrastructure, visibility and operational efficiency, the study offers practical insights for policymakers, hosting providers and digital strategists aiming to strengthen Slovakia's competitiveness within the European single market (Rêgo et al., 2021; European Commission, 2024; OECD, 2024).

The remainder of the paper is structured as follows: Section 2 presents the theoretical background of digital infrastructure and transformation. Section 3 describes the methodology and data collection process. Section 4 discusses the empirical results, and Section 5 concludes with implications for policy and further research.

2. Theoretical background

The concept of digital infrastructure has evolved into a multidimensional construct encompassing physical connectivity, software systems, data platforms and institutional frameworks that enable digital transformation and innovation. According to the OECD (2024), digital infrastructure represents the backbone of national competitiveness and public sector modernization. It includes not only broadband networks but also the interoperability and functionality of online systems that support communication, data exchange and service delivery. A resilient digital infrastructure is therefore a prerequisite for sustainable development and economic growth (European Commission, 2024; OECD, 2025).

From a theoretical standpoint, digital infrastructure can be analysed through the broader framework of digital transformation theory, which links technological development with organisational and social change. Gong and Ribiere (2021) define digital transformation as a strategic and continuous process of integrating digital technologies into all aspects of an organisation's operations. It is not limited to the adoption of new tools but involves reconfiguration of business models, decision-making structures and value creation processes. Similarly, Kraus et al. (2023) highlight that the success of digital transformation depends on the alignment between technological readiness, institutional capacity and human capital. This triad determines whether digital infrastructure becomes a catalyst for innovation and competitiveness or remains an underused asset. Within the European context, the Digital Decade framework and its country reports provide a comprehensive analytical model that evaluates digital progress through four dimensions: connectivity, digital skills, digital business integration and digital public services (European Commission, 2024). Slovakia's performance across these dimensions shows that while physical infrastructure has improved, structural gaps persist in business digitalisation, advanced skills and digital service integration (Vaňová et al., 2025). These disparities

underline the importance of analysing not only policy outcomes but also the real, measurable performance of digital systems.

Recent literature has introduced the notion of digital agility and digital competitiveness as key determinants of innovative performance in small and medium-sized enterprises (Kő et al., 2022). Digital agility refers to an organisation's ability to adapt rapidly to technological changes, while digital competitiveness reflects the capacity to use digital innovation and transformation maturity to create value. Both aspects are particularly relevant for national digital ecosystems, as they determine how effectively businesses and institutions respond to global digital turbulence.

Empirical studies also emphasise the growing role of data-driven innovation. Miklosik and Evans (2020) demonstrated that the use of big data and machine learning substantially enhances digital transformation in marketing, enabling organisations to extract actionable insights and improve customer experience. These technologies, when applied at a systemic level, can significantly improve the efficiency of national digital infrastructure by optimising information flows and service accessibility.

In the Slovak context, Ondrušová, Šimák and Benko (2023) identified a clear link between digital readiness and organisational performance. Their findings suggest that Slovak enterprises with higher levels of digital adoption achieve better market visibility and productivity. Chupaň Kunertová and Strenitzerová (2024) further argue that successful digitalisation requires coordinated progress across infrastructure, skills and governance dimensions in line with the goals of the European Digital Decade.

The theoretical background of this study therefore rests on three interconnected perspectives:

1. The structural perspective, which views digital infrastructure as a network of interdependent technologies, institutions and services.
2. The transformative perspective, which considers digitalisation as an ongoing process of organisational and societal change.
3. The analytical perspective, which focuses on measurable indicators and data-driven methodologies for assessing digital maturity.

Combining these perspectives allows for a comprehensive understanding of how the functionality of domains, websites and business profiles reflects the state of Slovakia's digital infrastructure and its position within the European digital economy.

3. Methodology

The research applied a quantitative methodological approach based on large-scale technical analysis of the Slovak digital environment. The main objective was to

examine the structure, functionality, and performance characteristics of Slovak web domains with a focus on the presence of content management systems (CMS), integration with social media, and indicators of digital transformation. The study was conducted during the second quarter of 2024 and relied on automated scanning of the national domain database of Slovakia. The dataset included all registered .sk domains obtained from the SK-NIC registry, representing a total of 486,233 domains at the time of analysis. The scanning process was executed using custom-developed Python scripts designed for large-scale web diagnostics. Each domain was tested for activity through HTTP requests, and only those returning valid responses (status code 200) were classified as functional. This procedure resulted in the identification of 203,479 active websites, representing 41.85% of the total domain pool.

The core of the technical analysis focused on evaluating multiple dimensions of digital infrastructure: technical accessibility, page performance, web architecture, and integration with external digital platforms. The primary analytical tools included Google PageSpeed Insights, Pingdom Tools, and Web Vitals, which provided standardized performance indicators such as loading speed, visual stability, interactivity, and uptime. These metrics were complemented by automated parsing of HTML and metadata using Python libraries BeautifulSoup and Requests, allowing for the extraction of structural data such as title tags, meta descriptions, links to social networks, and indicators of CMS usage.

An essential part of the methodology was the detection and classification of content management systems. The identification process was based on the analysis of page source code and meta tags that reveal characteristic patterns of popular CMS platforms such as WordPress, Drupal, Joomla, Webnode, or Atomer. When the CMS type could not be recognized, websites were categorized as "unknown" or "custom-built," reflecting the use of proprietary or less common frameworks. This categorization provided insight into the level of standardization, adoption of open-source technologies, and diversity of the Slovak web environment.

The collected data were cleaned, normalized, and stored in structured data frames for quantitative analysis. Subsequent processing was performed using the Python libraries Pandas and NumPy, as well as Microsoft Excel and IBM SPSS for statistical computation. Descriptive statistics were applied to summarize the data distribution, while comparative analyses were used to assess differences between functional categories, CMS types, and the presence of external integrations. Correlation analysis was employed to explore relationships between key technical and performance indicators such as page speed, availability, and CMS identification success rates.

Performance testing also included simulation of real-world network conditions to estimate the efficiency and scalability of the scanning infrastructure. During the automated scan, approximately 78.1 URLs per second were processed, which corresponds to a theoretical duration of 26 days for the full dataset. The actual runtime

of 29 days confirmed the operational feasibility of the applied technical pipeline, with the minor delay attributed to network latency, server downtime, and throttling protection mechanisms. These findings validate the reliability of the scanning procedure and confirm its scalability for national-level web ecosystem assessments.

The data processing workflow followed strict ethical and technical standards. Only publicly available information was collected, and no personal or sensitive data were included. The analysis adhered to the FAIR principles (Findable, Accessible, Interoperable, Reusable) to ensure the reproducibility and transparency of results. The overall methodological design enabled the triangulation of web performance data, CMS identification, and digital integration indicators into a cohesive framework for assessing the digital infrastructure of Slovak organizations.

The adopted methodological approach provides a comprehensive overview of Slovakia's digital infrastructure by combining technical diagnostics, metadata analysis and visibility metrics. This integrated model captures both the infrastructural and operational dimensions of digital ecosystems, enabling the empirical measurement of digital maturity at the national level. Similar approaches have been successfully applied in studies analysing the structure and quality of online ecosystems across Europe (Vykopal et al., 2021; Vaňová et al., 2025). Through this method, the research contributes new empirical evidence on how functional website performance, verified online identities and business visibility interact as key indicators of a digitally mature national economy.

4. Results

The technical analysis covered a total of 486,233 registered Slovak domains as of 24 May 2024. This dataset includes all domains (see Figure 2). This includes all domains in the national .sk registry, regardless of their active usage. From this dataset, 203,479 domains were identified as functional, representing 41.85% of all registered domains. The remaining 58.15% were classified as inactive, redirected, or non-resolving domains. The average annual number of newly registered domains was 85,775, corresponding to an estimated annual growth rate of 17.63%, assuming no significant expirations. This indicates a continuing upward trend in digital activity and domain ownership across the Slovak digital ecosystem.

A total of 376,994 business profiles registered in Google services were recorded, representing verified establishments visible in Google Business Profiles. The comparison of these figures reveals a considerable disparity between the number of registered domains, active websites, and verified business listings. The number of business profiles substantially exceeds the number of functional websites, which

implies that many organizations maintain digital visibility through Google's ecosystem even without a dedicated web domain.

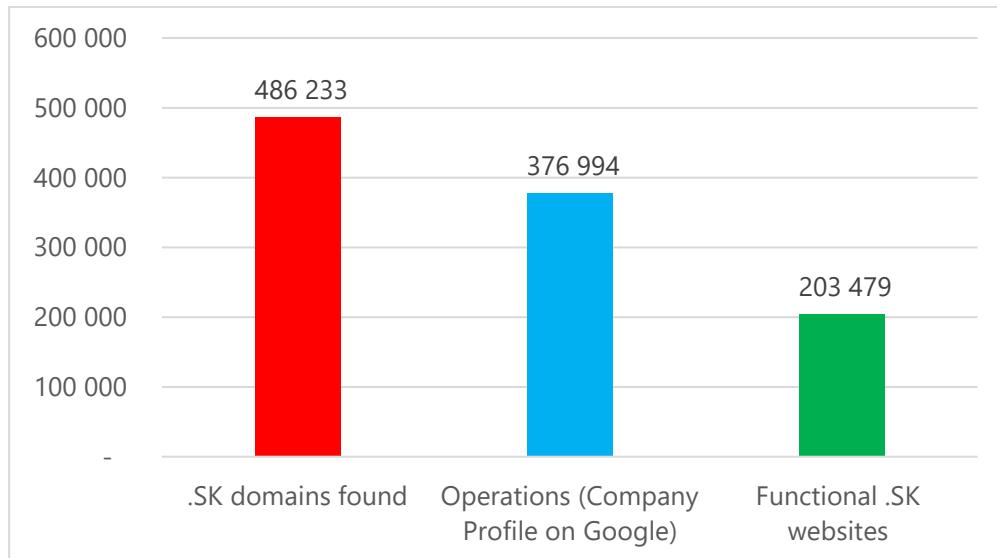


Figure 2 Number of domains, operations and functional websites in Slovakia (source: Own work)

Figure 1 illustrates the relationship between the total number of registered domains, verified business profiles, and functional websites in Slovakia, indicating a significant imbalance between registration and actual web activity.

The scan of Slovak websites also included an assessment of CMS utilization. Approximately 49% of all functional websites employed an identifiable content management system. The remaining 51% used either proprietary or undetectable CMS frameworks. Globally, the average share of CMS usage is estimated at 95%, which demonstrates a considerably higher level of standardization and digital adoption in international contexts.

Table 3 Share of known and unknown CMS systems in SK and Global (source: Own work)

CMS Category	Slovakia (%)	Global (%)
Known CMS	49.0	95.0
Unknown or custom CMS	51.0	5.0

Table 3 presents the share of known and unknown CMS platforms in Slovakia compared to global averages. The results indicate that nearly half of Slovak websites rely on recognizable CMS solutions such as WordPress, Drupal, Joomla, Webnode, or

Atomer. WordPress was found to be the dominant system, accounting for approximately 72.07% of all CMS-based websites in Slovakia.

Secondary data sources such as BuiltWith and W3Techs confirmed this predominance, though slight methodological discrepancies were observed due to differences in sampling and detection. Table 4 provides an overview of the most frequently detected CMS systems in Slovakia, including comparative data from two independent datasets.

Table 4 Analysis of CMS systems in Slovakia (source: Own work)

N	CMS Platform	Approximate Number	Total Share %	Number Builthwith	Builthwith Share %	Diff
1	WordPress	72 372	72,07%	89 247	52,82%	19,25%
2	Joomla	4 935	4,91%	6 059	3,59%	1,33%
3	WebNode	4 871	4,85%	4 939	2,92%	1,93%
4	SmartWeb	797	0,79%	863	0,51%	0,28%
5	Drupal	627	0,62%	2 558	1,51%	-0,89%
6	Prestashop	608	0,61%	2 457	1,45%	-0,85%
7	Atomer	541	0,54%	281	0,17%	0,37%
8	TYPO3	463	0,46%	571	0,34%	0,12%
9	Unisite Creative	416	0,41%	X	X	X
10	shop	322	0,32%	X	X	X
11	CeSYS	260	0,26%	X	X	X
12	Webflow	234	0,23%	689	0,41%	-0,17%

The scanning infrastructure processed 78.1 URLs per second, achieving a total runtime of approximately 29 days for the entire dataset. The theoretical time calculated from total URLs and the average scanning speed was 26 days, suggesting high computational efficiency. The difference between the theoretical and actual durations was attributed to temporary downtime, network latency, and rate limitations.

The results further included data on the integration of social media links across Slovak websites. The analysis covered hyperlinks and embedded references to Facebook, Instagram, YouTube, LinkedIn, and TikTok. The presence of these integrations was cross-referenced with official statistics of social media user bases in Slovakia as of 2023. Instagram and Facebook were found to be the most frequently referenced networks on corporate websites, while YouTube and LinkedIn showed lower levels of integration.

Table 5 presents the number of users for each social media platform and the number of Slovak websites containing corresponding links, based on automated detection.

Table 5 Websites in Slovakia and social networks (source: Own work)

Social network	Number of users 2023	Number of websites	Diff
Facebook	3 184 000	64 996	3 119 004
Instagram	1 690 900	72 661	1 618 239
TikTok	1 200 000	2 403	1 197 597
LinkedIn	823 000	10 708	812 292
X (Twitter)	272 100	8 789	263 311
YouTube		16 731	

Figure 3 visualizes the comparison between the popularity of social networks (measured by user base) and their actual web integration across Slovak websites. The data indicate that Instagram is the most frequently linked platform, surpassing Facebook in frequency of references, while LinkedIn and TikTok remain underrepresented relative to their active user communities.

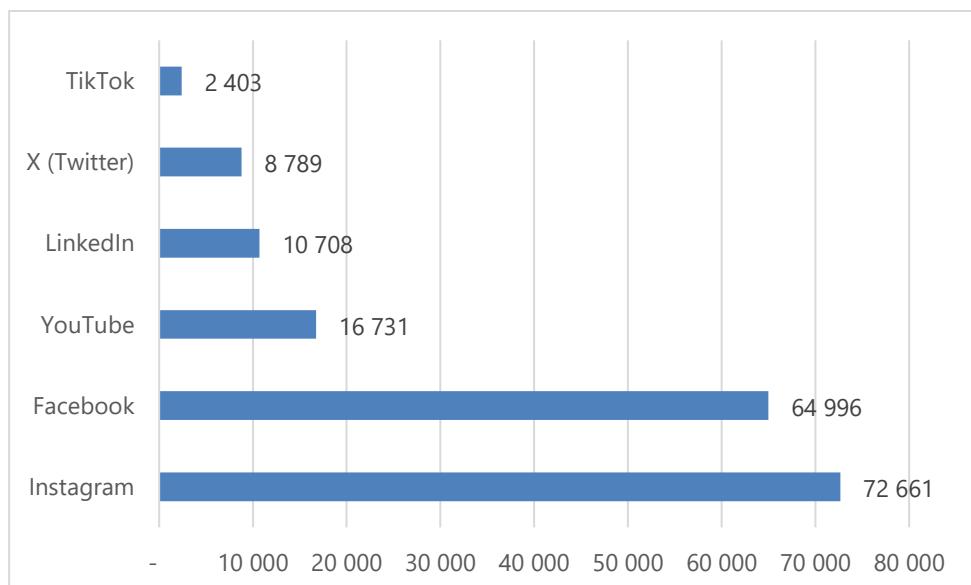


Figure 3 Social networks Slovakia (source: Own work)

Overall, the technical results reveal that Slovakia's web infrastructure is characterized by a high number of registered domains, a significantly smaller share of functional

websites, and a moderate level of CMS adoption. The dominance of WordPress highlights the prevailing preference for open-source, user-friendly solutions, while the relatively low integration with professional social networks suggests an opportunity for broader strategic engagement in the digital environment. These findings are consistent with international studies on SME digitalisation and infrastructure maturity across Central Europe (Kő et al., 2022; Kraus et al., 2023; OECD, 2024; Vaňová et al., 2025).

5. Discussion

The results of the technical analysis reveal a fragmented and uneven structure of Slovakia's digital ecosystem. Although the number of registered domains continues to grow, the low proportion of functional websites indicates that a significant share of the country's online space remains technologically inactive. This imbalance is consistent with findings from the *Digital Decade Country Report 2024*, which highlights Slovakia's challenges in transforming digital connectivity into tangible economic and service outcomes (European Commission, 2024). While network coverage and access have improved, the effective utilisation of these resources remains limited.

The presence of more than 370,000 verified Google Business Profiles confirms that a significant portion of Slovak organizations rely on platform-based ecosystems to maintain their digital visibility. This finding suggests that many businesses prefer externally managed platforms over proprietary websites, valuing accessibility and search engine visibility more than ownership of digital assets. However, this dependency can weaken the autonomy and data control of enterprises and limit long-term innovation capacity (Miklosik and Evans, 2020).

The dominance of WordPress, with more than 70% market share, represents both an opportunity and a potential vulnerability. Its widespread use simplifies development and user accessibility but also concentrates technical risks related to security, performance and maintenance. This trend aligns with findings from Kő et al. (2022), who emphasised that SMEs often prioritise user-friendly and cost-effective technologies, which enhance agility but may limit technological differentiation and innovation potential. The analysis of social media integration offers additional insights into the behavioural patterns of Slovak digital actors. Instagram and Facebook were the most commonly linked social platforms, reflecting the dominance of visual and consumer-oriented communication strategies. The limited integration of YouTube and LinkedIn suggests an underutilisation of platforms that are more closely associated with professional content, B2B communication and educational initiatives. These patterns correspond with the observations of Ondrušová, Šimák and Benko (2023), who noted that Slovak enterprises focus more on consumer visibility than on long-term strategic digital development.

From a methodological standpoint, the efficiency of the large-scale scanning process demonstrates the feasibility of empirical digital infrastructure studies at the national level. The achieved processing rate of 78.1 URLs per second and near-complete coverage of the national domain space provide a reliable empirical foundation for evaluating the structure and performance of online ecosystems. This approach complements existing policy-based indices such as DESI or Digital Decade metrics by offering direct, data-driven evidence on how digital infrastructures function in practice (OECD, 2024).

The relatively weak integration of Slovak websites with professional and data-driven platforms indicates underdeveloped connections between online visibility and organisational competitiveness. This observation supports the findings of Vaňová et al. (2025), who stress that digital transformation in Slovakia is progressing in infrastructure but lagging in adoption and performance quality. The preference for external visibility through Google or social media platforms instead of internally managed digital channels demonstrates the need for education, capacity building and innovation incentives.

From a policy perspective, the findings underline the necessity of shifting from a quantitative to a qualitative approach in national digital strategies. The Digital Transformation Strategy of Slovakia 2030 and the Digital Decade Country Report 2024 both stress the importance of integrating advanced digital technologies into public administration and business operations. However, the empirical results of this study indicate that progress remains slow in areas of website functionality, content management and user engagement. To achieve the European Digital Decade targets, Slovakia must foster stronger collaboration between government, academia and private sector stakeholders (Vaňová et al., 2025). Improving the technical quality of websites should be a national priority. Specific measures could include support for CMS optimisation, cybersecurity training, accessibility standards and automated performance monitoring. As Kraus et al. (2023) note, digital entrepreneurship and innovation thrive in ecosystems that balance technological openness with structured institutional support. This implies that Slovak policymakers should promote not only infrastructure investment but also education, open data policies and innovation incentives that encourage the creation of high-quality digital content.

Overall, the discussion confirms that Slovakia's digital infrastructure stands at a critical transition point. The quantitative expansion of domains and online profiles demonstrates progress in digital access, yet qualitative shortcomings persist in functionality, integration and performance. By focusing on the improvement of web quality, the standardisation of technologies and the development of digital skills, Slovakia can enhance its competitiveness within the European digital economy and contribute more effectively to the objectives of the Digital Decade (European Commission, 2024; OECD, 2024; Vaňová et al., 2025).

6. Conclusion

The empirical analysis of Slovakia's digital infrastructure provides a comprehensive view of the country's current stage of digital development and technological readiness. The results demonstrate that Slovakia has achieved a significant level of digital expansion, with more than 486,000 registered domains and a steadily increasing rate of domain registrations. However, the finding that only 41.85% of these domains are functionally active highlights a structural imbalance between digital potential and effective utilization. This indicates that while digital infrastructure in Slovakia continues to grow in quantity, its qualitative development remains uneven.

The dominance of platform-based visibility through Google Business Profiles illustrates the ongoing reliance of Slovak organizations on third-party ecosystems to maintain their digital presence. Although this trend supports accessibility and brand exposure, it also limits control over data, design, and customer interaction. A sustainable model of digital maturity requires organizations to balance their participation in platform ecosystems with the ownership and management of their own web infrastructure. The widespread use of WordPress confirms a preference for open-source technologies that combine affordability and scalability. This trend aligns with international best practices and reflects a pragmatic approach to digital adoption among Slovak organizations. Nevertheless, the relatively high proportion of undetectable or custom CMS solutions suggests that part of the national web environment operates outside standardized technological frameworks, which may constrain interoperability and long-term maintainability.

The analysis of social media integrations shows that organizations in Slovakia continue to prioritize visually oriented platforms such as Instagram and Facebook while underutilizing channels like LinkedIn and YouTube. This pattern indicates a marketing focus oriented toward consumers rather than professional or B2B communication. To achieve balanced digital maturity, it will be necessary to integrate web infrastructures with diversified communication platforms and analytics tools that support measurable engagement and strategic decision-making.

From a methodological perspective, the applied large-scale scanning model proved effective for capturing national-level digital metrics. The efficiency of data collection and processing confirms the potential of automated technical analysis as a reliable instrument for monitoring the evolution of digital ecosystems. Such approaches can support future policymaking, benchmarking, and academic research by providing objective, replicable indicators of web functionality and digital transformation.

In conclusion, Slovakia's digital infrastructure can be described as technically capable yet strategically fragmented. The country possesses the necessary resources

and technological base for advanced digital transformation, but the coherence and integration of its digital ecosystem remain incomplete.

Strengthening the link between infrastructure, organizational competence, and innovation strategy will be essential for improving the effectiveness of digital initiatives. Enhancing interoperability between domains, websites, and social platforms can significantly contribute to greater transparency, accessibility, and competitiveness within the national and European digital economy. These improvements would support Slovakia's alignment with the objectives of the European Digital Decade and strengthen its position within the evolving digital single market.

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Examination of the orientation of science and technology parks

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Abstract

Science and technology parks are areas that serve as a platform for collaboration between research institutions, companies and government agencies to foster innovation. The aim of the study is to examine the nature of science parks and innovation areas, identifying whether the parks involved in the research have a more research or rather a market orientation. The character of the parks in this aspect is determined by the nature of the settled organizations, the availability of the activities carried out there, and the degree of production and commercial activity.

The examination of the orientation of science and technology parks creates the opportunity to make specific management conclusions that help to find the strategic and action plans that best fit the development arc of the park, and to serve the settled actors to a higher degree. We assume that parks that have established relationships mainly with universities and research institutes, their activities are also related to this, and manufacturing is not present in their service portfolio, are mostly research oriented. In contrast, parks with more intensive manufacturing and commercial activities are more likely to have a market orientation. Proper knowledge of the transition between the two will contribute to the development of the right service portfolio.

The novelty of the research results stem from the fact that the analyses examining science and technology parks are less concerned with the evaluation of parks from a research and market point of view.

Keywords: Science and technology parks – park orientation – service portfolio – management decisions

1. Introduction

Science and technology parks operate according to the framework of the Triple Helix model, i.e. they promote cooperation between academia, industry and the state, in which the actors form an ecosystem that promotes innovation. These actors are essential actors in the knowledge economy, where knowledge transfer and synergies between actors determine innovation and competitiveness.

The aim of science and technology parks is not only to support basic research, but also to effectively commercialise research results and create new products, thus stimulating regional economic development. Although the basic mission of science and technology parks is to support innovation, they vary significantly in terms of their operational nature and focus. The literature base deals extensively with the knowledge transfer mechanisms and economic effects of science and technology parks, but a critical dimension of the internal operation of parks is a less studied area: whether the park has a primarily research or market orientation. This distinction is crucial, as it directly affects the type of organizations settling, the activities preferred, the infrastructure required, and the nature of the management support expected. Lack of the right strategy can lead to low occupancy and ultimately failure to achieve the park's mission. The examination of the orientation of the parks creates an opportunity to draw specific management conclusions that help to find the strategic and action plans that best fit the development of the park, and to serve the settled actors to a higher degree.

To bridge this research gap, the aim of this study is to investigate the nature of science parks in depth. The study examines whether the parks involved in the research have a more research or rather a market orientation. The nature of the parks in this aspect is analysed along the lines of the availability of the activities carried out there, the nature of the settled organisations, and the degree of production and commercial activity.

In the course of the research, we work with the following basic assumptions:

- Research orientation: We assume that parks that have established close relationships mainly with universities and research institutes, and their activities are also related to them (e.g. R+D, scientific analyses), i.e. manufacturing and trade are less present in their service portfolio, tend to have a research orientation. These parks focus on generating knowledge and deepening know-how.
- Market orientation: Parks with more intensive manufacturing and commercial activities (e.g. small series production, sales) are more likely to be market oriented.

These parks focus on the industrial and business application of research results and on marketization.

Understanding the transition between the research and market orientation of parks is vital. This contributes to the development of an ideal, tailor-made service portfolio for the parks, which more effectively supports the park and the established companies in their development.

2. Theoretical overview

Based on authoritative research, four categories are distinguished in terms of the nature of parks: research parks, technology parks, industrial parks and traditional parks. It can be said that the primary focus of the park influences its type, the strategic orientation can be research and development or industrial.

- Research Park:

According to the typology of Klofsten et al. (2025), the orientation of the research park is primarily research and technological. Research parks are essential in promoting national innovation strategies, especially in countries that prioritise boosting technological innovation and R&D. To achieve the goals, the research parks provide a developed infrastructural environment and activities aimed at talent management. Integration into national innovation strategies will ensure that these parks receive consistent support in terms of policy, funding and infrastructure development. Thus, the synergy between public property and research and technology strategies creates an innovation environment.

- Technology Park:

A Technology Park is a type of science and technology park that is usually characterized by private ownership and a strategic focus on research and technology. Through privately owned ownership, these parks operate along a market-driven logic, with the aim of bridging the gap between academic research and industrial application. They are usually located in developed economies where there is already a strong foundation of technology and innovation, with an industry focus typically focused on cutting-edge technologies. Close partnerships between private companies, universities and research institutes are an essential feature of these parks.

- Industrial park:

Industrial Parks are privately owned facilities that are strategically oriented towards business operations. Their goal is to support manufacturing, logistics and other operational industries. This approach differs from the focus of other research-focused science parks in that it places the primary focus on business operations. Industrial parks are present in both developed and developing countries. Collaborations focus on optimizing existing operations, often collaborating with local industries where they

have access to advanced infrastructure, which allows them to support high-tech business operations. In developing countries, they can rely heavily on partnerships with government agencies and international companies to build capacity and expand market access.

- Traditional park:

Traditional, parks owned by public institutions have historically focused more on business activities than on research and technology transfer. Originally created on political incentives, with limited academic involvement, they prioritized commercial and production activities, reflecting the traditional emphasis on business efficiency rather than knowledge transfer. In recent decades, there has been a gradual shift towards closer cooperation with research institutions. Still, some state parks continue to prioritize manufacturing and business activities.

1. Table: Summary of park types (Source: (Albahari, et al., 2013))

Dimension	Research Parks	Technology Parks	Industrial Parks	Traditional Parks
Basic features	Strategic orientation towards research and technology	Strategic orientation towards research and technology	Private Property and Strategic Orientation to Business Operations	Public Property and Strategic Orientation to Business Operations
	Variety: These parks often focus on high-tech industries, but the specific industry focus can vary widely based on regional strengths (e.g., biotechnology vs. electronics).	Variety: The focus of the industry depends heavily on the origin of the park and the sector of the founding companies.	Variety: These parks focus on industries with strong commercial potential, which may vary depending on market and investor interests.	Variety: Parks of this type can support a wide range of industries, often depending on the local business environment and regional needs.
Industry	IT, Biotechnology	IT, Biotechnology	IT, Digital Technologies	SME support, various industries
Examples of industries	National Innovation Leaders	Globally linked, with a high national impact	Regionally focused, supporting the local economy	Internationally recognized
Regional/national significance				

Partnerships	University collaborations	Global technology companies, universities	Local industry partnerships	International technology companies
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The fundamental nature, strategic direction, management and support mechanisms of science and technology parks are fundamentally determined by strategic orientation. Along the categories presented above, these are described below.

Technology Parks: Innovation hubs that support high-tech industries (e.g. biotechnology, IT, nanotechnology). Their success depends on research collaborations and access to funding for advanced technological development.

Research Parks: They facilitate research activities and the commercialisation of scientific discoveries, often with incubation services and specialised research facilities.

Industrial Parks: They primarily support manufacturing clusters, promoting supply chain integration and operational efficiency.

Traditional Parks: They include a diverse collection of different tenants – technology, research and industrial companies – providing a flexible environment for diverse innovation activities. (Klofsten, et al., 2025)

The orientation of the park is not only determined by the type of park, but also by the presence of universities and higher education institutions within the park. The following is how the active presence of universities can strengthen the research focus of parks:

- Significantly increases patent activity: Companies in parks with higher university participation perform significantly better in terms of the number of patent applications than companies operating in other types of parks. This is especially true for pure science parks, where the university is the majority owner. The magnitude of the difference is significant, with companies operating here filing roughly four times as many patents per employee.
- Companies operating in pure science parks have the highest patent performance but are associated with low sales of new products, indicating that the market focus in these cases is negligible. This contrast indicates that university-owned parks specialize in research.
- Utilization of university knowledge: The involvement of the university in the operation of the park allows companies to use the knowledge created at the university, which brings them additional benefits. Access to these research results will accelerate the development of the park and technological innovation.
- The universities themselves are interested in the development of parks in order to facilitate the commercialization and commercialization of academic research. (Albahari, et al., 2013)

The orientation of the parks is fundamentally determined by the level of involvement of the university, which results in two main types: the research focus path and the market focus path. The study by Hobbs et al. also confirms that the active role of universities in clean science parks is significant, where the university does not only appear as a player in the park, but is also present from the ownership and/or management side. This type of presence boosts patent and research activity. On the other hand, in industrial parks, university involvement is not typical with such a high level of involvement, as analyses show that high university involvement has a negative impact on the sales of tenant companies resulting from innovation, or slows down the transformation of innovations into market products. The purpose of market-focused parks is to strengthen sales and not the scientific sphere. (Hobbs, et al., 2017)

Villasalero's (2014) article confirms and further details the basic assumption that park rental companies follow different strategies in the utilization of university knowledge, resulting in two different orientations. The study also reflects this duality at the level of corporate strategy, distinguishing between companies according to whether they incorporate university knowledge into their operations in a "research-exploring") or "technology-selling" way.

- Research Orientation: Focuses on developing the company's internal R+D capacity by generating patents. This accurately reflects the research orientation assumed in the abstract (university relations, focusing on research activities).
- Market orientation: The emphasis is on the market utilization and sale of technological developments, which is the same as the market orientation described in the abstract (more intensive trade and production activity).

The study argues that STPs need to align their service portfolios and open innovation practices (e.g. their forms of collaboration with the university) to these two strategic orientations in order to make appropriate management decisions. This gives parks direct management advice on how to maximize the benefits of university knowledge:

- In case of research orientation: Deeper, R+D-based university collaborations should be supported.
- In case of market orientation: Promote contacts and services that help market uptake. (Villasalero, 2014)

In the article by Van Dinteren et al. (2024): According to the study, a good ratio between start-ups, scale-ups and mature companies is key to innovation, collaboration and economic growth, which reinforces the fundamental purpose of parks.

- Research orientation line: Start-ups and scale-ups represent the phase focusing on new knowledge and rapid R+D.
- Market orientation line: Mature companies bring with them production and trade experience, market relations and financial stability, thus strengthening the market focus of the park.

The most important finding for management is that there is no universally prescribed ideal ratio between company categories. To create the right mix, management must take into account:

- The overall goals of the park: If the goal is a research focus, then management should focus on start-ups and scale-ups. If the goal is market focus (commercial activity), then the involvement of larger, mature companies is the key.
- The needs of the local community and the long-term vision of the park.

The study emphasizes that the park should have an admissions strategy that goes beyond the company's lifecycle (i.e., taking into account research/market orientation) and provide services such as flexible leases and customizable office and laboratory spaces, which are attractive to both types of companies with a research and market focus. (Van Dinteren & Jansen, 2024)

Löfsten and Lindelöf's study examines technology-based new firms in Swedish science parks. The article examines performance along three outcomes:

- Research/Innovation: Existence of university relations, innovation activity.
- Market performance: Sales growth, profitability.
- Development performance: Employment growth.

The park's companies show a higher level of product and market innovation than independent companies outside the park. Although the article indicates market success (introduction of new products and markets) as the ultimate goal, it clearly considers academic relations as the driving force behind this. The research clearly shows that companies located in the park are significantly more likely to establish and maintain a relationship with a local university than companies located outside the park. This finding directly proves that the basic added value of the park environment is access to academic knowledge. (Löfsten & Lindelöf, 2001)

Löfsten et al. (2020) article shows that the most important point of connection between the university and the park is the attraction of students/graduates, whom it considers a strategic resource for innovation and entrepreneurship. This focus forms the basis of research orientation, as a skilled, university-trained workforce is essential for knowledge-intensive activities (research, R+D). Parks serve as platforms for collaboration (research institutes, companies, government) to stimulate innovation. The research reinforces this platform role of parks by demonstrating that park management is actively involved in the development of informal and formal partnerships between students and park companies (e.g. projects, theses, internships). The parks should actively develop services that support relationships between students, alumni and companies, such as: managing internship programs, career days and joint R+D projects. (Löfsten, et al., 2020)

In addition to the strength of the university's presence, the sectoral focus of the science and technology park can also be an influencing factor. Based on the study of Csordás (2025), it can be concluded that the most typical sectoral focus of the science parks and innovation areas involved in the research is ICT, Computer Science, Software Engineering, Biotechnology and Energy. This creates an opportunity to continue the

research, in which the relationship between the sectoral location of the science and technology park and the orientation of the park will be analyzed. (Csordás, et al., 2025)

3. Methodology

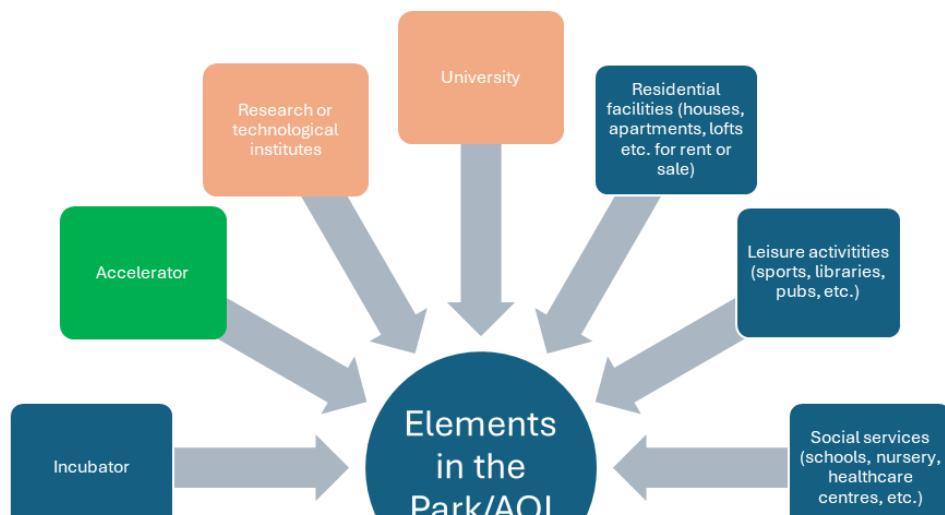
The research presented in this article is based on an examination of 113 parks of the International Association for Science Parks and Areas for Innovation (IASP).

The database of the research is based on three test hypotheses, which are the permissibility of park elements, park activities and manufacturing. The data series of the database contains 113 data, filled with yes-no values, forming binary data. In accordance with the nature of the data, the evaluation was carried out using the ARM (Association Rule Mining) method, which provides an opportunity to compare the available data portfolios and examine their relationship. With this method, we want to examine what kind of relationship can be explored between given factors. The data was processed with the Python program created for this purpose.

The practical part of the research can be divided into three parts, first the frequency of the examined elements is analyzed, then the examination of the relationship between park activities and park elements to production, followed by a comprehensive analysis of the complex data series.

4. Results

4.1. Frequency analysis



1. Figure: Types of park elements (Source: own editing)

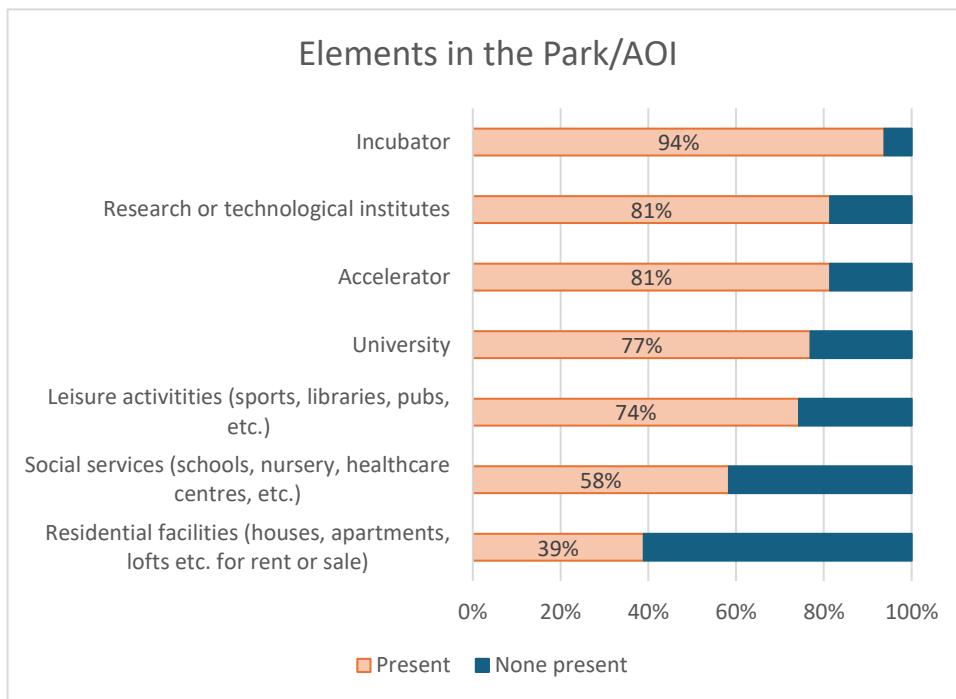
The figure shows the examined park elements of the science and technology parks participating in the research.

Elements marked in green tend to strengthen market focus, while elements marked in mauve color strengthen the research focus, and neutral elements are visible in blue.



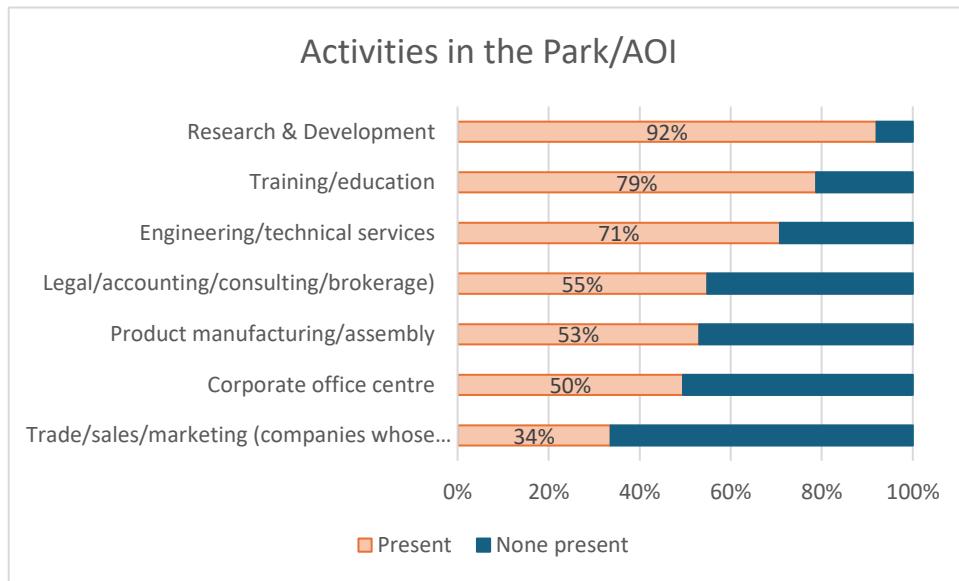
2. Figure: Types of park activities (Source: own editing)

The following figure shows the park activities examined during the research. The corporate office center is a neutral area, but Research and Development and Training and Education definitely strengthen the research focus. On the other hand, Product manufacturing, assembly, Trade, sales, marketing, Legal/accounting/consulting/brokerage activities, and Engineering and technician activities emphasize the market focus.



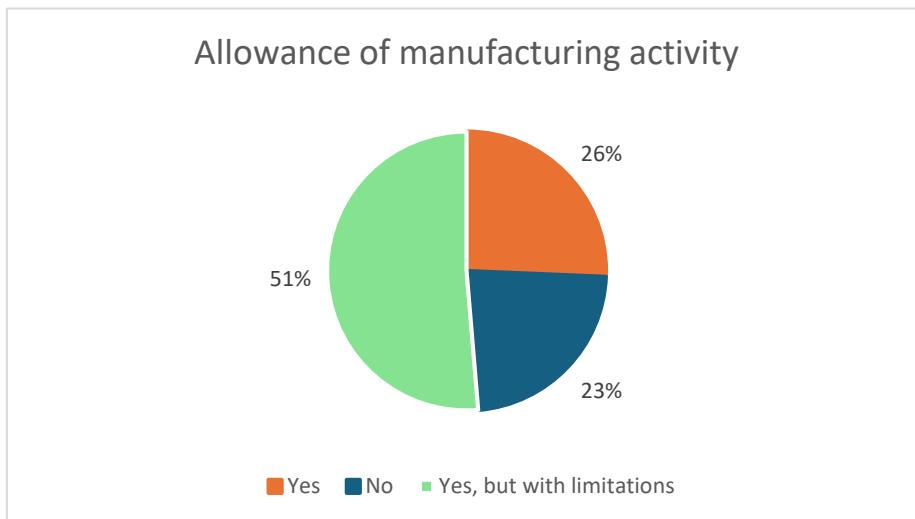
3. Figure: Presence of park elements (Source: own editing)

The figure illustrates the percentage of the given park elements in the case of the parks examined. It is clear that incubators, research and development organizations, accelerators and universities are present in more than three-quarters of the parks, so it can be assumed that the majority of the parks have a more research focus.



4. Figure: Presence of park activities (Source: own editing)

The most typical park activities are Research and Development, Training and Education, and Engineering and Technician Services. The first two of these characterize the research orientation, while the latter strengthens the market focus.

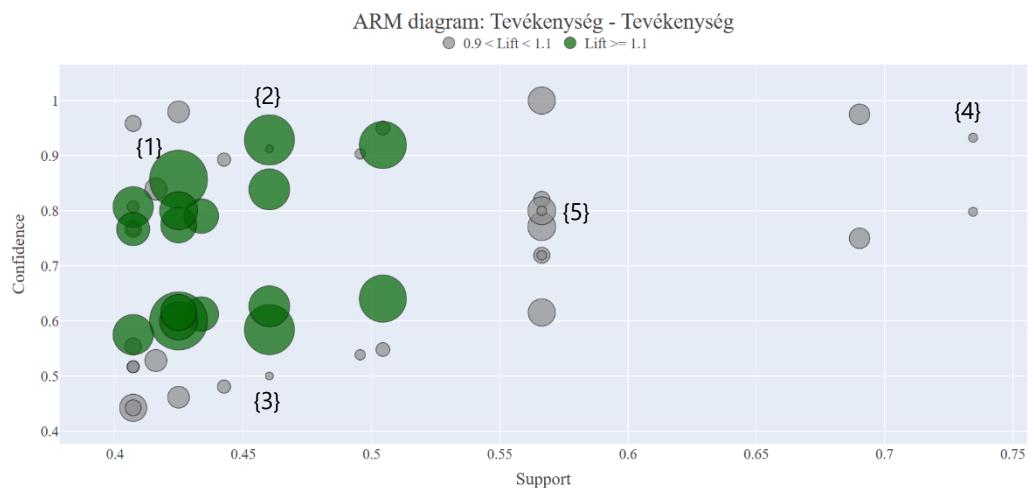


5. Figure: Allowing production (Source: own editing)

The figure shows the relationship to manufacturing activities. More than half (51%) of the parks surveyed allow manufacturing activities, but with restrictions, while 26% of the parks fully support the presence of manufacturing activities. These results can be linked to the previous ones, confirming that a smaller part of the parks examined have a dominant market orientation.

For further investigations, the question about the production admission was converted into yes-no data, i.e. the production permit with restrictions was also classified as 'yes', so 77% of the 113 parks examined allow production activities.

4.2. Internal connections



6. Figure: Internal relationships of park activities (Source: own editing)

In the figure, the internal relationships of the 7 park activity portfolios examined were mapped. The larger 'lift' values clearly appeared in two groups (marked in green).

The most typical element relationships of these are:

{1} Activity_Research & Development +
Activity_Legal/accounting/consulting/brokerage => Activity_Engineering/technical services

{2} Activity_Research & Development +
Activity_Legal/accounting/consulting/brokerage => Activity_Training/education

Overall, it can be said that a park that also carries out legal/accounting/consulting/brokerage activities in parallel with research and development activities has a high chance of engaging in engineering and/or educational activities.

The opposite can be said about points 3-5:

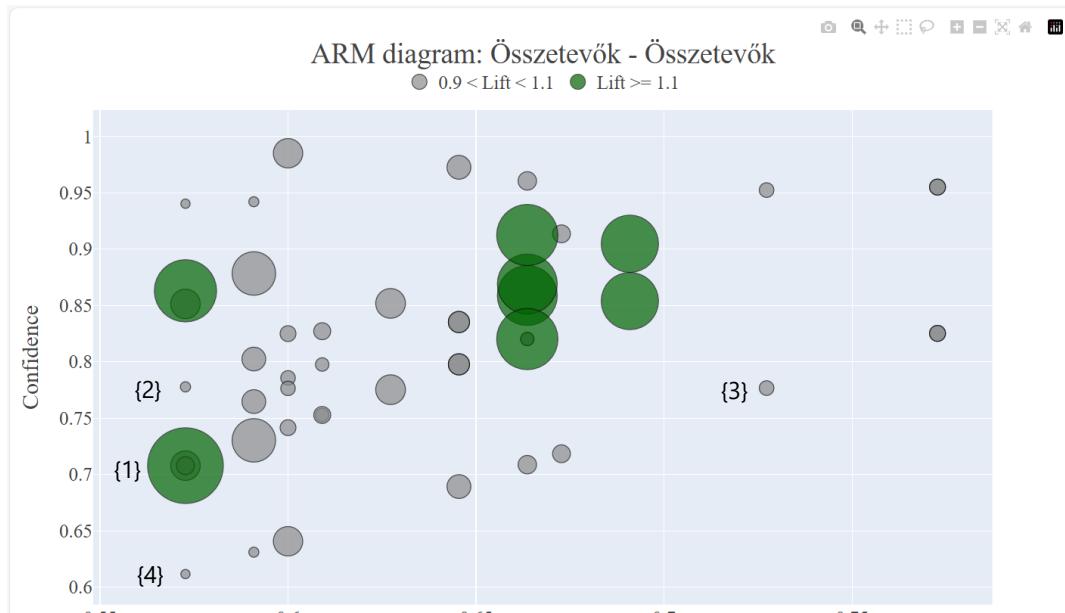
{3} Activity_Research & Development => Activity_Training/education' + Activity_Legal/accounting/consulting/brokerage

{4} Activity_Training/education => Activity_Research & Development

{5} Activity_Engineering/technical services => Activity_Training/education

A park that is likely to engage in research and development activities, but does not have legal/accounting/consulting/brokerage activities in addition to it, does not engage in educational activities in most cases, nor does a park that only provides engineering services without consulting.

The combined presence of R+D and business support services in legal/accounting/advisory indicates a mature, market-oriented ecosystem in the park. This combination requires engineering to create the product and education to maintain the knowledge base, as the goal is to manage and commercialize the entire chain of innovation locally. On the other hand, the lack of business services in addition to R+D indicates an academic center or a narrower technological focus. The reason for this is that without support services, the focus of the park often remains on basic research and education (research focus) or only performs specialized engineering tasks (market focus), but does not have the extensive support infrastructure necessary for complex business utilization.



7. Figure: Relationships of park elements (Source: own editing)

Based on the analysis of the relationship relationships of the 7 park elements, the following most characteristic pairs of elements present together can be highlighted:

{1} Element_Research institutes => Element_Accelerator + Element_University

On the other hand, the least typical pairs of elements in the figure are:

{2} Element_Leisure activities => Element_Incubator + Element_Accelerator

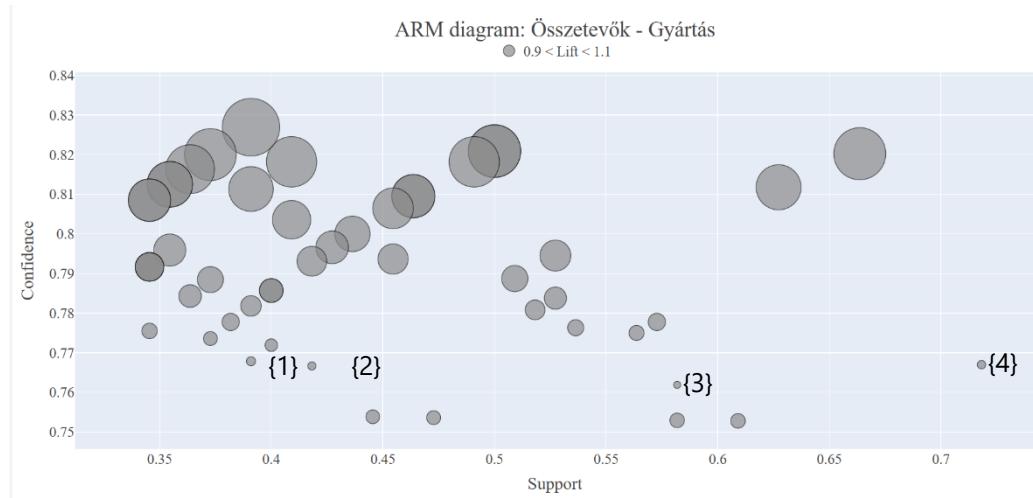
{3} Element_Incubator => Element_University

{4} Element_Incubator => Element_Accelerator + Element_Leisure activities

Science and technology parks that have a settled research institution usually have an accelerator and a university. Parks where leisure activity providers are in the majority are not typical incubators and accelerators.

The park, which also includes an established research institution, accelerator and university, realizes an ideal environment for knowledge-intensive innovation and rapid growth. The Research Institute and the University provide the basic knowledge base, the latest scientific achievements and a highly qualified workforce. This creates the basis for start-ups that want to commercialize scientific results. The presence of the accelerator indicates that the park is specifically supporting high-growth, high-risk startups with capital, mentoring, and go-to-market assistance. On the other hand, if the park is dominated by leisure activity providers, it suggests that the primary function of the park is real estate and service development, and therefore technology-based incubation and acceleration are missing from its operation.

4.3. Analysis of relationships between factors



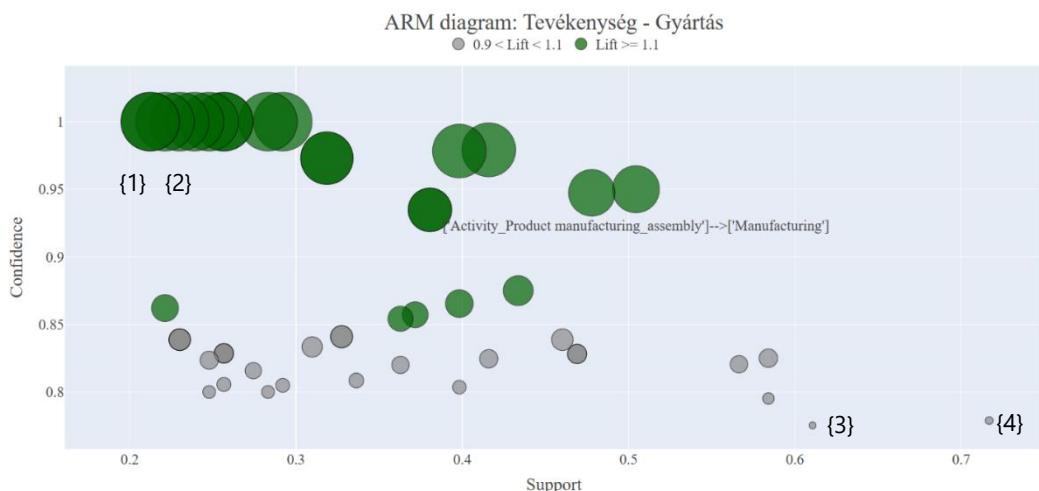
8. Figure: The relationship between production and park elements (Source: own editing)

With the ARM analysis, we examined the relationship between two portfolios (the admission of production and, firstly, the park elements). The conclusions of the analysis are based on the 'support', 'confidence' and 'lift' values of the ARM method (the latter is characterized by the size of the circles in the figure).

In general, it can be stated that there is no very strong relationship between the examined data, as the confidence value is below 0.85. However, it can be said that according to the analysis, despite the presence of certain factors, we did not find any manufacturing activity at all in the affected parks, these are the following (the related points are marked in the figure):

- {1} Element_Research Institute + Element_Social services
- {2} Element_University + Element_Leisure activities
- {3} Element_University
- {4} Element_Incubator

This also confirms that in science and technology parks where the university has an active presence, there is less typical production activity. This may be because these parks focus primarily on research and development (R+D), university knowledge transfer and innovation, where early prototype samples and experimental phases dominate instead of production. Manufacturing activities require special infrastructure and conditions, which is usually contrary to the characteristics of a knowledge-intensive, incubation environment close to the university.



9. Figure: The relationship between production and park activities (Source: own editing)

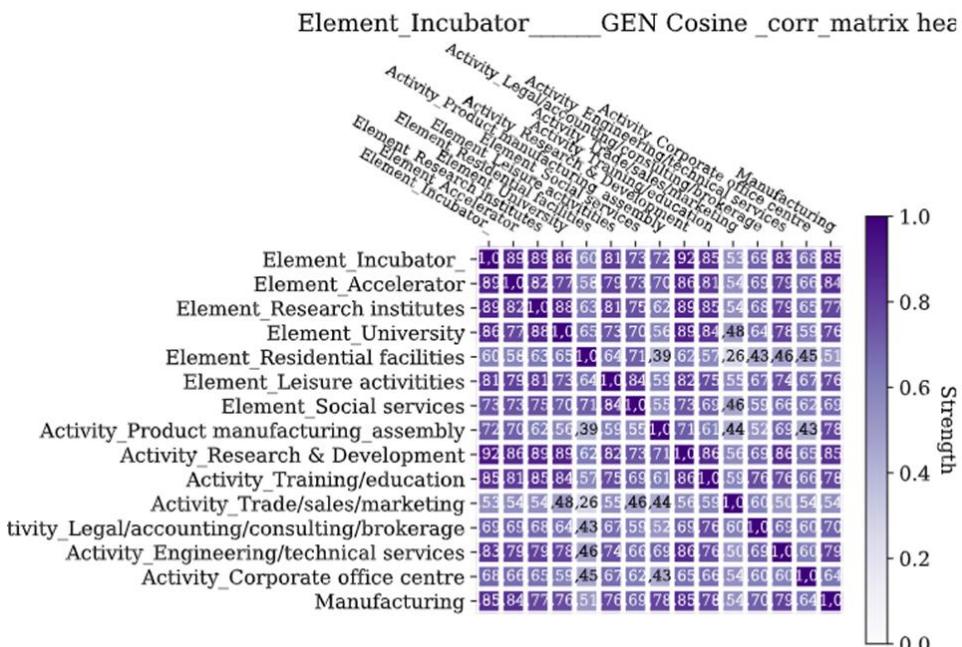
As the next step in the correlation analysis, the figure shows the relationship between park activities and manufacturing. Deducing from the green circles (confidence level above 0.85), it is clear that the existence of certain park activities appears together with the permission of production activities.

{1} Activity_Product manufacturing_assembly + Activity_Research & Development + Activity_Training/education + Activity_Legal/accounting/consulting/brokerage + Activity_Engineering/technical services

{2} Activity_Product manufacturing_assembly + Activity_Research & Development + Activity_Legal/accounting/consulting/brokerage + Activity_Engineering/technical services

The {3} Activity_Training/Education and {4} Activity_Research and Development markings in the figure indicate as a counterpoint that the existence of these activities cannot be observed together with the permission of manufacturing activities. This may be due to the fact that these activities presumably strengthen the research focus, as the workforce and resources are more concentrated on research and development. However, it is worth highlighting the circle shape marked with the number 1, which describes an entire innovation chain, as manufacturing activity is not isolated, but is a direct result of knowledge-based services and R+D, making the introduction of innovations to the market faster and more efficient. It is likely that due to the way the questions are conditioned, no negative relationship can be seen in the figure, since the individual factors reinforce each other individually and in combination.

4.4. Complex analysis results

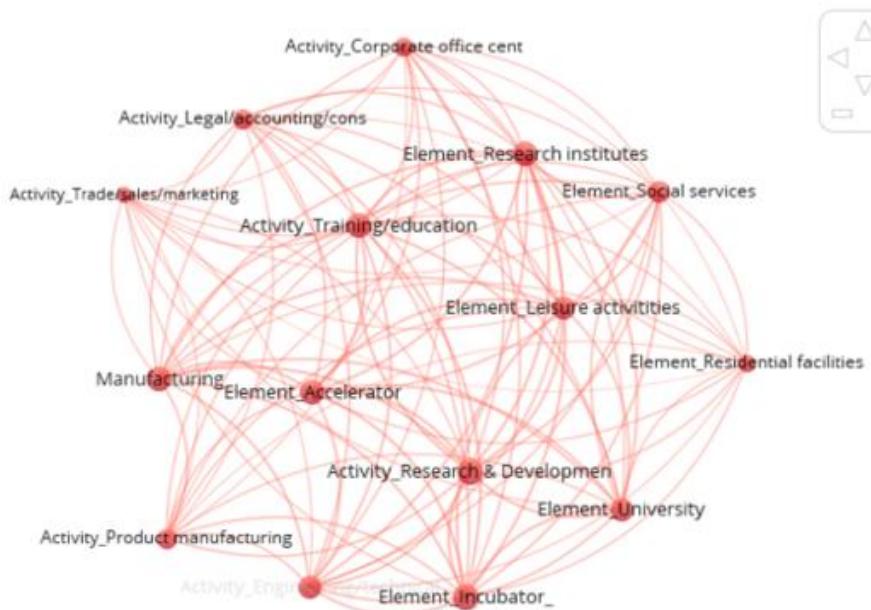


10. Figure: Correlation heat map (Source: own edit)

This correlation heat map shows the strength of the correlations between the elements and activities of the science and technology parks, while also taking into account the permissibility of production (the darker purple color indicates the strongest coexistence, 1.0 is the maximum correlation).

The strongest correlations are found between knowledge-based elements and professional support activities (values between 0.8 and 1.0). This indicates the basic, science-driven purpose of parks, the intensive research focus of parks.

- Element_Incubator, Element_Accelerator, Element_Research institutions, and Element_University are extremely closely related to each other (many values are above 0.8). This confirms that successful technology parks form an integrated network of these institutions.
- The previous grouping can be linked to the highest correlation (0.85–0.92) with the key support activities: Activity_Research & Development, Activity_Training/education, Activity_Engineering/technical services and Activity_Legal/accounting/consulting/brokerage. This shows that these activities constitute the real, knowledge-based core function of the park, without which incubation and research cannot successfully enter the market.
- Both Manufacturing and Product manufacturing_assembly correlate with all innovation elements (0.7-0.86), indicating that production in parks is typically a high-value-added activity closely related to R+D, rather than isolated mass production.



11. Figure: VOS figure (Source: My edit)

The focus of parks that cannot be classified as science-driven parks is market, in the case of which leisure and social services are more closely dependent on Activity_Trade/sales/marketing and Activity_Corporate office centre activities (values 0.55–0.70). This suggests that these elements are more typical of more traditional business parks, where the emphasis is on serving tenants on a daily basis rather than on the commercialisation of scientific findings. In terms of grouping, Activity_Trade/sales/marketing and Activity_Corporate office centre activities do not have a strong association relationship with each other or with the other factors, they form groups in themselves. And the VoOSviewer program, contrary to expectations, classified all the factors into a cluster. In terms of the strength of relationships, as expected, leisure and social services and Activity_Trade/sales/marketing were in the last two places in terms of the strength of relationships.

5. Conclusion

Based on the analysis of the relationship between the elements, activities and access to manufacturing activities of the studied science and technology parks, it can be concluded that the majority of the parks have a strong, integrated research and development (R+D) focus, while maintaining the possibility of market utilization.

For the 113 parks studied, the results supported the dominant research focus:

- The prominent presence of incubators, research institutions, accelerators and universities is a clear indication that the parks are specialized in supporting knowledge-based innovation and fast-growing technology enterprises.
- Research and Development, training/education and engineering services are the most typical activities. While R+D and education determine the research orientation (providing basic research and knowledge base), engineering services facilitate the market applicability and scaling of developments, forming a bridge between research and commercialization.
- More than half (51%) of the parks have restrictions and another 26% allow production activities to enter the park completely. The presence of the university and the R+D and educational activities reduce the permissibility of manufacturing activities, reinforcing the concentration on the research and experimental phases. In research parks, the goal is to transform knowledge with high added value into a product, rather than large-scale mass production that would require special infrastructure.

The complex relationships describe a mature, complete innovation ecosystem that is essential for successful commercialization:

- Close cooperation between incubators, accelerators, research institutions and universities is the basis for integrated knowledge transfer. Successful parks do not install separate institutions, but create an interconnected network.
- In the case of parks focusing on R+D, it is of paramount importance that legal/accounting/advisory services are present in addition to scientific activities. This indicates that a professional business infrastructure is essential

for the market exploitation of research results. If this support is lacking, the park's focus is limited to education or a specialized engineering task.

- R+D-driven Manufacturing: The strong correlation of manufacturing activity with innovation elements suggests that production in parks is not isolated mass production, but a direct extension of R+D that supports rapid time to market.

Where the focus of parks is not on knowledge and technology development, but rather on general services and convenience aspects, innovation mechanisms are weakened. The dominance of leisure activities and social services clearly indicates real estate and service development priorities. These elements are only weakly correlated with incubators and accelerators, and are more closely dependent on the activities of commercial/sales and corporate office centers. This suggests that these parks follow a more traditional business park model, where capital and mentorship are not concentrated on the growth of intensive, technology-based startups.

The vast majority of the science and technology parks examined represent a specifically research-oriented, integrated innovation model. This model is based on a triumvirate of university, research and acceleration, supported by essential professional (engineering, legal, financial) services. The aim of the parks is to manage the knowledge value chain locally: to market products with high added value from R+D quickly and efficiently. Manufacturing in this environment is not dominant, but is presumably limited to the prototype and experimental phase or high value-added production, indicating that science and technology parks are primarily focused on incubating and accelerating intellectual capital rather than mass industrial production.

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POLÁCHOVÁ, M., ŽAPKA, M. & STOJANOVÁ, B. / *The impact of national subsidy settings in the field of sustainable transport on the ESG scores of EU countries*

The impact of national subsidy settings in the field of sustainable transport on the ESG scores of EU countries

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Abstract

Transport is one of the most significant contributors to environmental impacts. Subsidy conditions for sustainable investments in transport do not focus solely on the economic value of the investment but also include social and environmental aspects. Policy makers at different levels are asking themselves how to set evaluation frameworks, criteria, and which methods to apply for evaluation the sustainability of investments. Within the EU, efforts are underway to harmonize these criteria and methods also for projects financed from EU funds. Some criteria and methods are mandatory for the provision of national subsidies (co-)financed by the EU. For the recommended criteria (EU), it is up to the individual countries to decide how strictly they will adhere to them. Using the ordinary least squares (OLS) and the weighted least squares (WLS) methods, the paper confirms the statistically significant relationship between the level of reporting obligations for criteria and methods specified in the requirements of national subsidies, and the overall sustainability ranking of selected countries (measured by the ESG Index – Risk Watch Initiative). It provides an answer to which criteria and methods are appropriate (from the perspective of achieving a higher level of sustainability) to adjust the degree of bindingness of the requirement.

Keywords: Sustainability assessment; transportation sustainability; sustainability indicator; subsidy policy; ESG index

JEL Classification: R42, Q58

1. Introduction

Achieving climate neutrality by 2050, as declared within the Green Deal, requires the allocation of private and public finance for the transformation of economies, both at EU level and national level (European Commission, 2018). The EU plans to allocate the largest share of these resources to the transport sector, as a major producer of greenhouse gases (Andersson et al., 2025; European Parliament and Council, 2020). Although the private sector is expected to play the primary role in financing the transformation of economies, significant support is also planned from the public sector at both EU and national levels. The settings of support conditions for sustainable investments, including appropriate indicators and methods for assessing the sustainability of investments, therefore plays a crucial role in meeting the stated sustainability goals.

2. Sustainable Transport

There is no single or universally accepted definition of the term sustainable transport within key EU documents as well as scientific literature (Karjalainen and Juhola, 2021). Sustainability in transport is generally defined through specific objectives. According to the United Nations, for example, the goal of transforming transport into a sustainable system by 2030 provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons." (Project Everyone, n.d.)

At the EU level, the issue of transport sustainability is addressed through the Sustainable and Smart Mobility Strategy – putting European transport on track for the future (European Commission, 2020). which sets objectives, scenarios, and identifies priority areas, among other measures. This strategy also addresses financial support from the EU through various funds, including the Connecting Europe Facility (CEF), the Cohesion Fund, the European Regional Development Fund, and InvestEU (European Commission, 2020).

Infrastructure subsidies are one of the tools that can be used to support the transition of economies (including those within the EU) to environmentally and socially sustainable investments (European Commission, 2020, 2018; Takman and Gonzalez-Aregall, 2024). Through subsidies, the state also supports investments that would not have been implemented without this financial support (for example, due to a high degree of uncertainty about the payback period). From the perspective of the efficiency of the use of subsidy funds, it is necessary not only to set the amount of

subsidies appropriately (Dueñas and Mandel, 2024; Song et al., 2022), but also to establish appropriate subsidy conditions (including evaluation criteria and their weights) under which subsidies are provided (Henke et al., 2020).

The criteria, methods, and the degree of their binding nature for the allocation of financial resources from EU funds are contained in Commission Regulation No. 480/2014 (European Commission, 2014) Commission Implementing Regulation No. 2015/207 (European Commission, 2015b), Guide to Cost-Benefit Analysis of Investment Projects (European Commission, 2015a) and Regulation (EU) 2021/1058 of the European Parliament and Council of the EU (European Parliament and Council of the EU, 2021).

For support of sustainable transport projects (investments), each EU country follows the above-mentioned regulations and sets its specific criteria and methods, the degree of binding nature within their subsidy titles and methodologies (see Methodology). The binding nature of these criteria and methods must comply with the minimum requirements set by the EU.

2.1. *Transport sustainability assessment criteria*

In connection with defining of sustainability goals, the question arises of which indicators and methods should be used to evaluate the achievement of these goals. There is no consensus in the scientific literature, regulations, methodological requirements, etc. on the evaluation frameworks, methods and criteria for assessing the sustainability of transport (sustainability investments).

Within the scientific literature, there is a large number of evaluation frameworks used (Badeanlou et al., 2022; Becchetti et al., 2022; Boix-Cots et al., 2025; Kays, n.d.) criteria and methods for assessing the sustainability of transport investments (Anastasiadou and Gavanas, 2025; Bruun and Vanderschuren, 2017; Velasco Arevalo and Gerike, 2023).

The criteria and methods used to assess the sustainability of transport can be sorted according to different classifications. The classification according to sustainability dimensions prevails in scientific articles. According to this classification, the criteria are traditionally divided into the following dimensions: economic, environmental and social. In the scientific literature, criteria from the economic and environmental areas predominate (Karjalainen and Juhola, 2021; Velasco Arevalo and Gerike, 2023). Some authors also use indicators of system efficiency and equity (Velasco Arevalo and Gerike, 2023). Anastasiadou and Gavanas, (2025) recommend including criteria from the areas of Strategic planning, design and construction and from function and operation.

Evaluation methods and criteria may also differ depending on who uses them and who is affected by the benefits/costs of the project (Velasco Arevalo and Gerike, 2023). They may also differ depending on whether they are intended to evaluate investments at the city/regional level or at the national level. There may be differences in policy objectives between different levels of government and therefore differences in the criteria required (Black et al., 2002; Figueroa and Ribeiro, 2013; Haghshenas and Vaziri, 2012; Liu et al., 2024).

Scientific studies primarily focus on the evaluation of urban/regional transport (Buenk et al., 2019; Haghshenas and Vaziri, 2012; Karjalainen and Juhola, 2021; Klinger et al., 2013). Castillo and Pitfield, (2010), Cavalcanti et al. (2017). Czech et al., (2022) are dedicated to evaluating the success of government policies at the national level. They discuss the establishment of appropriate criteria, frameworks and methods for evaluating the success of government policies in the field of sustainable transport. According to Colombo and Dijk (2023) national transport objectives should be derived from local transport needs. The criteria and evaluation methods should also be adapted to local transport specificities (Borgato et al., 2021; Klinger et al., 2013).

Unfortunately, the objectives set at different levels of public administration are not always aligned (Black et al., 2002; Haghshenas and Vaziri, 2012; Liu et al., 2024). Liu et al. (2024) Liu et al., using the example of the Netherlands, conclude that EU funding supports local efforts. In contrast, national funding focuses more on addressing bottlenecks, which does not necessarily support local investment.

The criteria proposed and used in the assessment of transport sustainability are usually quantifiable. However, a number of authors point to the absence or insufficiency of criteria, the unsuitability of the methodology for assessing qualitative aspects of sustainability (Ahonen et al., 2024; Karjalainen and Juhola, 2021). Among the qualitative indicators we can include the transport quality indicator. A smaller part of the scientific literature is devoted to the methodology of assessing transport quality (de Oña et al., 2016; Freitas, 2013; Jeon and Amekudzi-Kennedy, 2005; Klinger et al., 2013).

Some authors also point out the inconsistent methodology in obtaining the values of the given criteria. This then leads to problematic comparability of results for many indicators, including indicators of a qualitative nature. This inconsistency can also be due to the specifics of the given region, etc.(Karjalainen and Juhola, 2021).

Some authors also focus on the relationships between individual sustainability assessment criteria and factors influencing the value of the indicators. For example, Richardson (2005) uses diagrams of hierarchies to illustrate the influence and interconnectedness of factors on the main indicators of transport sustainability.

The most common methods used for the evaluation of (sustainable) transport investments are cost-benefit analysis (CBA) and multi-criteria analysis (MCA) methods (Anastasiadou and Gavanas, 2025). Due to their ability to express multiple dimensions of sustainability, including both quantitative and qualitative indicators using a single value, MCA methods predominate in the scientific literature (Anastasiadou and Gavanas, 2025; Bruun and Vanderschuren, 2017; Burchart and Przytuła, 2024; Velasco Arevalo and Gerike, 2023). Cost-benefit analysis (CBA), which requires the expression of all impacts, including intangible ones, using monetary units, still remains a frequently used method (also from the perspective of the EU methodology) (Bruun and Vanderschuren, 2017).

2.2. Sustainability assessment at the national level - ESG indexes

With international efforts to achieve climate neutrality, there is a need to measure the success of achieving this goal at the national level in an international context. One indicator of the success of countries in sustainability is the so-called ESG indices (ESG scores). Various aspects of sustainability are summarized within one value. There are several organizations that create ESG indexes. The methodology for calculating the indices varies. Gurhy and Gratcheva (Gurhy, 2024) compare ESG indicators from different providers.

The ESG index of the selected organization Risk Watch Initiative is calculated for 183 countries in the world. The calculation of this indicator is the result of an assessment of 65 variables in the areas of environment, human rights and health and safety ("Risk Watch Initiative ESG Index," n.d.). The index values are publicly available and updated annually. A number of variables for determining the value of the ESG score are part of subsidy requirements (including in support for sustainable investments - primarily in the environmental area). However, the requirements (criteria) of subsidy titles within the framework of transport support are specifically focused - concretized on a given area of support. According to the ESG index ("Risk Watch Initiative ESG Index," n.d.) the Czech Republic is ranked 20th globally for 2023. The Czech Republic's weaknesses are the high carbon intensity of the economy and the low share of renewable energy sources.

Within the scientific literature, efforts can be found to assess transport sustainability at the national level (for individual EU countries). For example, Czech et al. (2022) assess the sustainability of transport in individual EU countries using 30 indicators from the economic, environmental and social areas. The authors conclude that the founding countries of the EU generally achieve better sustainability values compared to the poorer results of the new countries from Central and Eastern Europe (Czech et al., 2022).

3. Metodology

The aim of this article is to assess whether there is a relationship between the ESG score of selected EU countries (dependent variable) and the level of binding requirements for the assessment of social and economic benefits of projects supported by subsidies in the field of sustainable transport (independent variables). Propose recommendations for setting the binding nature of criteria and methods within the framework of subsidy requirements.

To assess the relationship, it will first be necessary to determine the scope (level) of binding requirements for assessing the economic and ESG impacts of supported projects, based on an analysis and comparison of EU requirements and the requirements of current (2023-2025) national subsidy programs of selected EU countries. The subsidy requirements of countries usually remain unchanged for a certain period of time (of the order of several years).

To obtain the values (bindingness indicators) of the independent variables, the following documents were used:

- EU: European Commission Regulation No. 480/2014 (European Commission, 2014) and European Commission Implementing Regulation No. 2015/207 (European Commission, 2015b) and Regulation (EU) No. 1303/2013 of the European Parliament and of the Council (European Parliament, 2013), CBA Methodological Guide (European Commission, 2015a) and Regulation (EU) 2021/1058 of the European Parliament and of the Council (European Parliament and of the Council, 2021)
- Czech Republic: methodological documents within the framework of the Operational Transport Programme 2021-2027, Kritéria výběru projektů OPD (Ministerstvo dopravy, 2023a.); CBA Manual (Ministerstvo dopravy, 2023b); Rezortní metodika pro hodnocení ekonomické efektivnosti (Státní fond dopravní infrastruktury, 2024);
- Slovakia: Príručka CBA - OPII - Operačný program Integrovaná infraštruktúra (Ministerstvo dopravy Slovenskej republiky, 2024), Prehľad ukazovateľov Operačného programu Integrovaná infraštruktúra 2014 – 2020 vrátane popisu metodiky stanovenia hodnôt ukazovateľov (Ministerstvo dopravy Slovenskej republiky, 2014)
- Finland: email communication with the Finnish Transport and Communications Agency (Jouni Karhunen, personal communication)
- Portugal: documentation PO SEUR - Operational Programme for Sustainability and Efficient Use of Resources, including manual Critérios de seleção e prspetiva metodologia aprovada pelo comité de acompanhamento do (PO SEUR, 2015)
- Ireland: Project Appraisal Guidelines Unit 6.1 – Guidance on Conducting CBA (Transport Infrastructure Ireland, 2023a), Project Appraisal Guidelines Unit 6.2 – Preparation of Scheme Costs (Transport Infrastructure Ireland, 2023b); Infrastructure Guidelines (Department of Public Expenditure, NDP Delivery and Reform, 2023)

- Denmark: Vejledning i samfundsøkonomiske konsekvensvurderinger (Finansministeriet, 2023)
- Germany: The 2030 Federal Transport Infrastructure Plan (Federal Ministry of Transport and Digital Infrastructure, 2016a); R&D Infrastructure funding 2023 Call guideline (Bundesministerium Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie, 2023); Methodology Manual for the Federal Transport Infrastructure Plan 2030 (Federal Ministry of Transport and Digital Infrastructure, 2016b)
- Austria: Austria's 2030 Mobility Master Plan (Federal Ministry Republic of Austria, 2021); Call Guideline R&D Infrastructure Funding 2023 (Bundesministerium Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie, 2023)
- Slovenia: Resolution on the National Programme for the Development of Transport in the Republic of Slovenia until 2030 (Republic of Slovenia, Ministry of Infrastructure, 2017); Uredba o enotni metodologiji za pripravo in obravnavo investicijske dokumentacije na področju javnih financ (Vlada Republike Slovenije, 2016); Uradni list RS - 005/2017 (Vlada Republike Slovenije, 2017)
- France: Guide to socioeconomic evaluation of public investments in France (Direction générale du Trésor, 2017)
- Netherlands: CBA materials (MKBA, n.d.), a Werkwijzer MKBA bij MIRT (Modijefsky et al., 2024)
- Belgium: Plan national pour la reprise et la résilience Belgique (Cabinet du Secrétaire d'Etat à la Relance et aux Investissements Stratégiques, en charge de la Politique Scientifique, 2021)
- Luxembourg: Guide de l'Utilisateur FEDER 2021-2027 (Gestion assurée par le Ministère de l'Économie, Direction de la politique régionale, 2023); Accord de partenariat FEDER/FSE 2021-2027 (Grand-Duché de Luxembourg, 2021)
- Sweden: Trafikverket. Analysmetod och samhällsekonomiska kalkylvärden för transportsek torn: ASEK 8.0 (Trafikverket, 2024)

These following indicators and methods were identified in the analysis and comparison of the above documents: CBA (Cost-benefit analysis), Economic net present value (ENPV), Economic internal rate of return (ERR), Benefit-cost ratio (B/C), Sensitivity analysis, Risk matrix, Multicriteria analysis (MCA), External costs (noise, pollution), Assessment of comfort and perceived quality of infrastructure, Climate emissions, Evaluation of regional development, Impacts on secondary markets, Consideration of socio-economic effects (safety...), Sustainability analysis, Evaluation of time saved, Costs of traffic Accidents, Use of conversion factors for shadow prices, Consideration of environmental impacts, Specific analysis scenarios,

The level of (minimum) required binding (EU) of the observed criterion, method was transformed into a 5-level quantitative scale, which can be found in the following table. This quantification makes it possible to capture the variability in the approaches

of individual countries and to create measurable indicators of the binding nature of national requirements for the provision of subsidies.

Table 1. Rating scale for the binding nature of criteria and methods (source: own proposal)

Rating of criterion binding	Verbal expression of the level of requirement
5	mandatory with scenarios
4	mandatory
3	mandatory for large projects
2	mandatory for certain projects
1	recommended

- Recommended: The aspect is recommended by EU regulation or national methodology, which means that its use is not mandatory. Its use depends on the decision of the competent authority, the analyst or the specifics of the project.
- Mandatory for certain projects: This aspect is mandatory only for specific types of projects that meet certain conditions, such as projects generating revenue from traffic (toll systems, railways, airports, ...).
- Mandatory for large projects: This aspect is mandatory only for projects that exceed a certain financial threshold or have a large impact (for example on transport capacity or the environment). These are mostly projects with costs over EUR 50 million.
- Mandatory: This aspect is always required, regardless of the size, type or financing of the project.
- Mandatory with extended scenarios or with detailed scenarios: This aspect is mandatory and requires that detailed scenarios of changes (for example changes in the economic environment, traffic growth or climate effects) are considered. Mandatory with detailed scenarios. Or the aspect must be included and must be supplemented with detailed scenarios that simulate different variants of future development.

ESG score values (dependent variable) of selected countries are taken from the Risk watch initiative. The sample covers countries with different levels of economic development, geographical distribution and traditions within the EU. When selecting the sample, preference was given to European Union countries that achieve better (lower) ESG values compared to the former Czechoslovakia. Therefore, the sample contains a higher number of countries from Western Europe and advanced Nordic states.

Table 2. Summary of ESG Index values for selected countries (source: Own processing based on ESG index - Risk Watch Initiative ESG Index, 2023)

Country Code	Country Name	ESGI score 2023	ESGI Rank 2023
FIN	Finland	15,21	2
SWE	Sweden	15,74	3
PRT	Portugal	19,87	7
EST	Estonia	19,89	8
DNK	Denmark	20,44	10
LUX	Luxembourg	20,53	11
IRL	Ireland	21,57	12
DEU	Germany	22,05	14
AUT	Austria	22,4	15
NLD	Netherlands	22,61	16
BEL	Belgium	23,03	17
SVN	Slovenia	23,84	18
FRA	France	24,88	19
CZE	Czechia	25,15	20
SVK	Slovakia	27,68	30

The following complementary econometric approaches were used to identify the relationships between the levels of bindingness of the monitored criteria and methods for the evaluation of transport infrastructure and the ESG index of the given countries. The basic model was a linear regression measured using the Ordinary least squares (OLS) method, which makes it possible to quantify the direct effects of individual aspects of the evaluation on the overall ESG index of the landscape. From the beginning, there was a high number of multicollinear independent variables in the analysis (sensitivity analysis, multicriteria analysis, external costs, consideration of socio-economic impacts, evaluation of saved time, use of conversion factors for shadow prices, consideration of environmental impacts and specific scenario analyses), which were detected by the VIF test and therefore had to be removed from the measurement. When measured by diagnostic tests, this method was found to be insufficient and therefore the weighted least squares method (WLS) was used. WLS is used when the explanatory power of the OLS method is insufficient or when heteroskedasticity is present in the given model. This approach is suitable for small samples with the presence of outliers or heterogeneous observations, as it allows adding weights to individual landscapes based on their variability.

When using regression analysis using the WLS method, it was necessary to create a weighted estimate (weight) for individual landscapes using the two-step feasible

generalized method of squares (FGLS), where in the first step residuals from the original OLS analysis are obtained. Subsequently, it was possible to perform the transformation to weight using (Mutiu, 2015).

$$(1) \quad \text{weight} = \frac{1}{(|\text{OLS residual}|+0,001)^2}$$

Where the denominator represents the residuals from the OLS model for the selected country and the constant 0.001 to ensure numerical stability for countries with very small residuals. In this way, higher weights will be assigned to countries with fewer residuals in OLS (better predictable observations). Lower weights will be assigned to countries with more residuals (potential outliers or specific cases). This procedure effectively reduces the impact of outliers on the coefficients and can improve the accuracy and predictive value of the model as a whole. Both models are implemented in the Gretl software, which allows and describes detailed diagnosis of the results.

The key indicators of the quality of analyses are the coefficient of determination, the modified coefficient of determination, the probability value of the statistical F-test, which shows the statistical significance of the model as a whole, and the t-test of the parameters, which express the statistical dependence of the individual parameters of the regression analysis.

To verify multicollinearity between independent variables, the VIF test is used. The following diagnostic tests were also used - tests of correct specification such as Ramsey RESET test and nonlinearity tests for squares and logarithms, homoscedasticity tests of residuals (Breusch-Pagan test), Q-Q graph of residuals and White's test, and tests of normality of residuals with graphical assessments of correctness.

4. Results of the comparison of national subsidy requirements and the influence of the degree of bindingness of criteria and methods on the ESG scores of selected countries

To achieve the objective of this article: assess whether there is a relationship between the ESG score of selected EU countries (dependent variable) and the level of binding requirements for the assessment of social and economic benefits of projects supported by subsidies in the field of sustainable transport (independent variable). Propose recommendations for setting the binding nature of criteria and methods within the framework of subsidy requirements.", it was first necessary to conduct an analysis and comparison of subsidy titles and methodologies of selected countries.

4.1. Transport sustainability assessment criteria

The basic method for evaluating investments according to the European Commission Implementing Regulation No. 2015/207 (European Commission, 2015b)

is the cost-benefit analysis (CBA). It is mandatory for large projects financed from European funds (especially from the Cohesion Fund and the European Regional Development Fund), but many countries use it compulsorily for all projects. MCA methods, despite their more frequent use in the scientific literature, are only recommended by the EU. The level of obligation of their use within the subsidy titles of EU countries is also among the lowest.

According to the above-mentioned regulation, it is mandatory to include intangible impacts in the CBA, such as the value of time saved as a result of the project and environmental impacts. The level of mandatory use for these indicators reaches the highest values.

Furthermore, the Regulation defines basic requirements, such as the inclusion of the economic net present value (ENPV), the economic internal rate of return (ERR) or the benefit-cost ratio (B/C). These indicators are modified dynamic indicators of investment efficiency evaluation, which include the intangible impacts of the investment within the cash flow of the project's benefits and costs.

The lowest average level of binding is achieved by the qualitative indicators of comfort and perceived quality of infrastructure, assessment of impacts on secondary markets and multi-criteria analysis. This assessment confirms the lower emphasis on assessing the sustainability of transport using qualitative indicators.

From the subsidy criteria and methods found within the EU regulation and methodology, there is an obvious "overlap" in selected criteria. Some criteria and methods are stated in a rather general way (allowing for the inclusion of multiple impacts), some are defined specifically.

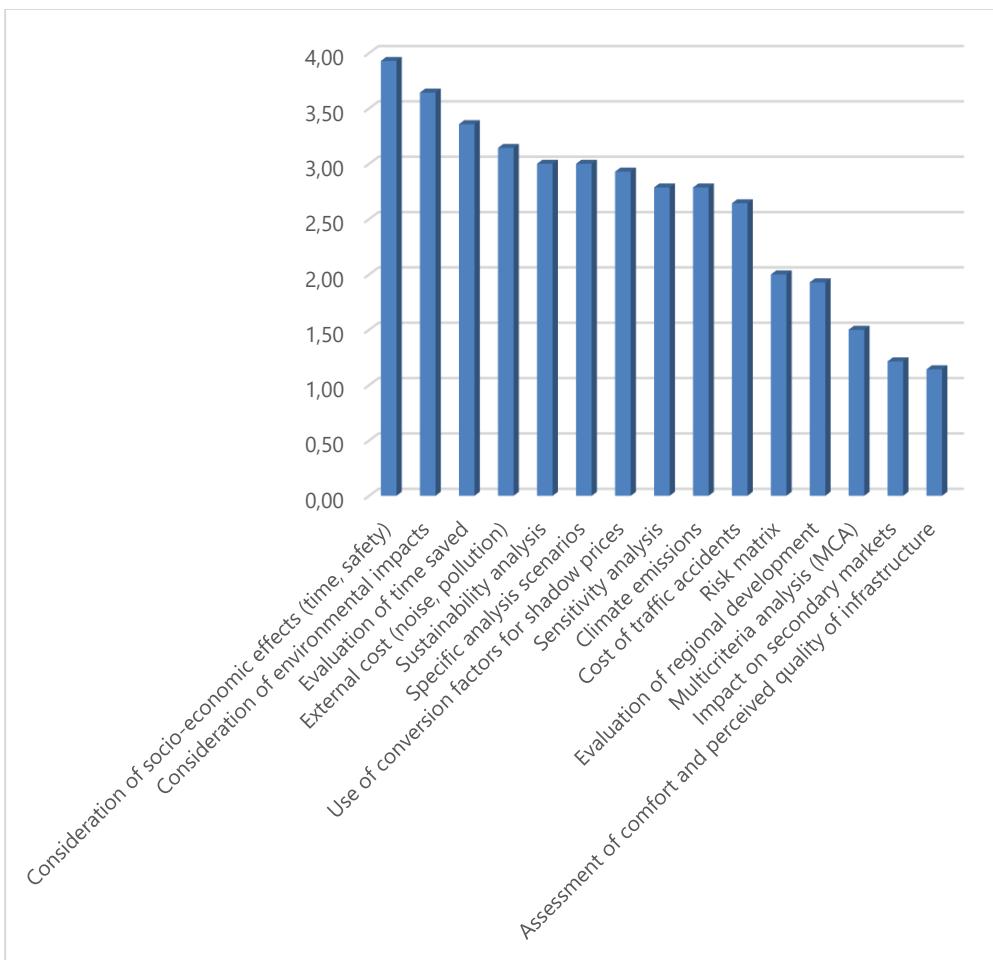


Figure 1. Average level of binding subsidy requirements by country (source: own processing)

Germany, Ireland and Sweden have the strictest conditions for evaluating investments in sustainable transport (in terms of the degree of binding criteria and methods). These countries are also in the top half of the best-ranked countries in the ESG index. Belgium, Luxembourg, Austria and Slovakia have the least strict requirements for reporting criteria and use of methods.

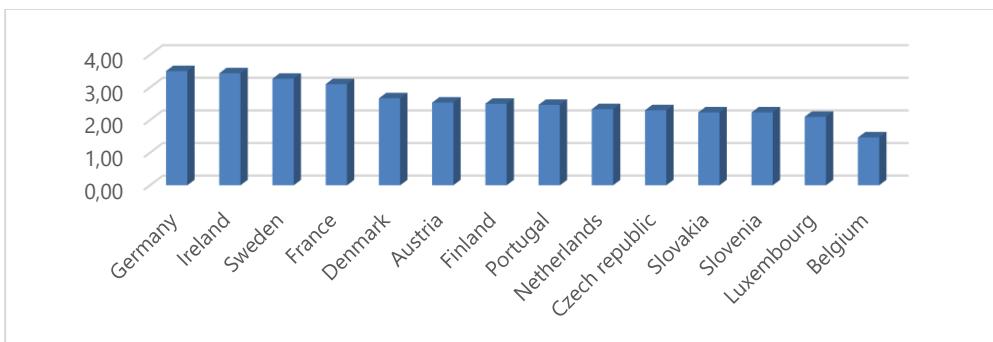


Figure 2. Average level of binding subsidy requirements by country (source: own processing)

4.2. Results of regression and correlation analysis

After removing the independent variables that suffered from multicollinearity in the regression analysis, the following variables remained: risk matrix, comfort assessment, climate emissions, evaluation of regional development, impact on secondary markets and sustainability analysis. The selection was guided by a combination of economic relevance and multicollinearity diagnostics (see Methodology).

Subsequent correlation analysis serves to check the multicollinearity of the variables. The following table, which shows the correlation matrix between the dependent variable ESG index and the independent variables, it can be seen that the highest value with the dependent variable is climate emissions and sustainability analysis. However, it is necessary to emphasize the indication of strong dependence ($r=0.86$) between these two variables, which may distort the result, but after performing the VIF test, there is no multicollinearity.

Table 3. Correlation matrix (source: Own processing using the Gretl program)

	Risk matrix	Comfort rating	Climate emissions	Evaluation of regional development	Impact on secondary markets	Sustainability analysis	ESG
Risk matrix	1	0,1498	0,6261	0,2645	0	0,4854	0,0292
Comfort rating	0,1498	1	0,3483	0,1682	0,2091	0,27	-0,3262
Climate emissions	0,6261	0,3483	1	0,5713	0,3277	0,8631	0,3385
Evaluation of regional development	0,2645	0,1682	0,5713	1	0,3891	0,4429	-0,0283
Impact on secondary markets	0	0,2091	0,3277	0,3891	1	0,2541	-0,2162
Sustainability analysis	0,4854	0,27	0,8631	0,4429	0,2541	1	0,2603
ESG	0,0292	-0,3262	0,3385	-0,0283	-0,2162	0,2603	1

After testing for the correct specification, the results of the square and logarithm nonlinearity test (0.6805) and the result of the Ramsey RESET test (0.8681) came out, which prove the correct specification of the given model because all the test results had p-value greater than 0.05. This means that the model does not need to be further modified by adding or transforming variables. Diagnostic tests of residual heteroskedasticity, specifically the Breusch-Pagan test, which yielded the result of 0.1040. This result is close to the classification boundary between heteroscedasticity and homoscedasticity of the residuals, but White test demonstrated the fact that the residuals of the model are homoscedastic with a result of 0.8024. The final diagnostic test, the residual normality test, proved the fact that the residuals do not have a normal distribution with a result of 0.0039.

The statistical insignificance was also found for the variables comfort assessment, impact on secondary markets and sustainability analysis. This caused statistical insignificance of the model as a whole and affected its explanatory value. The model can only explain ESG to 67.44%. This result may be due to various factors, such as overfitting of the variables and insufficient degrees of freedom, hidden heteroscedasticity of the residual that was not captured by the diagnostic tests.

In response to this result, the residuals of the OLS variables were inserted into the formula for calculating the weight mentioned in the methodology, that would be used as a weight in the WLS model.

The regression model based on the WLS principle, in the diagnostic tests of statistical significance, demonstrated the statistical significance of all selected independent variables and the model as a whole.

Diagnostic tests for the WLS model were not directly available in the Gretl software. However, the exceptionally high explanatory power of the variability of the dependent variable ($R^2 = 97.6\%$), the statistical significance of all coefficients at the 1% level, and the highly significant F-test ($p < 0.001$) provide strong evidence of the validity of the model. The WLS transformation was designed to remove possible hidden heteroskedasticity that may not have been identified in the OLS model.

The following text will explain the regression equation of the previously mentioned WLS model and the influence of individual independent variables on the ESG index of the selected country.

$$\text{ESG} = 27,6 - 1,55 * \text{Risk matrix} - 5,26 * \text{Assessment of comfort} + 3,92 * \text{Climate emissions} - 0,950 * \text{Evaluation of regional development} - 2,22 * \text{Impact on secondary markets} - 1,00 * \text{Sustainability analysis}$$

The first coefficient β_0 (27.6) explains the fact that if all explanatory variables were zero, the value of the ESG index would be 27.6-unit points for the selected country. The coefficient β_1 (-1.55) says that if the Risk Matrix increases by 1 unit, *ceteris paribus*, the predicted value of the ESG index will decrease by 1.55 points. Coefficient β_2 (-5.26) indicates the assumption that if the Rating of comfort and perceived infrastructure quality increases by 1 unit, *ceteris paribus*, the ESG index will decrease by 5.26 points. The coefficient β_3 (3.92) indicates the assumption that if the value of the variable Climate emissions increases by 1 unit, *ceteris paribus*, the value of the ESG index will increase by 3.92 points. Coefficient β_4 (-0.950) indicates the assumption that if the value of the variable Evaluation of regional development increases by 1 unit, *ceteris paribus*, then the value of the ESG index will decrease by 0.950-unit point. The coefficient β_5 (-2.22) indicates the assumption that with an increase in the influence on the secondary market for selected countries, *ceteris paribus*, the value of the ESG index will decrease by 2.22-unit points. The coefficient β_6 (-1.00) indicates the assumption that if the value of the variable increases by 1 unit, *ceteris paribus*, the value of the ESG index will decrease by 1 unit point.

5. Discussion and Conclusion

The results of this study are of practical importance for better setting the conditions of subsidy titles in the form of predetermined degrees of binding of individual criteria and methods of managing projects subsidized by European funds, especially in the context of fulfilling ESG (Environmental, Social, Governance) objectives (in terms of ESG index methodology).

Public administration bodies responsible for investments should incorporate the identified key criteria into their evaluation processes to minimize the resulting value of the ESG index (i.e. improve ESG performance). For example, in the assessment of climate emissions, where the given criterion is highly binding, such as in the form of scenarios, the monitored ESG index is negatively affected. As a result, the value of the ESG index increases and the ESG performance decreases.

Indicators and methods such as the risk matrix, assessment of comfort and quality of infrastructure and impact on secondary markets should become part of the standard assessment at least of large transport projects (the level of bindingness of these criteria and methods should be increased) co-financed from EU funds.

Assessment of comfort and quality of transport, some impacts on secondary markets (non-quantifiable) are among the qualitative indicators. Qualitative indicators are used to a lesser extent than quantitative indicators for assessing transport sustainability (see Karjalainen and Juhola, 2021) and, as we can see in the comparison, they achieve a lower level of reporting obligation within the framework of subsidy titles.

Emphasis on these aspects can help identify projects with a higher sustainable benefit and support investments that will lead to higher sustainability, including a possible improvement of the country's ESG index.

Within the monitored countries, worse ESG performance (measured by the ESG index of the Risk watch initiative) is evident in Central European countries (Czech Republic, Slovakia). Czech et al., (2022), also points to worse ESG performance in the field of transport (in Central and Eastern European countries). This study found that these countries not only achieve worse results in the area of sustainability, but also their subsidy requirements are usually less stringent (i.e. they achieve worse results in terms of the degree of bindingness of the monitored criteria and methods). At the same time, it is necessary to add that the ESG index used is not a direct aggregation of the requirements of national methodologies in transport.

We recommend scaling the weights when evaluating projects according to the reliability of estimates (similar to the WLS model) so that projects with better predictable impacts have a more appropriate impact on the overall evaluation - this will reduce the risk that a few non-standard projects (outliers) will distort the decision-making.

Regarding the limiting conditions of the research, the study includes only 14 European countries, which represents a relatively small sample. In addition, the selection is not completely random - more advanced EU countries with a better ESG balance were preferred. This may limit the general validity of the findings, and the results may not be directly transferable to other countries (for example, developing economies or countries outside the European Union).

The relatively high value of R^2 in the WLS model (97.6%) with such a small number of observations may indicate the risk of overfitting the model to the data. Although the diagnostic tests confirmed the correct specification and significance of the model, the normality of the residuals was not fully satisfied and there was a borderline indication of heteroskedasticity. The small number of countries and the number of variables also implies a low degree of freedom, which limits the statistical reliability of the estimates. The results show correlations but do not necessarily demonstrate causality. It is possible that countries with better ESG performance are also more likely to adopt stricter methodologies, and not necessarily the other way around.

In conclusion, the analysis revealed a significant association between the level of binding national assessment methodologies and the level of ESG performance in the studied countries. Ordinary linear regression (OLS) showed that not all rating aspects have a statistically significant impact, and the model was able to explain approximately 67% of the variation in the ESG index. Some variables (for example, the assessment of comfort and perceived quality of infrastructure or the impact on secondary markets) did not show a significant effect in the OLS model, indicating the limited explanatory power of the model as a whole. However, after the application of weighted regression (WLS), all included variables reached statistical significance (at the 1% level) and the explained variability of the ESG index increased to 97.6%. This dramatic change indicates that, after taking into account the hidden heterogeneity in country residuals (e.g. outliers), the relationship between the qualitative assessment of projects and ESG results is extremely strong. From a content point of view, the results indicate that countries that require consistent and more binding risk matrices and assessments of infrastructure comfort and quality generally achieve better ESG performance. On the contrary, in the case of climate emissions, the coefficient is positive, i.e. stricter requirements are empirically associated with an increase in the ESG index (deterioration). The findings support the argument that the systematic integration of ESG criteria into public investment decision-making goes hand in hand with better sustainability results at the national level.

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Szőcs, A. / *Geographical and sectoral distribution of the most valuable start-ups in the DACH countries (Germany, Austria, Switzerland)*

Geographical and sectoral distribution of the most valuable start-ups in the DACH countries (Germany, Austria, Switzerland)

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Abstract

This study provides a quantitative analysis of unicorn startups (privately held companies valued at over \$1 billion) in the DACH region (Germany, Austria, Switzerland), examining their geographical distribution and sectoral focus. A further aim of the research is to assess the educational background of the founders. The study is based on a primary dataset comprising 39 unique unicorn companies and their 86 founders.

The analysis reveals a pronounced German dominance within the regional ecosystem, with 84.6% of the unicorns originating in Germany. The geographical distribution is exceptionally concentrated, establishing two primary hubs: Berlin (48.7%, 19 companies) and Munich (17.9%, 7 companies). This strong centralization in Germany's two largest tech centers underscores the crucial role of concentrated talent and capital pools in achieving scale-up success. Sectorally, the DACH region's profile is dominated by Enterprise Technology (B2B) (11 companies). The second most frequent sector is Consumer & Retail (9 companies), followed by Financial Services (8 companies). However, a Chi-Square test investigating the link between Sector and Founding City yielded a p-value of $p \approx 0.081$, indicating that strong regional sectoral specialization cannot be statistically verified.

The founder analysis reveals a highly educated cohort (Master's: 69.8%; PhD: 19.8%). Key findings highlight extreme founder mobility: only 31.4% exhibit Local Loyalty to their university city. Statistical tests found that the level of advanced education does not significantly correlate with Local Loyalty, reinforcing the high mobility of top talent. Crucially, International Study experience (60.5% of founders) was found to be significantly correlated ($p \approx 0.021$) with the pursuit of a Business Management Qualification (53.5%).

The research concludes that the DACH unicorn ecosystem is fueled by highly mobile founders who proactively combine global exposure with formalized business skills. Policy implications emphasize the need to attract global talent, prioritize applied business training, and promote gender equity to fully utilize the region's human capital potential.

Keywords: start-up, unicorn, innovation ecosystem

JEL Classification: G21, G23, G38, M13

1. Introductory thoughts

The rise of technology startups has brought about a significant transformation in the geographical distribution of innovation ecosystems over the past two decades. In particular, the DACH region – encompassing Germany (D), Austria (A), and Switzerland (CH) – has become one of the defining centers of the European startup sphere. Unicorn startups emerging in the region – private technology ventures whose market valuation reaches or exceeds 1 billion US dollars – are not only economically relevant but can also be interpreted as indicators of innovation capacity, human capital flow, and regional competitiveness.

While in 2013 we could speak of only a few dozen unicorn startups globally, their number is projected to exceed 1,200 by 2025 (CB Insights, 2025). On a global scale, this number still means that, like the mythical unicorn, their occurrence is quite rare. Their emergence among the economic players of a given country or region is still considered an outstanding achievement, making them key indicators of the startup ecosystem's development and success. The fact that Germany has created the highest number of unicorns in the European Union raises the question of which factors contributed to achieving this prominent position.

The research also examines which regions and cities within Germany and the DACH region play a decisive role in startup development. More than 60% of the examined unicorns originated from just two cities, Berlin and Munich. Naturally, Zurich in Switzerland and Vienna in Austria also play significant roles, but the two mentioned German metropolises have become major factors even at a European level in recent times. Berlin has transformed over the past decades into a multicultural metropolis, making it one of Europe's most influential cities both economically and culturally. Munich, due to the presence of large corporations such as BMW, Allianz, Siemens, and MAN, is a major economic hub not just in Europe, but globally. A defining factor for both cities is their possession of traditionally strong higher education institutions. The Humboldt and Technical Universities in Berlin, and the TUM (Technische Universität München) in Munich, provide fertile ground not only for large corporations but also for the development of innovative, emerging companies.

The literature dealing with innovation ecosystems has a significant history. A key element of this research is examining the previous studies that analyze the success of certain regions, cities, and their agglomerations. Initiatives supporting cooperation between the corporate sector and higher education institutions, the availability of research infrastructure, government support, or a favorable regulatory environment are all important factors. The next chapter of this analysis, within the framework of the literature review, presents the development and sectoral characteristics of the DACH countries and their key cities. Through this analysis, the aim was to look behind the

curtain and understand what role the founders and their educational backgrounds play in the creation of the most successful startups.

2. Literature review

2.1. A Brief History of Innovation Ecosystems in the DACH Countries

The innovation profile of the DACH region (Germany, Austria, Switzerland) is deeply rooted in traditional industrial strengths and high-value manufacturing (Porter, 1990). Germany's Mittelstand (small and medium-sized enterprises) has historically served as the backbone of technological advancement, ensuring long-term, incremental innovation (Audretsch & Lehmann, 2005; Pahnke & Welter, 2019).

The accelerated development of the startup ecosystem can be traced back to the early 2000s, primarily in Berlin, with the emergence of company builders like Rocket Internet (Gans, 2016). This early phase was characterized by B2C (consumer-facing) models and "copycat" strategies. However, the focus shifted significantly in the 2010s towards B2B (Enterprise Tech) and Deep Tech solutions, leveraging the region's strong engineering and scientific heritage (OECD, 2019). Today, the innovation system has largely moved towards "knowledge-intensive business services" (Müller & Kornmüller, 2020).

2.2. The DACH Startup Ecosystem: Key Cities and Characteristics

The DACH region's ecosystem exhibits significant heterogeneity and centralization, a pattern strongly supported by the unicorn data analyzed in this study.

Urban Hubs

- Berlin: Initially emerged as a cultural and lifestyle center, and today ranks as one of Europe's largest Fintech and Consumer Tech hubs. It is characterized by a high influx of international talent and a strong presence of Venture Capital (VC) (Startup Genome, 2023). The literature frequently highlights the capital's ability to achieve rapid scale-up growth.
- Munich (Bavaria): The stronghold of technological and industrial innovation. It specializes primarily in Deep Tech, B2B software (e.g., Enterprise Tech), and Mobility Tech. It is typically more closely linked to local major corporations and top-tier academic institutions (TUM) (Feld, 2018).
- Zurich/Vienna: Smaller, yet highly specialized focus points. Zurich (Switzerland) is strong in Fintech and Blockchain, often due to its proximity to ETH Zurich (WEF, 2021). Vienna (Austria) functions as a gateway to Central and Eastern Europe,

often specializing in Health Tech and EdTech (Austrian Economic Chamber, 2022).

The ecosystem is increasingly defined by its B2B (Business-to-Business) orientation, reflecting the region's industrial foundations. However, the gender gap remains a significant concern. Research indicates that the proportion of female founders in the region consistently lags behind the European average (European Commission, 2024), which is confirmed by the fact that there are currently only two female founders among the 86 DACH unicorn founders surveyed.

2.3. Higher Education Systems in the DACH Countries and their Link to Startups

Higher education institutions in the DACH region are world-class in technology transfer and supporting spin-off company formation (Etzkowitz, 2003).

- **Innovation Institutions:** Technical universities such as TUM (Munich), ETH Zurich, and KIT (Karlsruhe) actively support entrepreneurship through dedicated incubation programs and departments (Wadhwa & Wadhwa, 2014). Unicorns linked to these universities (such as Celonis from TUM) highlight the success of the academic spin-off model.
- **Economic Expertise:** Alongside technical knowledge, institutions like the University of St. Gallen (HSG) and other top business schools provide the necessary economic, financial, and management capabilities essential for global scale-up. This explains the high proportion of founders with an economics/business background.
- **Knowledge Transfer:** Collaboration between higher education institutions and startups has intensified in the past period. Consequently, there is a growing number of startups in deep tech and research-intensive areas (Audretsch, 2002; Wright, Clarysse, Lockett, & Knockaert (2018).

3. Methodology and data

A primary database was compiled for this research, containing data on 39 unicorn startups operating in the DACH region. The data for the examined unicorn companies were organized along the following variables:

- Company Valuation
- Date of Achieving Unicorn Status
- Country and City of Establishment
- Sector (Industry)

The companies included in the sample are associated with a total of 86 unique founders, for whom the following data were collected and organized into the database:

- Founder's Name
- Gender
- Age
- Higher Education Institution Attended, level and field of the degree, and its City.

3.1. Analysis of the geographical distribution of DACH unicorns

A strong concentration is observable regarding the geographical distribution of the unicorns founded in the DACH countries. Approximately 85 percent (84.6%) of the examined startups were founded in five cities: Berlin, Munich, Zurich, Vienna, and Lausanne.

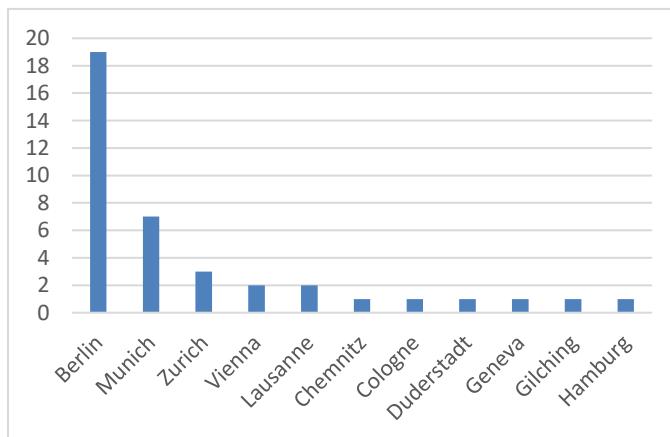


Figure 1. The founding location of the DACH unicorns (source: own edition based on CB Insights, 2025)

A similar concentration can be observed in terms of the locations of the universities attended by the founders of DACH unicorns. However, in this case, Munich takes Berlin's place as the dominant higher education location in Germany.

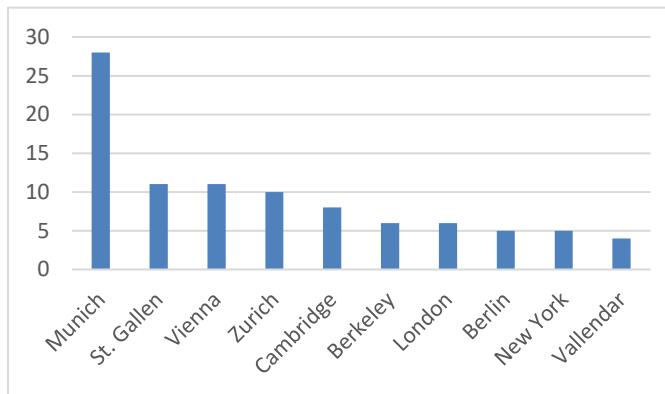


Figure 2. Location of universities graduated from by founders of DACH unicorns (source: own edition based on LinkedIn, 2025)

To explore the relationship between the founder's academic background and the geographical focus of their venture, a Chi-Square Test of Independence was conducted. The analysis sought to determine if there is a statistically significant association between the city where a founder completed their higher education and the city where they established their unicorn.

- Null Hypothesis (H0): There is no statistically significant association between the location of the founder's university city and the founding location of the unicorn.
- Alternative Hypothesis (HA): A statistically significant association exists.

For a robust test, the data were aggregated into a 2x2 contingency table, comparing whether the founder studied in a Top 5 DACH Hub (Berlin, Munich, Zurich, Vienna, Lausanne) versus elsewhere, against whether the startup was founded in one of these same Top 5 Hubs versus elsewhere.

The Chi-Square test yielded a highly determinant result (Chi-Square = 19.587, $df = 1$, $p < 0.001$). Since the calculated Chi-Square value (19.587) significantly exceeds the critical value (3.841) and the p-value is well below the significance threshold of 0.05, the null hypothesis is rejected. This outcome confirms that a statistically determining association exists in the DACH region between the location of a founder's higher education and the founding city of their successful venture.

As shown in the contingency table, founders who studied in a Top 5 Hub were decisively more likely to establish their unicorn in one of those same hubs (90.9% of founders who studied in a hub founded there, compared to 58.0% of those who studied elsewhere). This result strongly supports the concept of academic clustering

or "brain drain," where major educational centers not only attract talent but also successfully retain them to form the core of the local entrepreneurial ecosystem. The highest-value ventures tend to be founded by individuals who are already integrated into the dense network of knowledge and capital offered by these leading urban centers.

3.2. *The correlation between the educational background of the founders and the founding city*

The following descriptive analysis establishes the academic profile of the 86 founders of the 39 examined DACH unicorn companies. The data, aggregated across seven key dummy variables, highlights the highly educated and specialized background of the individuals who spearheaded these billion-dollar enterprises. The analysis focuses on achieved qualification levels, the presence of specific business-related training, and the degree of international exposure and local engagement during the founders' university careers.

Table 1. Academic profile of the 86 founders of the 39 examined DACH unicorn companies (source: own editing based on LinkedIn profiles)

Variable (Academic Trait)	N (Count)	Proportion (%)
Bachelor's Degree	80	93.00%
Master's Degree	60	69.80%
PhD/Dr. Iur. Degree	17	19.80%
International Study (Outside DACH)	52	60.50%
Business/Management Qualification	46	53.50%
Local Loyalty (Graduated in Founding City)	27	31.40%

The descriptive analysis reveals a profile characterized by high educational attainment across the board. A commanding majority of founders (93.0%) hold at least a Bachelor's degree, and nearly seven out of ten (69.8%) have attained a Master's degree. The proportion of those holding a PhD or Dr. Iur. degree is significant at 19.8%, indicating a strong presence of deep academic and domain expertise within the DACH founder pool.

Key findings regarding professional specialization and mobility are as follows:

- **International Mobility:** Most founders (60.5%) have studied outside the DACH countries, which confirms a high level of international exposure and openness to mobility among the group.

- Business Specialization: Slightly more than half of the founders (53.5%) possess a business or management qualification, emphasizing the necessity of formal management knowledge alongside technical expertise.
- Local Loyalty: The most critical finding is the low rate of Local Loyalty. Only 31.4% of the founders established their unicorn in the same city where they graduated from university. This means less than a third of the founders remained in their academic city for their entrepreneurial venture, pointing to the high mobility of top-tier talent within the DACH ecosystem.

This analysis investigates whether the attainment of a high academic degree (Master's or PhD/Dr. iur. degree) has a significant correlation with the founder's Local Loyalty (founding the unicorn in their university city).

Hypothesis and Calculation

- Null Hypothesis (H0): There is no correlation between high academic qualification and local loyalty.
- Alternative Hypothesis (H1): A correlation exists.
- Variables (N=86): High Academic Qual (Master or PhD) and Local Loyalty.

Table 2. Contingency Table (Observed Frequencies) (source: own editing)

Column heading	Local Loyalty (Yes)	Local Loyalty (No)	Total
High Academic Qual (Yes)	19	41	60
High Academic Qual (No)	8	18	26
Total	27	59	86

The Chi-Square statistic is calculated as follows:

$$\chi^2 = \sum (O - E)^2 / E$$

Where O is the Observed frequency and E is the Expected frequency.

- Result: $\chi^2 \approx 0.00656$
- Degrees of Freedom (df): 1
- P-value: $p \approx 0.935$

Conclusion

- **Finding:** Since the calculated p-value ($p = 0.935$) is far greater than the significance level of $\alpha = 0.05$, we do not reject the null hypothesis.
- **Interpretation:** There is no statistically significant correlation between having a high academic qualification (Master's or PhD) and the founder's decision regarding local loyalty. The level of advanced education alone does not influence the choice of founding city.

This analysis examines whether international academic experience (studying outside the DACH countries) correlates with the propensity to obtain specific business or management qualifications.

Hypothesis and Calculation

- **Null Hypothesis (H0):** There is no correlation between studying abroad and having a business/management qualification.
- **Alternative Hypothesis (H1):** A correlation exists.
- **Variables (N=86):** International Study and Business Management Qualification.

Table 3. Contingency Table (Observed Frequencies) (source: own editing)

Column heading	Business Quals (Yes)	Business Quals (No)	Total
International Study (Yes)	33	19	52
International Study (No)	13	21	34
Total	46	40	86

- **Result:** $\chi^2 \approx 5.286$
- **Degrees of Freedom (df):** 1
- **P-value:** $p \approx 0.021$
- **Phi Coefficient (ϕ):** $\phi \approx 0.248$ (A measure of correlation strength for 2x2 tables).

Conclusion

- **Finding:** Since the calculated p-value ($p = 0.021$) is less than the significance level of $\alpha = 0.05$, we reject the null hypothesis.
- **Interpretation:** There is a statistically significant correlation between studying abroad and possessing a business/management qualification. The correlation is positive, suggesting that founders who have international academic experience are significantly more likely to pursue additional business-focused professional courses. This indicates that global exposure enhances the demand for practical, professional skills.

3.3. Analysis of the geographical distribution of DACH unicorns

A comparable concentration was observed in the sectoral distribution of the 39 unicorns examined. The CB Insights portal, which serves as the basis for the database, classifies unicorn startups globally into eight main sectors. Among the companies examined in the DACH region, four main sectors show a particularly high concentration.

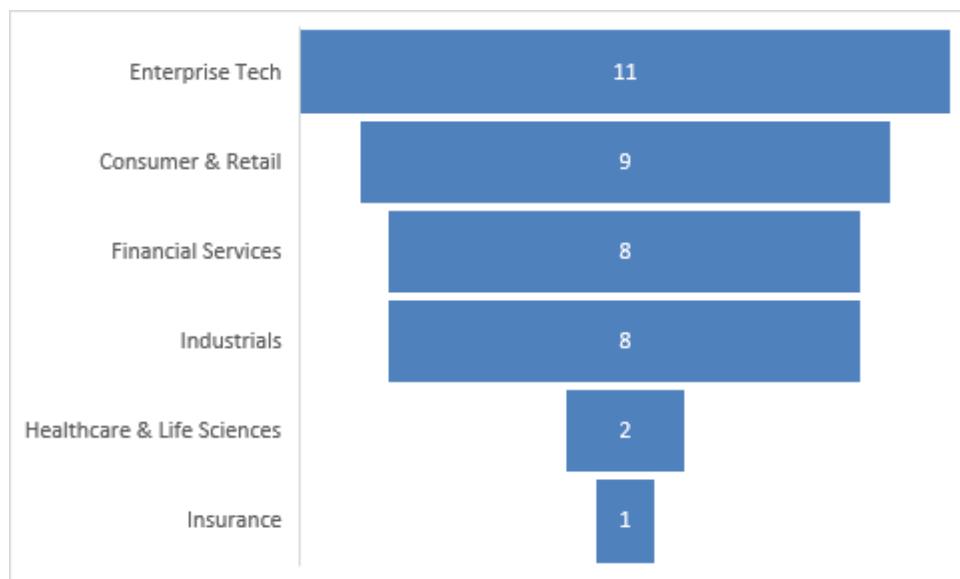


Figure 3. Sectoral distribution of DACH unicorns (source: own edition based on CB insights, 2025)

This study also aims to determine whether the distribution of unicorn companies across different industry sectors is independent of their founding location within the DACH region.

Hypothesis and Calculation

- Null Hypothesis (H0): The industry sector of a unicorn is independent of its founding city/hub.
- Alternative Hypothesis (H1): A significant correlation exists between the industry sector and the founding city/hub.
- Variables (N=39 companies): Simplified Sector Categories (R=4) and Simplified City Hubs (C=3).

Table 4. Contingency Table (Observed Frequencies) (source: own editing)

Sector category	Berlin (19)	Munich (7)	Other DACH Hubs (13)	Total (39)
Consumer & Retail (C&R)	8	0	1	9
Enterprise Tech (ET)	2	4	5	11
Financial Services & Insurance (FS & Ins)	5	1	3	9
Industrials & Others (I & O)	4	2	4	10
Total	19	7	13	39

The Chi-Square statistic is calculated as follows for the 3x4 table:

- Degrees of Freedom (df): 6
- Chi-Square value: (χ^2): $\chi^2 \approx 11.23$
- P-value: $p \approx 0.081$

Conclusion:

- Finding: The Chi-Square test for independence between the Industry Sector and the Innovation Hub City yielded a p-value of ($p = 0.081$). As this value is above the conventional significance threshold of $\alpha = 0.05$, we do not find a statistically significant correlation between the industry type and the unicorn's founding city.
- Interpretation: This result suggests a crucial divergence from initial expectations: the unique clustering of certain sectors in specific cities (e.g., Industrials outside major hubs) is not statistically strong enough to confirm a definitive pattern of regional industrial specialization across the entire DACH unicorn landscape. While certain concentration trends are observable, they cannot be generalized as a statistically proven characteristic of the ecosystem.

Although the correlation is not statistically significant, strong observable trends remain, which should be described but interpreted with caution:

- Berlin: Exhibits a visible concentration in the Consumer & Retail sector (8 out of 19 Berlin companies), a pattern almost entirely absent in Munich (0 out of 7 companies). Berlin can be cautiously described as the most dominant C&R hub.
- Munich: Shows a clear focus on Enterprise Tech (4 out of 7 companies).
- Other Hubs: Demonstrate a more balanced profile, with a strong presence of both Enterprise Tech and Industrials & Others sectors.

3.4. Analysis of the gender distribution of DACH unicorns

Considering that only two female founders were found among the 39 unicorns and 86 founders examined, further statistical analysis was not possible. However, these circumstances call for important policy implications, as the most successful startups in the DACH countries are not able to represent the female 50% of the society.

4. Conclusion

This study aimed to quantitatively dissect the characteristics of the DACH unicorn ecosystem by analyzing the geographical and sectoral distribution of 39 companies and the academic profile of their 86 founders. The findings offer nuanced insights into the roles of both locational factors and individual human capital in achieving high-growth success.

4.1. Geographical Distribution and Regional Specialization:

The analysis confirms Germany's strong dominance (84.6% share) and the centralization of companies in two primary hubs: Berlin (48.7%, 19 companies) and Munich (17.9%, 7 companies). However, the hypothesis of significant regional specialization was not supported by the data. The Chi-Square test investigating the link between Industry Sector and Founding City yielded a p-value of $p \approx 0.081$. As this value is above the conventional $\alpha = 0.05$ threshold, the clustering of sectors within specific cities cannot be statistically verified. This suggests that founders, regardless of their industry, are primarily drawn to the largest concentrations of capital and talent, indicating a higher degree of locational flexibility than previously assumed.

4.2. The Academic Profile and Founder Mobility:

The founder profile is marked by high academic achievement, with a majority possessing a Master's degree (69.8%) and a significant proportion holding a PhD (19.8%). The most salient findings relate to mobility and training:

- A high percentage of founders (60.5%) have International Study experience.
- Local Loyalty is notably low, with only 31.4% of founders establishing their unicorn in their university city.
- The Chi-Square tests confirmed that the level of advanced education (Master's/PhD) does not significantly correlate with Local Loyalty ($p > 0.93$), reinforcing the high mobility of top-tier talent.
- In contrast, International Study showed a statistically significant positive correlation ($p \approx 0.021$) with the pursuit of a Business Management Qualification.

In conclusion, the DACH unicorn ecosystem is fueled by highly skilled, globally experienced, and highly mobile founders who are not constrained by their academic location. Success appears to be less dependent on rigid geographical-industrial alignments and more on the intentional combination of global exposure and formalized business management training.

5. Policy Implications

The research provides several actionable insights for policymakers and regional development agencies seeking to cultivate successful startup ecosystems:

- Promote Global Talent Flow: Given the low rate of Local Loyalty and the high rate of founders with international experience (60.5%), policy should prioritize attracting and retaining global talent. Efforts should focus on simplifying visa and residency permit processes for foreign students to maximize the benefit of this highly mobile founder base.
- Prioritize Applied Business Training: The significant correlation between International Study and Business Qualification highlights a market demand for practical skills. Universities and government-supported accelerators must incentivize technical and science graduates to combine their domain expertise with dedicated training in management, scaling, and fundraising.
- Address Gender Equity: While not directly tested, the known underrepresentation of women in the DACH startup scene requires proactive measures. Policy should implement targeted quotas in investment funds and support programs, along with establishing robust mentoring and networking infrastructures specifically for female founders, to fully utilize the region's human capital potential.

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KORCSMÁROS, E., MACHOVÁ, R., FEHÉR, L. & CSINGER, B. / *Technological challenges of small and medium-sized enterprises as a result of critical managerial thinking*

Technological Challenges of Small and Medium-sized Enterprises as a Result of Critical Managerial Thinking

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Abstract

For small and medium-sized enterprises (SMEs), technological development and digitization offer opportunities for innovation and increased competitiveness, but at the same time they also involve many challenges. The rapid development and spread of technology presents both individuals and organizations with new challenges. The ever-increasing use and dependence on technological devices creates new stress factors in people's lives, which we call technostress. During the research, the authors aim to highlight that in the 21st century, technostress can be identified as an organizational challenge that small and medium-sized enterprises cannot ignore, especially nowadays, when digitalization plays a key role, not only for individuals, businesses also in his life, especially in order to maintain competitiveness. In order to get a comprehensive picture of the investigated area, we conducted a two-round questionnaire inquiry using primary data collection in the small and medium-sized business sector operating in the Central Transdanubian region of Hungary. Taking into account the results obtained during the research, it can be said that technostress is present among the employees of the interviewed companies, although not yet to a high degree. Technostress has a significant impact on the daily life and work of employees of small and medium-sized enterprises. The investigation also made it clear that techno-overload is an extremely important factor in this context, and that the biggest problem for employees is not necessarily the technological complexity, but rather the overload caused by computer networks. This is a kind of awareness

raising and warning for the organizations that there is still time to react appropriately and reduce its impact.

Keywords: technology, organization challenge, digitalization, innovation, competitiveness, technostress

JEL Classification: M15, M29

1. Introduction

In an era characterized by rapid technological development and global integration, the process of digitization has emerged and is present as a critical catalyst for the transformation of businesses and the entire economy. The digitization of industries and businesses includes the adoption and integration of digital technologies into various aspects of business life in order to increase efficiency, competitiveness and innovation [1-2]. However, the significance of digitalization does not only stem from the adoption of technologies, but also from the fact that they bring about fundamental changes in business models, processes and strategies. The effects of successful digitalization are manifested in improved operational efficiency, better customer experience, data-driven decision-making and access to new markets. Consequently, in today's fast-paced, connected world, the ability to exploit the potential of digitization has become a key factor for competitiveness and long-term sustainability. Although digitalization offers enormous opportunities for companies, it also presents unique challenges. Issues such as the digital divide, data security concerns and the rapid obsolescence of technology are issues that organizations must deal with, especially SMEs, which form the backbone of most economies and contribute significantly to job creation and to economic growth [3]. In European economic re-search, the categorization of enterprises according to size plays a key role in both policy formulation and empirical analysis [4]. Small and medium-sized enterprises (SMEs) account for 99% of all enterprises in the European Union. The definition of this company category is determined by EU Recommendation No. 2004/3/361. The main factors that determine whether a company is classified as an SME are the number of employees, annual net sales, and annual total assets [5].

Table 1. Definition of small and medium-sized enterprises according to the European Union (European Commission, 2020)

Corporate category	Number of employees	Annual net sales	Annual balance sheet total
Micro enterprise	< 10 people	≤ 2 m €	≤ 2 m €
Small enterprise	< 50 people	≤ 10 m €	≤ 10 m €
Medium enterprise	< 250 people	≤ 50 m €	≤ 43 m €

Small and medium-sized enterprises play a significant role in the economic development sector worldwide. SMEs play a vital role in the industrial systems of developed and developing countries in the current global economy. Since small and medium-sized enterprises account for the largest percentage of enterprises, as a result of which they employ an extremely large part of the workforce, it can be stated that they contribute to poverty alleviation and sustainable economic growth [6-7]. The role of small and medium enterprises in expanding local development is vital in eradicating poverty, inequality and unemployment in rural sectors, as these enterprises support people in meeting their basic needs [8]. In addition, SMEs encourage inclusive and sustainable economic growth and reduce inequalities through their commitment to the United Nations Sustainable Development Goals [9]. In any economy, this is the most productive corporate sector in terms of job creation [10]. Small and medium-sized enterprises build local technology bases and provide a training ground for the development of entrepreneurial and managerial skills [8]. In emerging countries, these businesses serve as centers for more jobs, market-based economic growth, and poverty reduction and democratization. Overall, it can be said that SMEs play a critical role in the economic development of every country [11] and play a key role in creating and maintaining global economic growth and equitable development [12]. As a result, understanding the specifics of digitization in the context of SMEs is key to enhancing their efforts and results. These enterprises often carry out economic activity within limited resources, technical expertise and financial constraints, so digitization initiatives are particularly complex and distinctive. Consequently, it becomes crucial to explore and understand the specific needs, obstacles and advantages experienced by small and medium-sized enterprises during the digitization process in order to create more effective solutions and strategies adapted to their unique circumstances [4].

The present study provides a valuable contribution by providing a detailed overview of the area of technostress experienced among employees of small and medium-sized enterprises. By clearly distinguishing individual technostressors, the article provides valuable insight into which of the five technostressors represent the greatest challenges in the life of small and medium-sized enterprises. Although numerous studies in this field provide both a theoretical and practical framework, empirical data collected directly from Hungarian SMEs is relatively scarce. In order to remedy this deficiency, the article presents primary empirical data obtained during a survey of small and medium-sized enterprises in Hungary, which offer a contribution to the existing literature, relying on the real experiences and perspectives of these enterprises

2. Literature review

The appearance of digital technology with the development of the Internet enabled the development of humanity, the World Wide Web revolutionized businesses embracing the digital world, while Web 2.0 and social media communication underwent a dramatic change. Technology has changed the world, made people's lives easier, and is now so integrated into everyday life that it is almost impossible to live without it. The flow of information and data generated by electronic devices has exceeded the boundaries of the physical environment [13]. Technology changes the way people work, and rapid technological development makes continuous change inevitable [14]. It is not just a simple resource, nowadays it has become an organizational actor that employees must rely on in order to achieve company goals, perform diverse tasks, renew work patterns and achieve and maintain competitiveness in the long term. In a constantly changing technological environment, the need to use and continuously update knowledge and skills is considered a key requirement. While new skills and needs are required of employees, there are consequences, including increased workload, stress and social pressure, which can lead to psychosocial problems. The continuous and rapid development of technology not only resulted in higher efficiency but also contributed to the emergence of a new type of stress [15].

The term technostress was coined and used for the first time by the American psychologist Craig Brod in 1984 in the booklet "Technostress: The Human Cost of the Computer Revolution" published by Addison Wesley. The psychologist first referred to the stress associated with the use of technologies [13]. Brod defined technostress as follows: "Technostress is a modern adaptation disease caused by the inability to cope with new computer technologies in a healthy way. It manifests itself in two separate but related ways: the struggle to accept computing, and the more specialized form of overidentification with computing." [16]. In 1997, Brod's concept was re-vised and expanded by two American psychologists, Larry Rosen and Michelle M. Weil [17]. In their analysis, the meaning of technostress becomes broader, indicating the negative impact directly or indirectly caused by technology on attitudes, thoughts, behavior or psychology [13]. Brod [16] stated that technostress can manifest itself in several ways. Physical symptoms include increased heart rate, cardiovascular disease, digestive system disease, muscle pain, tingling in the limbs, insomnia and sleep-wake rhythm disorders, headaches and neck pain, chronic fatigue, hormonal disorders, and stress-related skin conditions. In addition, the group of mental symptoms can include irritability, depression, behavioral changes, crying spells, and apathy [13]. The negative emotional state of technostress can slow down response time and interrupt normal work. People with technostress have negative attitudes and emotions towards technology. Factors influencing this stress factor include experience, age, perceived control and organizational atmosphere. Weil and Rosen [17] stated that technostress is an adjustment problem where individuals are unable to cope with the physical, social, and cognitive demands associated with technological adaptation, such as using technology [14]. Examples of technostress include constant online presence, information overload, work-related technology un-certainty, multitasking, frequent updating of information systems, and technical problems with technology.

Technostress is therefore a feeling against technology, which can potentially cause workplace overload, discouragement, information fatigue, lack of motivation and job dissatisfaction [18]. It is true that in the beginning, researchers considered technostress as a kind of illness, but as time progressed, this approach changed and over time, it was seen more as an inability to adapt to the changes caused by information and communication technology (ICT). David-Milis [19] stated that technostress creates pressure to adapt new technology, especially when the technology standard and training supports are inadequate. However, according to Clark and Kalin [20], the cause of technostress is the organization's inability to cope with technological changes. It was found that technostress is a natural reaction to technology, as a result of which, in order to manage and reduce technostress, in addition to managerial intervention, all employees must be ready to adopt new technology [21]. It is conceivable that the optimal level of technology is used to maximize workplace productivity, but if its use exceeds an acceptable level, it can be an important stressor [22].

When individuals are exposed to technostress, they are not able to cope with the rapid changes of ICT, they are not able to process information quickly and efficiently and they have little time for creative and innovative search, as a result of which they tend to make more mistakes and thus their productivity decreases. Being constantly online makes it difficult to distinguish between home and workplace contexts, thus hindering the creation of a balance between work and private life. However, other variables can also influence the occurrence of technostress, such as the acceptance of the use of technologies at work, professional expectations, the way of building a career [15], the individual's attitude to the IT background, the workload, the complexity of the work, the digital literacy and user involvement [23]. Conditions related to technological stress usually make professionals less committed to the goals and values of the organizations they work for. In addition, dissatisfaction with work and lack of organizational commitment worsen the performance of employees, which means a significant increase in costs for companies [15]. The application of information and communication technologies plays an extremely important role in today's information-driven society. Without its use, meaningful professional and economic growth and development are not possible. The proper use of ICT brings many benefits, such as increased productivity, efficiency and accuracy. On the other hand, technostress is becoming an increasingly inevitable part of everyday life [21]. According to the stress theory, stress is caused by so-called stressors, and it is no different in the case of technostress, in which stress is induced by techno-stressors [24]. Technostressors are stressors that the individual evaluates as harmful [23]. The phenomena that cause the technological adaptation problem are called techno-stressors. These authors refer to information and communication technology conditions or factors that create stress results among the members of the organization. Such factors include, among others, frequent software and hardware updates, continuous information overload and expectations related to a continuous online presence [25]. In 2007, Tarafdar [26] and his colleagues defined a technostress component consisting of five main components, which are the following: tech-no-overload, techno-invasion, techno-complexity, techno-uncertainty and tech-no-

variability [26]. The first dimension is tech-no-overload, which refers to the stress resulting from the overloaded use of information technology. In this case, ICT forces the user to learn more intensively and handle the technology faster, which results in a feeling of tension [18]. According to Tarafdar et al. [26], techno-invasion, as the second dimension of technostress, refers to the development of technology and the intrusion into people's personal lives. Thus, during techno-invasion, technology invades privacy and takes more energy and time from users, which results in psychological anxiety and a decrease in employee performance [18]. Technological complexity is the complexity of the operation of information and communication technology, which can cause mental degradation and increase the feeling of lack of confidence in the use of technology [18]. Techno-uncertainty is a feeling of fear and threat from the development of technology. Users are afraid of losing their jobs or being replaced by another person who is more competent in the use of technology [18]. The last dimension is none other than techno-unpredictability, which refers to a situation where information and communication technology (ICT) users feel uncertain, as technology is constantly changing over time [21].

The consequences of technostress can appear in many forms, both behaviorally and psychologically. The main focus of the existing technostress studies is to explore the causes, as well as its negative consequences for individuals within the workplace, as well as its impact on organizational results. Technostress manifests itself in a number of work-related consequences, such as low job satisfaction, reduced productivity, high turnover, and low organizational commitment. Most of the literature explores the harmful effects of technostress on individual productivity [26-27], organizational commitment [21; 28-31] and focuses on job satisfaction [21; 28-30; 32]. However, several studies [21; 29; 33] reported conflicting results regarding the impact of technostress on organizational commitment. More specifically, the relationship between technostress and individual productivity has been empirically verified, proving that a lower level of technostress results in higher productivity for individuals at work [26]. In addition, evidence shows that conditions that cause technostress have a negative impact on job satisfaction [21; 28-29; 34], end-user satisfaction [25; 32; 35], individual performance [35-36], and innovation [36]. Technostress, like other types of stress, can be managed using different coping strategies. Methods such as "user-friendly software", continuous education about new technology, and mental and physical relaxation can help [13]. Ragu Nathan [28] suggests that general stress management activities such as exercise, meditation and health care also reduce levels of technostress. A good strategy should also include increased employee training, which plays a key role in reducing techno-stress levels [13].

3. Materials and methods

During the research, the authors aim to highlight that in the 21st century, tech-no-stress can be identified as an organizational challenge that small and medium-sized enterprises cannot ignore, especially nowadays, when digitalization plays a key role, not only in the lives of individuals and businesses as well, especially in order to

maintain competitiveness. In order to get a comprehensive picture of the investigated area, we conducted a two-round questionnaire inquiry with the help of primary data collection in the small and medium-sized business sector operating in the Central Transdanubian region of Hungary. Figure 1 illustrates the course of the research process.

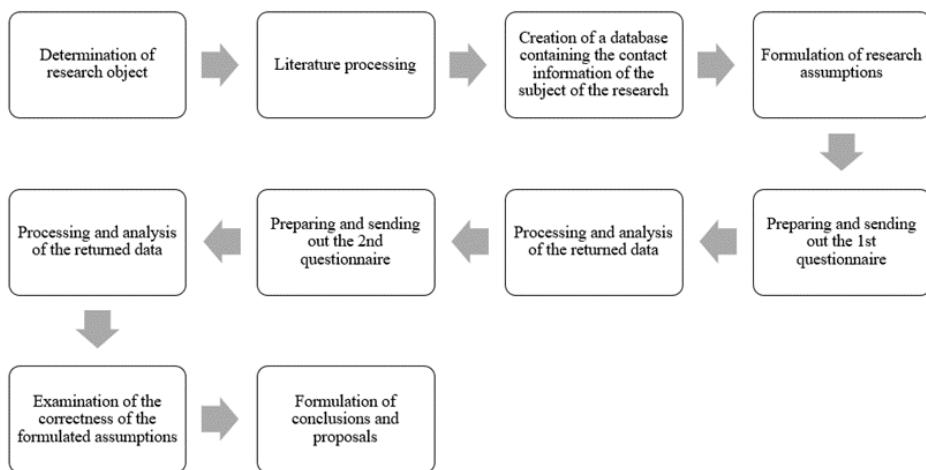


Figure 1. Graphic representation of the research process (own editing based on the research)

As the first step of the research, the authors collected the contact information of the companies engaged in economic activity in the Central Transdanubian region, in which they were greatly helped by the website of the Hungarian Chamber of Commerce and Industry, where they had the opportunity to collect the most important information by county. The enterprises were selected according to the region in which they operate. The authors conducted an investigation in the Central Transdanubian region, which includes the counties of Komárom-Esztergom, Veszprém, and Fejér. The research process lasted from February 2023 until May of the same year. In the questionnaire survey, the subjects of the research were completely anonymous. In this regard, the subjects of the research were informed by e-mail as well as in the introductory text before the start of the research, thus the completion was completely voluntary. Based on the data of the Central Statistical Office (KSH) up to March 31, 2023, it can be said that there were a total of 168,009 registered businesses in the region. As a next step, the authors established with the help of the KSH that 37.8% of these enterprises, or 6353 organizations, were classified as small and medium-sized enterprises at this time. After that, the authors organized the data of the enterprises in an Excel table in order to have at their disposal the database necessary for the successful conduct of the research. After the creation of the database, the research hypotheses were formulated, which are summarized in Table 2.

Table 2. List of assumptions (own editing)

Assumption 1	The larger the size of business, the more often it faces information technology (ICT) adaption as an enterprise challenge.
Assumption 2	Techno-overload is more common among employees working in medium-sized enterprise than in the case of micro-enterprises.
Assumption 3	The impact of techno-invasion is more likely to exist among employees working in medium-sized enterprises than in the case of small enterprises.
Assumption 4	Techno-uncertainty occurs more often among micro-enterprise employees than among employees of small enterprises.
Assumption 5	Techno-variability occurs most often in the life of medium-sized enterprises.

When examining the correctness of the assumptions, we used a statistical method, focusing on the Chi-square test. During the data analysis, it is crucial to identify the measurement levels of the individual variables, because the existence of this information is essential for the use of the statistical program, and the analysis method can be determined with the help of the measurement level of the variables. Two groups of measurement levels can be distinguished: non-metric and metric scales. The concept of non-metric scales includes mainly discrete characteristics that show the presence or absence of a given characteristic. Nominal and ordinal scales belong to this group of scales [37]. During the analysis, a significance level of 5% was determined. Cross-tabulation analysis is a widespread statistical analysis method that examines the relationship between two or more variables and shows the combined frequency distribution of these variables. Taking into account the analysis, the key question in all cases is the determination of the independent and dependent variables. From the group of statistical analyzes related to the crosstab analysis, the Pearson's Chi-square test is one of the most frequently used methods. With the help of this statistical test, it can be determined whether a statistical correlation can be found between the two variables defined by the authors [37]. The Chi-square test provides a suitable solution for testing the correctness of the remaining two hypotheses, as it can be applied well in the case of a nominal or an ordinal measurement level variable [37]. The formula for the Chi-square test is:

$$\chi^2 = \sum_{i=1}^n \frac{(O_i - E_i)^2}{E_i} \quad (1)$$

where O is the observed frequency and E is the expected frequency [38]. During the research, the authors also used Cramer's V index to examine the closeness of the relationship between the two variables. The formula of the coefficient can be determined as follows:

$$V = \sqrt{\frac{\chi^2}{N(k-1)}}$$

(2)

To calculate the formula, the following three variables are needed: the Chi-square test value (χ^2), the sample size (N), and the number of known categories that offer fewer possibilities (k) [37]. With the help of this information, our aim is to highlight the fact that today, in the world of digitalization, technostress has become an unavoidable topic from the corporate side. As a result, we consider it extremely important to present results by verifying and/or rejecting assumptions, with the help of which we will be able to draw conclusions and formulate proposals that businesses operating in the SME sector can use to their own advantage in the future. As a next step, the authors created their first survey using the Survio questionnaire creation software. The primary purpose of the first questionnaire was to select from the data set collected in the database those companies that best correspond to the topic of the investigation. In order to assess this, the first questionnaire included only 4 questions. The authors distributed the questionnaire to businesses in the form of "direct mail", by sending 100 e-mails per person per day. As a result, the questionnaires were successfully delivered to the organizations within 16 days. The inquiry process took place in April 2023. After narrowing down the subjects of the research, the authors prepared the second questionnaire, which, in addition to general demographic questions, focused on the area of technostress affecting employees. Before sending out to businesses, the two questionnaires went through a testing process, during which the authors made sure that the URL address was correct, that there were no grammatical errors in the questionnaire, and that the questionnaire worked according to the correct logic. After the testing phase, the questionnaires were sent to the enterprises using the established and narrowed database. As the final step of the research process, the received answers were evaluated, which is described by the authors in the following section.

4. Results

In the first part of this chapter, the most important results of the research we carried out are presented, with the help of various diagrams for better clarity. After that, the examination of the correctness of the previously formulated assumptions will be the focus. In the second half of the chapter, the conclusions drawn by the authors, as well as the suggestions formulated, are explained based on the results of the research.

4.1. Analysis of the data of the first questionnaire

In the case of the first questionnaire, the willingness to answer was 13%, as a result of which we received feedback from 826 businesses. The first question of the survey focused on the classification of enterprises according to the number of employees,

which was followed by a question concerning the scope of activities of the enterprises. The returned results are illustrated in Figure 2.

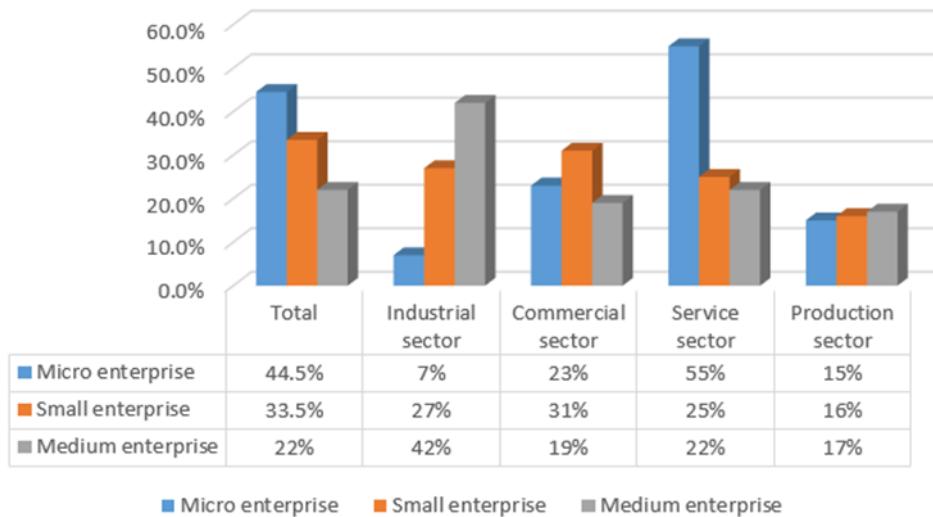


Figure 2. Distribution of companies by scope of activity by company size (own editing based on research)

Most of the responses returned came from micro-enterprises (44.5%), the largest part of which (55%) is active in the service sector. This group is followed by the class of small businesses (33.5%), a significant part of which (31%) conducts economic activity in the commercial sector. The fewest fillings came from medium-sized enterprises, which are present in the smallest proportion on the market (22%). In terms of scope of activity, the largest part of this group of companies (42%) operates in the industrial sector. In the case of the third question, we were interested in how long the interviewed companies have been conducting economic activity on the market. The distribution of the responses is illustrated in Figure 3.

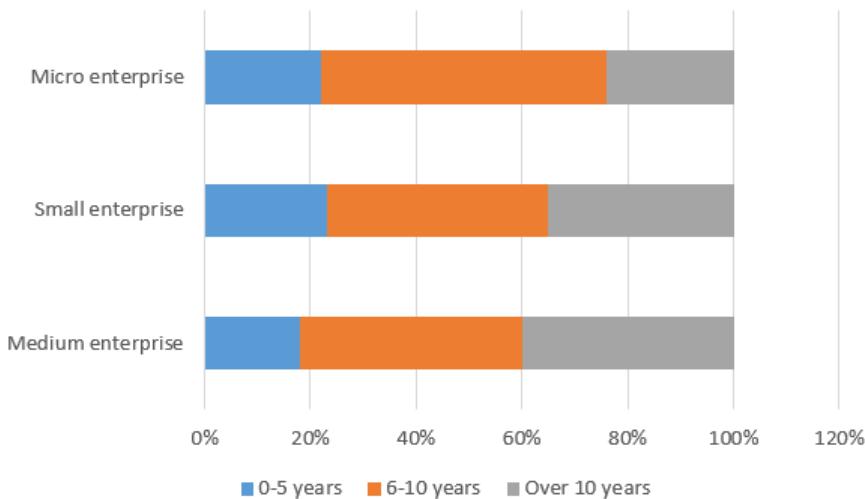


Figure 3. Distribution of business activity time by company size (own editing based on research)

Based on the results obtained, it can be said that in the case of all three areas of activity, the largest number of enterprises are present with relatively large professional experience, since they have been present on the market for 6-10 years. The second largest category is followed by the group of companies with a market presence of 6-10 years. Finally, the smallest number of companies that have been active in the business sphere for a maximum of 5 years were present in the research. In the next question of the first questionnaire, we were interested in the county in which the interviewed companies operate within the region under investigation. The results are summarized in Figure 4.

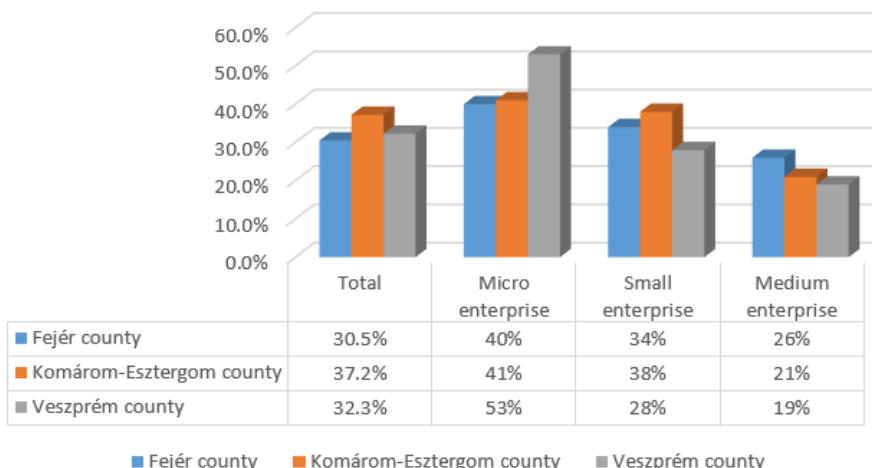


Figure 4. Distribution of enterprises by county based on company size (own editing based on research)

Since our research was conducted in the Central Transdanubian region, three answer options were available to the respondents. Based on the results, the largest number of responses returned came from the county of Komárom-Esztergom, which represented 37.2% of the businesses surveyed. 32.3% of the remaining responses came from the county of Veszprém, and 30.5% from the county of Fejér. Based on Figure 6, it can also be said that in the case of all three counties, the majority of responses came from micro-enterprises. The next question focused on the extent to which the interviewed company relies on IT systems and digital tools in its daily work. The results are illustrated in Figure 5.

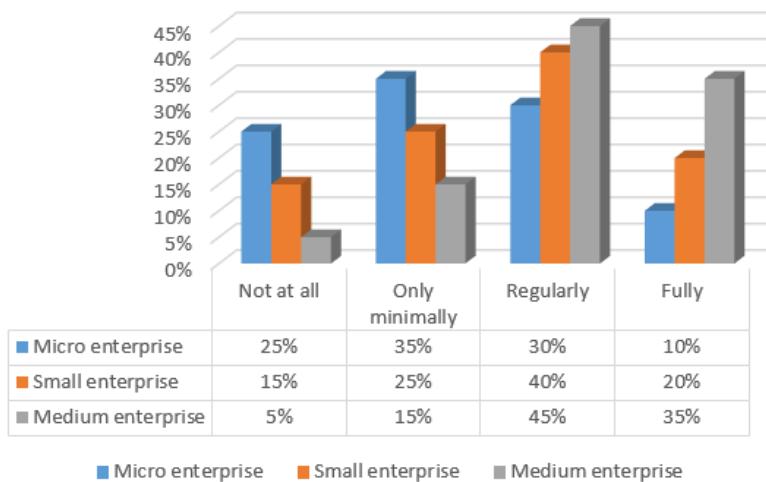


Figure 5. The attitude of companies to digital technologies during everyday work (own editing based on research)

Finally, during the last question, we asked the respondents to rate on a scale from 1 to 5 the extent to which they feel stressed if they have to use a computer technology system at their workplace. In this case, the value 1 meant "I don't feel tense at all", while the value 5 included the meaning "I feel completely tense". The results are illustrated in Figure 6.

A tense feeling

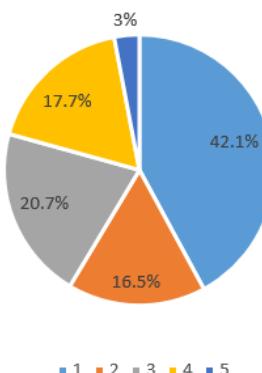


Figure 6. The attitude of companies to digital technologies during everyday work (own editing based on research)

The average value of the answers is 2.23. A large proportion (42.1%) can say that the interviewed employees do not feel stressed at all if they need to use a computer technology system at their workplace. Based on the results, we can say that the majority of employees do not suffer from technostress, however, by carefully observing the figure, it is also clearly visible that the second most common answer (20.7%) was value 3, which means: I feel stressed and neither. This was followed by the response option I feel tense with a rate of 17.7%. This leads to the conclusion that many employees have a feeling of tension when it comes to the use of computer systems. Based on the author's criteria system, companies that:

- comply with the system of criteria for small and medium-sized enterprises;
- have more than 5 years of business experience;
- they rely heavily or very heavily on IT systems and digital devices during their daily work, as well as;
- with a rating of at least 4 (I feel stressed), they stated the extent to which they feel stressed if they have to use a computer technology system at their workplace.

In the case of the first questionnaire, the willingness to answer was 13%, as a result of which we received feedback from 826 businesses. Based on the results, 78% of these enterprises (642 enterprises) met the criteria on the basis of which the second questionnaire could be sent to them, the results of which are described by the authors in the next chapter

4.2. Analysis of the data of the second questionnaire

As mentioned, the authors sent the second questionnaire to 642 companies in the form of "direct mail", similar to the first round of inquiries. The authors sent out a total of 100 e-mails to the businesses per day, as a result of which the questionnaire was delivered to all businesses in 7 days. The research process took place in the month of May 2023. In this case, the response rate was 25%, resulting in feedback from 164 businesses. In the second questionnaire, the area of technostress affecting employees was specifically focused on. In connection with the previous topic during the introductory question, we wondered whether the obtained results would change if the employees had to use computer systems in the presence of their colleagues. The results are presented in Figure 7

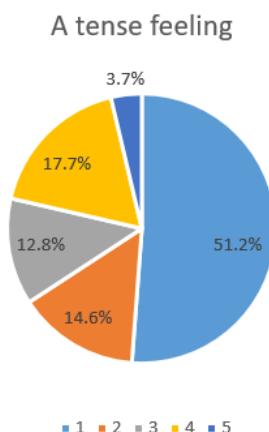


Figure 7. A feeling of tension related to the use of computer systems in the presence of a colleague (own editing based on research)

The average value received based on the feedback is 2.1. Compared to the previous question, the results changed only slightly. Basically, the majority of employees (51.2%) stated that they do not feel stressed if they need to use their knowledge of computer systems in the presence of a colleague. However, unlike the previous result, they are followed by the group of people with 17.7% who feel tense in such a situation. This change suggests that in cases where employees need to use computer systems alone, they feel less stressed than in cases where a colleague is also present. In our opinion, in such situations, employees feel more pressure in connection with the fact that they do something wrong, mess it up, and as a result, their co-workers and they develop an unfavorable image of them. Today, we live in a world where the opinion of others is almost more important to us than our own point of view. This may explain

why the result may have changed. For the sake of better understanding, continuing the investigation, taking into account the groups of technostress creators, we formulated different statements related to technostress for the respondents, in connection with which we asked them to evaluate the extent to which they feel that each statement is typical for themselves. The results are summarized in the table below.

Table 3. Distribution of responses to statements about technostress (own editing based on research)

Technostress creators	Rate of positive feedback
Techno-overload	
Forcing to work faster	55 people = 34%
Forcing to do more work	37 people = 23%
Being forced to stick to a tight schedule	54 people = 33%
Coercion to change work habits	53 people = 32%
Greater workload	56 people = 35%
Techno-invasion	
Less time with family	45 people = 27%
Continuous connection while on vacation	65 people = 40%
Sacrificing vacation and free time	37 people = 23%
Invasion of personal life	44 people = 27%
Techno-complexity	
I don't know enough about technology	31 people = 19%
It takes a long time to understand new technology	31 people = 19%
I don't find enough time to study and develop	34 people = 21%
Additional knowledge of new employees	52 people = 32%
Techno-uncertainty	
Understanding new technology is complicated	36 people = 22%
Constant threat of being fired	36 people = 22%
Constantly updating skills	42 people = 26%
The threat of newer tech-savvy coworkers	36 people = 22%

I don't share my knowledge	39 people = 24%
Less knowledge sharing	39 people = 24%
Techno-variability	
New development in technology	62 people = 38%
Software updates	53 people = 32%
Hardware upgrades	44 people = 27%
Updating computer networks	33 people = 20%

During the evaluation, we took into account the answers that represented at least a value of 4 (agree) or 5 (completely agree). Similar to the previous statements, in this case as well, a five-point Likert scale was available for the employees to answer. The respondents considered the statement that, thanks to technology, they should be in touch with their workplace even during their vacation as the most typical. In addition, a large number of them stated that there are continuous new developments in the technologies used in their organization. The statement that technology forces them to work much faster was considered the third most characteristic factor. In addition, based on high feedback values among the response options considered typical, it can be stated that they are forced to change their work habits in order to adapt to new technologies, they have a higher workload due to increased technological complexity, and they are forced to work with extremely tight schedules. We also considered it worthwhile to observe which factors were not considered typical at all. Based on the results, it can be said that the majority of employees do not feel that they should not share their knowledge with their colleagues, fearing that they will be replaced. The reason for this is that they do not feel threatened by colleagues with newer technological skills. It is also important to highlight that, considering the emergence of new technologies, they do not feel threatened by dismissal from the workplace. In our previous question, we were interested in the extent to which employees feel stressed when they have to use a computer system. The next question was aimed at getting to know the company's way of thinking. We were looking for an answer to whether the statements regarding the formulated company manager are present within the given organizations. The results of the feedback are summarized in the figure below.

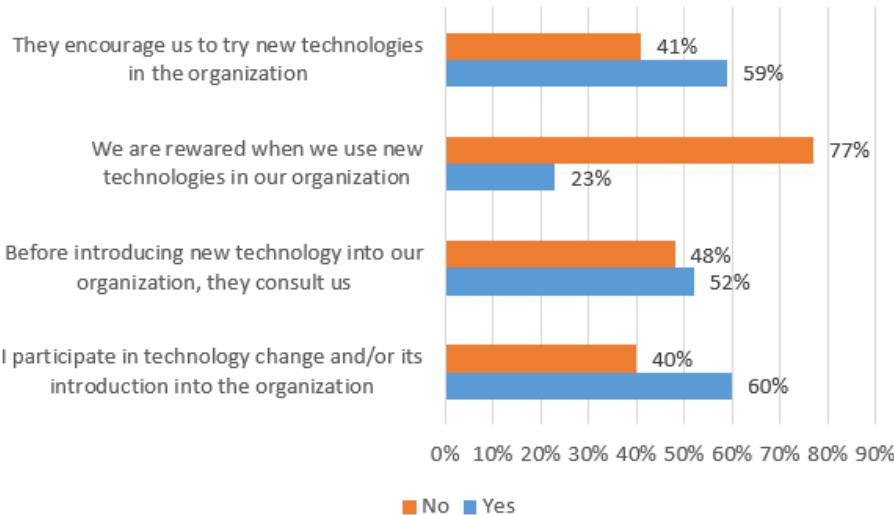


Figure 8. Distribution of properties for businesses research (own editing based on research)

There were mixed results. On the one hand, although the majority of employees stated that the company management encourages them to try out new technologies in their organization, they participate to a large extent in the change of technology and its introduction into the organization. We cannot ignore the fact that the number of employees who reported that these qualities are not present in their organization was also very high, which means that it is not possible to make a unified statement that managers in companies place great emphasis on this. Furthermore, there is no complete agreement that the management should consult with the employees before introducing new technology into the organizations. In this case too, we obtained similar results, the employees spoke positively about several organizations, but almost as many claimed the opposite. Based on the feedback, however, it can be stated that in the majority of companies, employees do not receive any rewards if new technologies are used in the organization. In the last question of the questionnaire, the authors asked the respondents to state which factors, in their opinion, would make them feel safer/better at their workplace when introducing a new technology. Employees considered continuous communication to be the most important factor. This was followed by the existence of supportive management, ensuring the possibility of further training, ensuring continuous involvement/cooperation in the introduction of new technology, as well as regular feedback from the management.

4.3. Examination of the correctness of assumptions

Before starting the research process, five assumptions were formulated. The first assumption was: The larger the size of a business, the faster it faces adaptation to information and communication technology (ICT) as an intra-company challenge. In this case, we examined the relationship between the size of the enterprises and the adaptation to ICT, these factors made up our two examined variables. In order to prove the correctness of the assumption, the values of the two variables were summarized with the help of a diagram created by the Microsoft Excel program, which is illustrated in Figure 9.

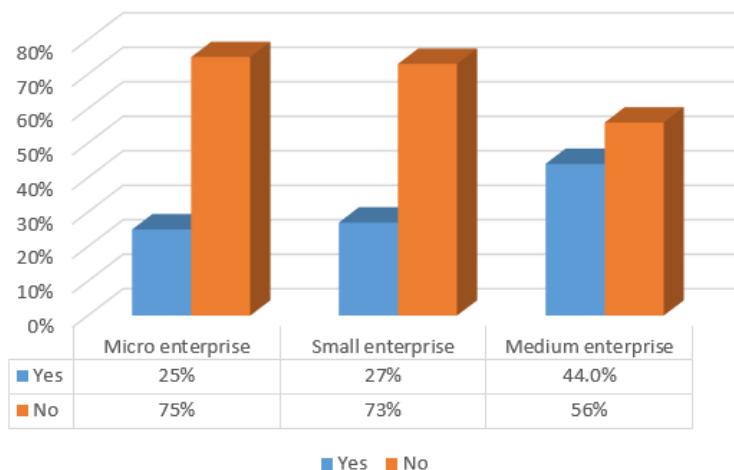


Figure 9. The relationship between the size of the enterprise and the presence of adaptation to ICT as a corporate challenge (own editing based on research)

The figure provides a comprehensive picture of how, as the size of the enterprises increases, the employees expressed to an increasing extent that adaptation to information and communication technologies, as a corporate challenge, is present in the life of their organization. As a result, our first assumption turned out to be true. The result is not surprising, since the larger the size of a company, the more and more serious technological systems it uses, during which the greater the likelihood that adaptation to these technologies will appear in the life of the organization as a corporate challenge. In our second assumption, we assumed a relationship between the size of the enterprise and the frequency of the presence of techno-overload. The assumption was as follows: Techno-overload is more common among employees working in medium-sized enterprises than among micro-enterprises. Techno-overload involves a type of communication and information overload that refers to individuals being exposed to more information than they can effectively manage and

use (Ragu-Nathan, 2008). Five statements regarding techno-overload were formulated in the questionnaire, which are summarized in the following table.

Table 4. Statements related to Assumption 2 (own editing based on research)

Statement 1	This technology forces you to work much faster.
Statement 2	This technology forces me to do more work than I can handle.
Statement 3	This technology forces me to work on a very tight schedule
Statement 4	I am forced to change my work habits to adapt to new technologies.
Statement 5	Due to the increased technological complexity, my workload is greater.

The obtained results are summarized using a diagram. During the investigation, we looked at the number of feedbacks for each company category that received a rating of 5 (completely agree) or 4 (agree) on the given scale. The results are illustrated in Figure 10.

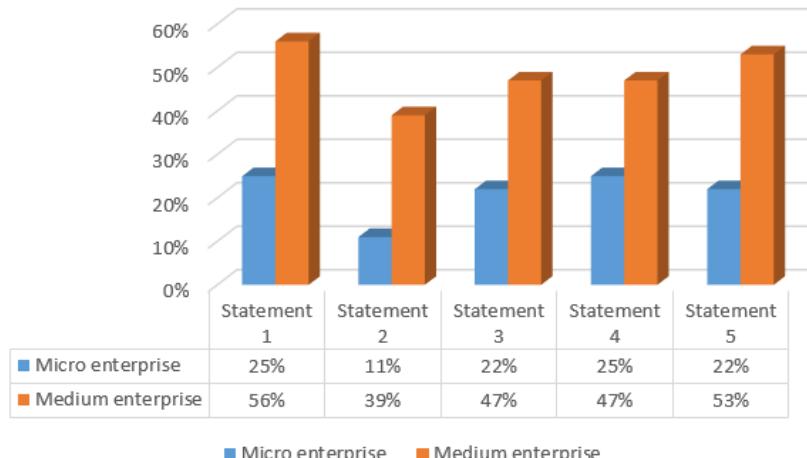


Figure 10. The effects of techno-overload on micro- and small business (own editing based on research)

The following table shows the results obtained during the Chi-square test for the statements.

Table 5. Chi-square test and Cramer's V results (own editing based on research)

	Pearson's Chi-square	df	Asymptotic Significance (2-sided)	Cramer's V
Statement 1	32.312	12	0.000	0.313
Statement 2	49.620	12	0.000	0.265
Statement 3	42.150	12	0.000	0.283
Statement 4	36.130	12	0.000	0.140

Statement 5	40.480	12	0.000	0.244
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Taking into account the results of the figure and the table, it can be clearly stated that employees working at medium-sized enterprises are affected by techno-overload to a greater extent than employees of micro-enterprises, based on which it can be stated that the second assumption also proved to be true. The next assumption was that: The impact of techno-invasion is more likely to exist among employees working in medium-sized enterprises than in the case of small enterprises. Techno-invasion refers to the fact that employees feel "always vulnerable", that is, they feel that they need to be reached anywhere and at any time and that they need to be constantly available (Ragu-Nathan, 2008). Regarding the questionnaire, techno-invasion included the following four statements.

Table 6. Statements related to Assumption 3 (own editing based on research)

Statement 1	Thanks to technology, I spend less time with my family.
Statement 2	Because of technology, I need to be in touch with my family even during my vacation.
Statement 3	I have to sacrifice my vacation and weekend time to stay up to date with new technologies.
Statement 4	I feel like my privacy is being invaded by technology.

Similar to the previous assumption, the analysis process was carried out on the basis of a similar principle during this study. The obtained results are illustrated in Figure 11.

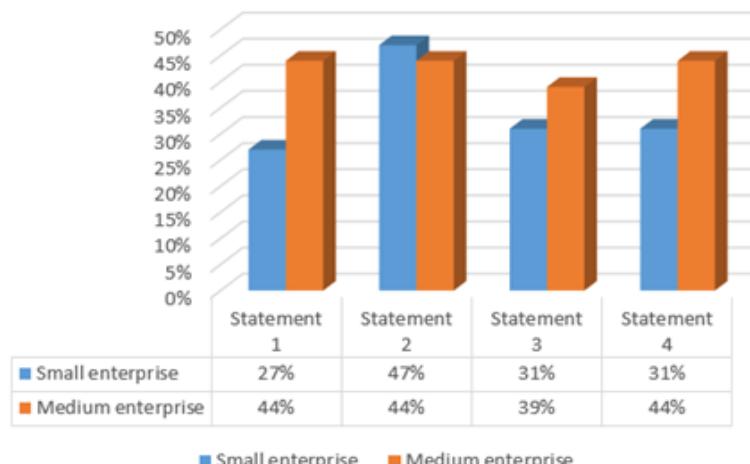


Figure 11. The effects of techno-invasion on small and medium-sized enterprises (own editing based on research)

Table 7. Chi-square test and Cramer's V results (own editing based on research)

	Pearson's Chi-square	df	Asymptotic Significance (2-sided)	Cramer's V
Statement 1	34.520	12	0.000	0.212
Statement 2	31.190	12	0.316	0.345
Statement 3	45.370	12	0.000	0.243
Statement 4	47.510	12	0.000	0.184

Taking into account the results, it can be said that in the case of medium-sized enterprises, except for one statement (statement 2), there is actually a greater chance of techno-invasion among employees than in the case of small enterprises. As a result, our third assumption also holds true. In the course of our fourth assumption, we examined the classification of enterprises according to the number of employees, as well as the frequency of occurrence of techno-uncertainty among employees. The hypothesis was as follows: Techno-uncertainty occurs more often among employees of micro-enterprises than among employees of small enterprises. Technological insecurity is related to situations where people feel threatened about losing their jobs to others who are more familiar with newer computing tools (Ragu-Nathan, 2008). In the survey, we dealt with the issue of techno-uncertainty in connection with four statements, which are summarized in the table below.

Table 8. Statements related to Assumption 4 (own editing based on research)

Statement 1	I feel a constant threat to the safety of my workplace due to new technologies.
Statement 2	I have to constantly update my skills to avoid being replaced.
Statement 3	My co-workers with more technological knowledge are threatened.
Statement 4	I don't share my knowledge with my coworkers because I'm afraid they'll replace me.
Statement 5	I feel that there is less knowledge sharing among colleagues because they are afraid of being replaced.

The obtained results are summarized in Figure 12.



Figure 12. The effects of techno-uncertainty on micro and small enterprises (own editing based on research)

Table 9. Chi-square test and Cramer's V results (own editing based on research)

	Pearson's Chi-square	df	Asymptotic Significance (2-sided)	Cramer's V
Statement 1	44.370	12	0.000	0.115
Statement 2	34.810	12	0.000	0.237
Statement 3	35.680	12	0.000	0.163
Statement 4	42.300	12	0.251	0.389
Statement 5	38.910	12	0.000	0.205

Looking at the results of Figure 12 and the results of the Chi-square test, it can be said that the fourth assumption did not prove to be true, since the probability of techno-uncertainty among employees is proportionally higher in the case of small enterprises than in the case of micro-enterprises. Our last assumption was aimed at the area of techno-variability. The assumption was as follows: Techno-variability occurs most often in the life of medium-sized enterprises. Technological volatility refers to contexts where continuous changes and developments in information and communication technology unsettle users (Ragu-Nathan, 2008). Unlike previous assumptions, in this case all three company categories were investigated. In the query, we examined four statements that can be classified into the category of techno-variability. Table 10 summarizes these statements.

Table 10. Statements related to Assumption 5 (own editing based on research)

Statement 1	There are always new developments in the technologies used in our organization.		
Statement 2	Computer software is constantly changing in our organization.		
Statement 3	Computer hardware is constantly changing in our organization.		
Statement 4	Computer network updates are frequent in our organization.		

The results obtained during the test process are presented in Figure 13.

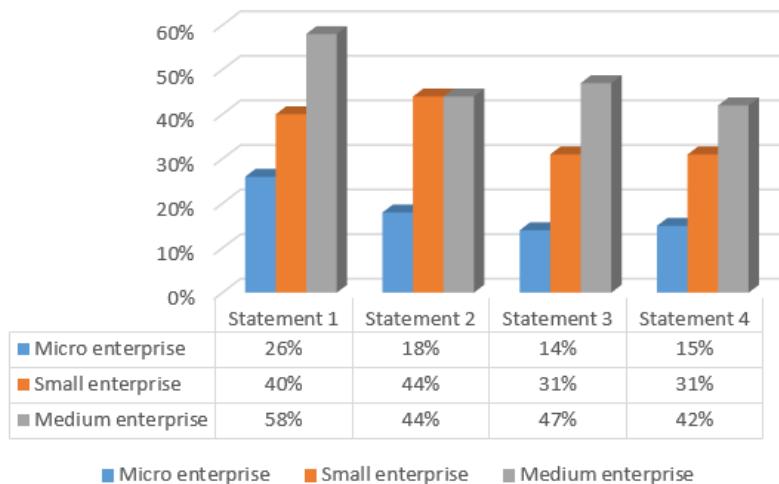


Figure 13. The effects of techno-variability on micro, small and medium-enterprises (own editing based on research)

Table 11. Chi-square test and Cramer's V results (own editing based on research)

	Pearson's Chi-square	df	Asymptotic Significance (2-sided)	Cramer's V
Statement 1	44.370	12	0.000	0.197
Statement 2	34.810	12	0.128	0.204
Statement 3	35.680	12	0.000	0.213
Statement 4	42.300	12	0.000	0.194

Looking at Figure 13, it is clear that the value of statements about techno-variability turned out to be the highest for medium-sized enterprises in all cases, except for one statement (statement 2). As a result of this, it can be stated that the assumption also proved to be true, since overall, techno-variability occurs with the greatest frequency in the life of medium-sized enterprises. In the next chapter of our study, the authors'

conclusions are drawn based on the research results and hypothesis tests, and the authors' proposals are formulated.

5. Discussion and Conclusion

As part of our research, we tried to assess the level of technostress among employees. In this regard, we made different statements to the respondents within the groups of technostress creators, examining which technostress creators are most present among employees. Based on the answers, we came to the conclusion that among the employees of the surveyed small and medium-sized enterprises, techno-overload as a techno-stress creator is present to the greatest extent. As explained before, tech-no-overload involves stressful situations that contribute to working longer and faster than normal. As a result, employees need to handle a huge amount of information, which can cause fatigue, memory problems and loss of control over employees. Based on the feedback, the smallest problem is caused by the techno-complexity group. This leads to the conclusion that the employees do not necessarily have a problem with performing complex technological tasks, since relatively few say that they do not know enough about technology, or that they do not find enough time to understand new technologies, it is a much bigger problem that are burdened by computer networks, that this causes them the greatest stress, since this kind of load forces them to work faster and more, to keep tight schedules and to change their work habits. In this regard, we recommend that organizations continuously monitor the extent to which their own employees are burdened in connection with the use of computer networks within the organization and, if necessary, reduce this type of overload. In our opinion, companies can achieve this if, among other things, they define the boundaries in terms of when it is necessary and when it is not necessary to use computer systems, and train their employees to use technology carefully, purposefully when it is really necessary, but also provide people with rest time, since they cannot be expected to spend 100% of their working time in front of computer systems. With the help of these suggestions and their incorporation into the daily routine, techno-overload can be reduced, while the general well-being can also be increased in parallel. In order to be able to help businesses even more, as a final question we were also curious as to what would make employees feel safer and better when introducing a new technology. Continuous communication and supportive leadership were clearly emphasized during the results. It is also clear from this that sometimes huge results can be achieved without investing money, if only we pay a little more attention to each other. Overall, taking the results into account, the effect of technostress is already present in the lives of employees of small and medium-sized enterprises, which company managers cannot ignore.

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Thinking Gender-Based Price Disparities in Croatian Retail: Insights from the Pink Tax Phenomenon

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Abstract

The phenomenon known as the "Pink Tax" does not represent an actual tax burden but rather denotes a price difference between products and services marketed to women and those intended for men, even when the products are identical or highly comparable. This form of gender-based price discrimination has been documented in several international studies, yet empirical evidence of its existence within the Croatian market remains scarce. The primary objective of this paper is to conduct a pioneering study on the presence and extent of the Pink Tax in the Republic of Croatia. The research collected prices of nearly identical products that differ only in their gender-oriented marketing from retail chains operating within the NACE Rev. 2 Section G – Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles. Using the t-Test for Paired Two Sample for Means, the analysis examined whether significant price differences exist between products targeted at women and men. The findings reveal a statistically significant disparity, indicating that female-oriented products are, on average, priced higher than their male counterparts. These results confirm the existence of the Pink Tax in certain product categories within the Croatian retail market. The study contributes to the broader understanding of gender-based economic inequalities and provides a foundation for future academic inquiry and policy discussions on gender-sensitive market regulation and consumer protection and fair pricing practices within the retail sector.

Keywords: Pink Tax, Croatia, gender-based price discrimination

1. Introduction

Gender issues strongly influence people's daily lives. Both women and men often face various forms of gender-based discrimination, whether through the media, communication, or the educational system. Existing stereotypes have resulted in a significant gender gap, with women generally receiving less support than men academically, financially, and physically (Harb, 2023). Market segmentation based on gender has led to price discrimination, i.e., selling the same product to different consumers at different prices, which has contributed to the emergence of the so-called "pink tax" — a situation in which products marketed to women are often more expensive than identical products marketed to men (Salman & Ayoubi, 2018; Moshary et al., 2023).

The concept of the pink tax refers to the additional amount women pay for certain products and services, such as personal hygiene items, clothing, or specific services, compared to men. This additional cost does not arise from differences in quality, quantity, or functionality, but rather represents a form of gender-based price discrimination (Šimunović, 2023). In other words, it is a form of gender-specific price discrimination that disproportionately affects women (Habbal, 2020) and, from an economic perspective, *ceteris paribus*, reduces their real income.

Globally, several studies have confirmed the existence of the pink tax. Notable examples include research by Menin (2015) and Moshary et al. (2023) in the United States and by Bernadette et al. (2022) in the Philippines. However, in Croatia, to the authors' knowledge, no primary research has been conducted to investigate the presence of the pink tax. Therefore, the aim of this pioneering study is to examine the existence of the pink tax in Croatia and thus contribute to reducing the research gap in this area.

The structure of the paper is organized as follows: after the introduction, the second section presents the conceptual framework of the pink tax; the third section describes the research framework, including data collection and methodology; the fourth section presents the research findings, while the final section provides conclusions, limitations, and recommendations for future research.

2. Conceptual Framework of the Pink Tax

2.1. Definition of the Pink Tax

The pink tax refers to the additional amount that women, as consumers, routinely pay when purchasing products and services that are similar or identical to those marketed to men (Lafferty, 2019). It involves charging higher prices for products and services primarily targeted at women compared to comparable or identical products

intended for men, despite similar production costs (Wishart et al., 2024). The pink tax is prevalent across various products designed for female use, and price differences are often not related to actual production costs but rather to perceived value. The perceived added value of specialized branding is frequently used to justify higher prices.

Similarly, service-based discrimination represents a widespread form of the pink tax, where women are charged more than men for the same services (Lafferty, 2019). The assessment of the average price difference between male and female products produced by the same manufacturers and sold in the same retail locations is referred to as the "pink gap" (Moshary et al., 2023).

The term "pink tax" originates from the historical tendency for products marketed to women to be colored pink. This tax can manifest in two ways. First, the tax may exist explicitly and directly increase the product price (rarely). Second, and more commonly, the product price does not include an actual tax, yet products intended for women are more expensive without any justified reason; this is the form most frequently studied. Although it is not a tax in the literal sense, most women feel compelled to pay more for the same product, effectively placing a greater financial burden on women compared to men (Habbal, 2020).

2.2. *Gender-Based Price Discrimination*

Salman and Ayoubi (2018) identify several types of price discrimination in product pricing, which represents one of the key decisions in any business. Price discrimination involves charging different prices for the same product to different consumers, for example based on age or gender. This practice provides benefits to the economy and allows suppliers to manage market demand. However, despite the advantages for both consumers and suppliers, price discrimination can also be harmful, as some consumers benefit from lower prices while others pay more.

A key determinant of gender-based price discrimination, which forms the basis of the pink tax, is the gender of the consumer for whom the product is intended (Bhatia et al., 2021). Due to gender socialization, certain companies may sell nearly identical products at different prices to women and men, ultimately allowing them to charge different prices to different segments of society. Over time, such price differentiation has become socially accepted (Yazicioglu, 2018).

The pink tax represents a growing trend that has attracted significant attention in recent years, yet it remains a persistent problem affecting women worldwide. The problematic cost difference experienced by women when purchasing products and services identical to those marketed to men is referred to as the "pink tax." Women are often charged higher prices for products and services specifically targeted at them due to their gender, even though they already face unequal pay globally (Barari et al., 2023).

Gender-based pricing persists in part because women often believe that female-oriented products should generally cost more, even when they are sometimes of lower

quality than comparable products for men. Young women commonly pay higher prices for certain products to demonstrate their femininity, regardless of the product's actual cost. For example, in products such as razors used by both genders, a simple color change from blue to pink can increase the price of the same item. In theoretical terms, this can be considered a "tax" symbolizing the additional cost of products marketed to women (Atkin, 2018).

2.3. Marketing and Advertising in the Pink Market

The term "pink" is used due to the presence of the color pink, which is traditionally perceived as a "female" color and thus targets a female audience. Companies employ profit-maximization strategies to charge higher prices for products and services aimed at women, capitalizing on market trends, preferences, and consumer behavior (Jeweetha & Gayathiri, 2022). However, the price difference does not necessarily depend on the color of the product; pink has become a characteristic feature of female-targeted products subject to higher prices (Kardetoff & Heshmati, 2022).

There are several forms of the pink tax. The first form is evident in gender-based pricing, where nearly identical products are priced differently based on gender. For example, women's personal care products, such as razors and deodorants, often cost more than their male equivalents. Similarly, women's clothing generally has a higher price than comparable men's apparel. This form of the pink tax highlights how companies use gender-targeted marketing strategies to justify elevated prices. The second form of the pink tax is observed in differentiated packaging and branding, where the same product is sold differently to men and women through changes in packaging and color. Products aimed at women are often packaged in traditionally "feminine" colors, such as pink, and labeled with features that align with gender stereotypes. Even when the product is almost identical, the version targeted at women frequently comes at a higher price. This form is prevalent across various products, from personal care items to toys, where the only differences may be color or design. Price discrimination is also common in service industries, representing another form of the pink tax. Women are charged more for the same services compared to men, which can be observed in hair salons, where women often pay more for similar or identical hairstyles. Additionally, women may face higher prices for car repairs or dry cleaning, based on the assumption that they are less likely to negotiate or question prices. This practice reflects underlying biases in service industries, resulting in higher costs for women. "Luxury" marketing is another significant form of the pink tax, where products or services that cater to women's needs and desires are offered at higher prices. Companies often assume that women are willing to pay more for certain products, especially in luxury markets (Wishart et al., 2024).

Analysis of specific brands shows that products are gender-categorized, as indicated by labels such as "for her" or "for him." However, companies may target products to a particular gender even without explicit labeling, using color, scent, or other characteristics to make products more appealing to women or men (Bhatia et al., 2021).

Economic analyses suggest that gender-based pricing is an intentional strategy to exploit gender socialization rather than merely reflect different consumer preferences. Social media and influencers exacerbate this problem by reinforcing gender stereotypes and promoting consumerism, leading to increased spending on gender-targeted products. The strategic placement of gendered products in stores also influences purchasing decisions. However, these gender-based marketing strategies may become less effective as consumer awareness increases. Generation Z, for example, shows a preference for gender-neutral products, which could encourage companies to adopt fairer pricing strategies (Wishart et al., 2024).

2.4. Review of Selected Existing Research on the Pink Tax

Research on the pink tax in Croatia is still in its early stages, especially compared to the United States, where studies confirm the existence of this socially undesirable phenomenon. Moshary et al. (2023) conducted a study in the U.S. using Nielsen Retail Scanner data from 2015 to 2018, based on shelf prices in stores. The results indicate that products targeted at women are more expensive in four out of nine analyzed categories, while no statistically significant price differences between female and male products were observed in the remaining five categories. However, when considering the average percentage difference across all nine categories, products for women are on average 10.6% more expensive than products for male personal care. The results also show that gender-based market segmentation is pervasive in the personal care product market and that significant differences exist in retail prices of female and male products of the same brand. Menin (2015) also confirms that personal care products for women are more expensive than those for men; his study in the U.S. found that female products in this category are about 13% more expensive than male products. The study extended beyond personal care products to other categories, including clothing, footwear, products for children, household items, and products for older adults. Overall, the study indicates that women, on average, pay 7% more for nearly identical products than men.

In addition to quantitative investigations of the pink tax, some studies employ qualitative methods. Jeeweetha and Gayathiri (2022) conducted research aimed at exploring price differences in consumer products, with a particular focus on the pink tax, investigating how products are sold at different prices depending on gender. The study found that 70.3% of respondents had not heard of the term "pink tax." Approximately 41% agreed that marketing strategies are predominantly aimed at women, while 28.6% believed that pink is a soft color associated with girls, explaining the differentiation in product colors. Likewise, 28.6% of respondents considered pink to be primarily intended for women. Bernadette et al. (2022) conducted research among Filipino consumers. The study's results confirm that respondents are aware of the pink tax, but mainly in terms of definitions and price differences for specific products. Participants recognized that this phenomenon applies to various products, such as personal care items, but after being surveyed, they indicated that they were no longer willing to purchase products subject to the pink tax.

3. Research Framework

3.1. Data Collection Process

For the purpose of investigating the existence of the pink tax in the Republic of Croatia, data on product prices were collected through field research. Between March and August 2025, prices of products targeted at women and their male equivalents were monitored in retail chains and selected online stores. The study included products for women and men, including personal care items, clothing, footwear, as well as products for children, namely girls and boys, such as toys. The data collection process was based on Menin's study (2015), with products of the same brand, appearance, and quantity selected to minimize differences among products and ensure comparability of price samples by gender. The data collection process was generally divided into two phases.

The first phase of field research involved defining products with identical characteristics from the same manufacturer, with the only difference being that one product was intended for women and the other for men. Products exclusively intended for one gender were excluded in this phase.

The second phase involved visiting physical and online stores, collecting, and recording product price data. Recorded information included the date the product was found at a specific price, store name, brand, product description, price of the product intended for women, and the price of the same or similar product intended for men.

During the study period, a total of 200 product units were collected for research purposes, comprising 100 pairs of nearly identical male and female products: 100 products for women and 100 products for men, totaling 200 prices. Data on products and their prices were collected from 17 retail stores operating within NACE Rev. 2, Section G – Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles (Eurostat, 2008), including both physical and online stores in the Republic of Croatia. Products and their prices were categorized into the following groups: personal care, clothing, footwear, and children's toys.

3.2. Research Methods

The primary method for determining the existence of the pink tax in the Republic of Croatia is the comparison method, specifically comparing prices of products intended for women and men. The aim is to analyze the prices of these products and determine whether products for women and girls are more expensive compared to products for men and boys. To this end, the percentage price difference between female and male products was calculated using the following formula (1):

(1)

$$\% \text{ price difference} = \frac{\text{price of female product} - \text{price of male product}}{\text{price of male product}} * 100$$

The identified percentage differences were analyzed using descriptive statistics, primarily the arithmetic mean, which provides insight into the average percentage difference in prices of products intended for women and men.

In addition to descriptive statistics, inferential statistics were employed to empirically determine whether the difference between male and female product prices is statistically significant. The aim is to test the difference between the means of two dependent samples, i.e., the difference between prices of male and female products, thereby determining the existence of the pink tax. Samples are considered dependent when, according to Bahovec et al. (2016), the data refer to matched pairs whose members are as similar as possible. This assumption of matched product pairs was fulfilled in this study. To assess the difference in means of dependent samples, a t-Test for Paired Two Sample for Means was used at a 95% confidence level. The t-test was performed using MS Excel. The existence of a statistically significant difference indicates the presence of the pink tax, whereas its absence suggests otherwise.

4. Results

4.1. Descriptive Statistics Results

Out of a total of 100 analyzed product pairs, in 47% of cases the price of the female product was higher than that of the male product, in 10% of cases the male product was more expensive than the female product, while in the remaining 43% of cases the prices of male and female products were equal.

The products were categorized into four groups: personal care products (19 items), clothing (35 items), footwear (32 items), and children's products (14 items). Based on the percentage price difference between female and male products (calculated using formula 1), the average price differences by gender were analyzed for each category, and the results are presented in Figure 4. The results indicate that, on average, personal care products for women in Croatia are 7.13% more expensive, while in the U.S., according to Menin (2015), these products were approximately 13% more expensive. Clothing for women in Croatia is on average 7.38% more expensive, compared to around 8% in the U.S. according to Menin (2015). Footwear for women in Croatia is approximately 8.08% more expensive than that for men. In the children's products category, items for girls in Croatia are 13.49% more expensive than products for boys, whereas in the U.S., according to Menin (2015), prices for girls' products were 7% higher for toys and accessories and 4% higher for children's clothing. Overall, across the 100 product sample, products targeted at women in Croatia are on average 8.41% more expensive than those intended for men, whereas in Menin's (2015) study, the average difference was around 7%.

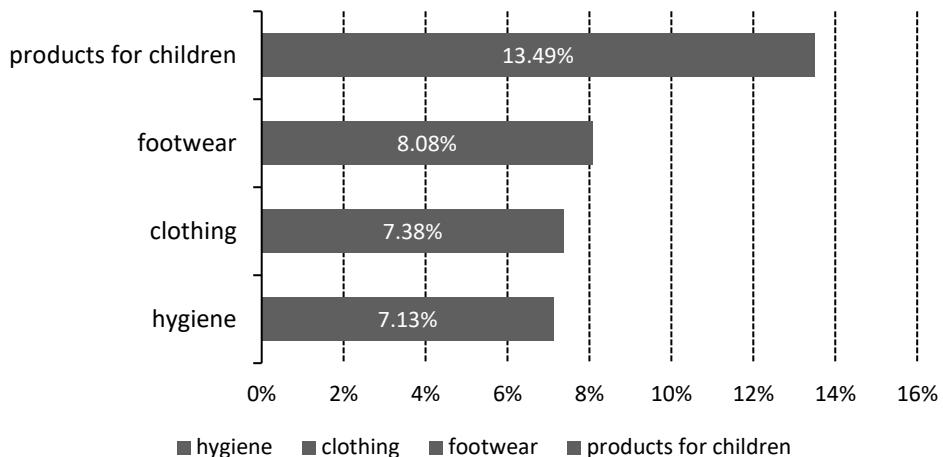


Figure 4. Pink Tax in the Republic of Croatia (source: author's calculation)

4.2. Results of the Paired Two-Sample t-Test for Means

The results of the paired-sample t-test are presented in Table 6. Based on a sample of 100 pairs of male and female products, at a 95% confidence level, it is evident that there is a statistically significant difference in the prices of male and female products, confirming the existence of the pink tax in the Republic of Croatia. The analysis indicates that the mean prices are statistically different at any level greater than 0.46%.

Table 6. Results of the Paired Two-Sample t-Test for Means

	Price of a women's product	Price of the male product
Mean	57.5349	53.8365
Variance	2932.458526	2522.574849
Observations	100	100
Pearson Correlation	0.972896543	
Hypothesized Mean Difference	0	
df	99	
t Stat	2.898116238	
P(T<=t) one-tail	0.002311383	
t Critical one-tail	1.660391156	
P(T<=t) two-tail	0.004622766	
t Critical two-tail	1.984216952	

Source: author's calculation

5. Conclusion

The study confirms the existence of price discrimination against women in the Republic of Croatia, that is, the presence of the pink tax. Although this is a pioneering study conducted in selected retail stores registered in the Republic of Croatia within NACE Rev. 2, Section G – Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles, the results show that women, on average, pay 8.41% more for almost identical products compared to men. These findings are further supported by the Paired Two-Sample t-Test for Means, which indicates a statistically significant difference in average prices, with women paying, on average, more for products than men.

As this is a pioneering study, its limitations are evident in the number of products included. While Menin's (2015) study covered 794 items, this study analyzed 200 products, i.e., 100 male–female product pairs. Furthermore, only four product categories were included: personal care products, clothing, footwear, and children's products. Therefore, future research should aim to increase both the number and variety of product categories, including products for older age groups as well as household items, following the example of Menin (2015). Additionally, future studies should incorporate qualitative methods to explore awareness of the pink tax in the Republic of Croatia.

The study also included products for which the prices of male and female versions were equal, i.e., where no gender-based price discrimination existed. Such practices should be the norm rather than the exception. However, there are some products for men that are more expensive than equivalent products for women, although these cases are significantly less common. Given that the pink tax imposes an additional burden on women's real income, discussion of its existence should lead to measures to reduce it and ensure equality for all consumers, regardless of gender. To achieve this, more comprehensive research is needed, as well as educational and promotional activities targeting the public to raise awareness of gender-based price discrimination.

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Work Organization Issues in a Turbulently Changing Economic Environment

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Abstract

Globalization and the Industry 4.0 revolution have fundamentally reshaped the models of work organization. As a result of digitalization and automation, flexible and atypical forms of employment have come to the forefront, replacing traditional, location-bound work structures. The aim of our research was to examine how company size, the location of work, and the reorganization of workflows influence efficiency. Our findings show that large companies tend to use more formalized and digitalized organizational structures, while smaller firms are characterized by greater flexibility and informal operations. The place of work also affects performance: remote work can increase individual productivity but may weaken teamwork. Efficiency can be improved when workflow reorganization is supported by appropriate technological and managerial conditions. The results of this study provide valuable guidance for companies and policymakers in developing modern work organization strategies.

Keywords: work organization, company size, atypical work form, organization efficiency

JEL Classification: L22, L25, J81, D24

1. Introduction

Over the past decades, models of work organization have undergone fundamental transformations, primarily as a result of globalization (Dabić et al., 2023) and the impacts of the Fourth Industrial Revolution (Ivaldi et al., 2022). This process has been accelerated by technological innovations, economic pressures, as well as psychological and socio-cultural changes. The advancement of digitalization, the growing demand for flexibility in the labor market, and the constraints caused by the

COVID-19 pandemic have all contributed to the emergence of new forms of work that transcend traditional, location-bound employment systems (Urukovičová & Rošková, 2024; Ng et al., 2021). These developments have fundamentally reshaped corporate operations, management practices, and employee behavior.

At the same time, the dynamic transformation of work organization and employment can be observed globally, encompassing the expansion of new technologies, the intensification of global competition, and the changing expectations of employees. Digitalization, the Fourth Industrial Revolution, and globalization have led to the emergence of new working methods and atypical employment forms that significantly challenge and replace traditional, fixed working-hour models (Dabić et al., 2023; Ivaldi et al., 2022). The resulting more flexible organizational frameworks and work arrangements have had a substantial impact on both the operational efficiency of companies and the well-being of employees.

Existing research has examined the effects of the mode and location of work, as well as corporate strategies, on productivity from multiple perspectives (Patulsky, 2019; Urukovičová & Rošková, 2024). However, findings in several areas remain contradictory - for instance, regarding the impact of remote work on organizational culture and efficiency (Hassard & Morris, 2024). Company size, structure, and innovation capacity also appear to play a significant role in determining which forms of employment create the greatest added value (Cruces Aguilera & de la Fuente Sanz, 2024).

In response to the current transformation of the labor market, our research seeks to answer the following questions: (1) What is the relationship between company size and work organization? (2) Is there a connection between the location of work and work efficiency? and (3) Has the reorganization of workflows led to increased effectiveness? Addressing these issues is of particular importance, as the future of modern workplaces - whether small and medium-sized enterprises or large multinational corporations - largely depends on their ability to adapt to rapidly changing technological and social environments (Zhang & Chen, 2024).

Our aim is twofold: first, to establish a theoretical foundation for the topic, and second, to draw practical conclusions through empirical investigation based on the research questions. To this end, we compare previous findings and identify the key factors that may enhance or hinder work efficiency. The ultimate goal of our study is to formulate evidence-based recommendations for organizations and policymakers to support more effective and sustainable employment practices in light of the challenges of the twenty-first century.

2. Theoretical Framework

Work organization is a dynamically evolving field, continuously shaped by new technologies and changing organizational strategies. Companies apply various work organization practices that influence work efficiency, employee performance, and engagement (Giauque, 2024). Over the past decades, work organization has undergone significant transformation driven by digitalization, new work methods, globalization, and changes in the work environment, which have collectively enabled the spatial and temporal reconfiguration of work (Hassard & Morris, 2024).

Digital transformation has had a substantial impact on work organization, particularly in the construction and service sectors. The emergence of automation, new management systems, and intelligent technologies has redefined production processes, working conditions, and employee tasks (Cruces Aguilera & de la Fuente Sanz, 2024). In parallel with digitalization, remote work and atypical forms of employment have become increasingly common. Consequently, work organization has become more flexible, but this shift has also led to greater inequality among employees and increased job insecurity (Eurofound, 2020). At the same time, digital innovations have progressively reshaped production value chains and altered the structure of subcontracting relationships between companies (Cruces Aguilera & de la Fuente Sanz, 2024).

In the constantly changing socio-economic environment of the 21st century, where consumer demands evolve rapidly, it is essential to pay close attention to the growing prevalence of atypical forms of employment (Korcsmáros, 2018). The workforce is the most important and complex resource of companies, as employees work not only for financial remuneration but also for the prestige of the workplace, the company's image, corporate culture, and numerous other factors that determine their level of commitment. Therefore, hiring employees alone is insufficient; proper motivation, conscious efforts to maintain loyalty, and the purposeful organization of work processes are all necessary (Poór et al., 2017).

An essential factor in the effectiveness of new models of work organization is the promotion of employee well-being, a core issue in human resource management (Buick et al., 2024). Employee well-being is closely linked to performance and productivity (Soriano et al., 2020). However, employees in the public sector often face challenges such as downsizing, cost-cutting initiatives, and increased expectations, which may raise workloads and negatively affect well-being (Buick et al., 2024; Van der Voet & Van de Walle, 2018).

Employee well-being consists of two key components: the hedonic and the eudaimonic dimensions. Hedonic well-being refers to the balance of positive emotions (e.g., joy, satisfaction) and low levels of negative emotions (e.g., stress,

anxiety). Eudaimonic well-being, on the other hand, is achieved when individuals feel aligned with themselves, experience personal growth, and see their goals fulfilled. Both components are essential for employees' overall well-being (Chingan Thottathil & Nandakumar, 2024; Bartels et al., 2019).

Employee well-being and work organization practices are closely interconnected, as organizational structure, work methods, and workplace culture fundamentally influence employee satisfaction and motivation (Riaz et al., 2024). Traditional employment models based on fixed working hours and stable environments are increasingly being replaced by more flexible, atypical arrangements. These include remote work, project-based employment, and platform-based work, all of which have become necessary due to global competition and rapidly changing economic conditions (Patulsky, 2019). However, this also means that companies must constantly adapt to new challenges, rethink their work organization processes, and modernize management practices (Zhang & Chen, 2024).

The success of new work organization models depends on how well organizations and employees can adapt to changing circumstances. Strategies focused on job crafting (JC) - the redesign of individual work roles - play a particularly important role, especially with the spread of flexible work arrangements. The essence of JC is that employees consciously tailor their work roles to align with their own resources and needs, thereby improving both their efficiency and well-being. Two major theories help to explain this process. The Job Demands-Resources (JD-R) model suggests that workplace resources, such as autonomy and social support, can mitigate the stress caused by job demands. Conversely, the Conservation of Resources (COR) theory posits that preserving and expanding personal resources can reduce burnout and enhance employee well-being over time (Urukovičová & Rošková, 2024).

The form and location of employment cannot be determined solely by cost-saving or "atypical" considerations; company size, the nature of work organization, and the continuous transformation and development of workflows all contribute to operational effectiveness. An increasing number of people now work remotely or in mobile settings, which enhances the flexibility of working time and workspace but also raises new challenges for both employees and employers (Wheatley, 2021). Remote employees often enjoy greater job security, more autonomy in scheduling, and a better work-life balance (Felstead & Henseke, 2017). However, remote work can also lead to long working hours and blurred boundaries between work and private life (Nätti et al., 2011).

For self-employed remote workers, the benefits are less clear, as they often face lower income, more precarious conditions, and higher turnover rates (Atherton et al., 2016). Research by Wheatley (2021) shows that the relationship between workplace

flexibility and work quality is complex and highly dependent on specific work conditions.

Companies of different sizes approach work organization in varying ways, as each faces distinct challenges in enhancing efficiency. Larger firms tend to operate more formal and bureaucratic structures, while smaller enterprises often rely on flexible and informal organizational solutions (Kotasková et al., 2020). In larger organizations, specialization is more pronounced - tasks are distributed across narrower professional domains. In contrast, in smaller firms, employees frequently perform a variety of tasks due to less hierarchical and more adaptable structures (Belás et al., 2019).

For instance, in smaller companies, a development task may be handled by just a few specialists, whereas in large corporations, separate departments are responsible for development activities. Increasing company size also intensifies the need for internal coordination, as workflows become more complex. Therefore, larger organizations must rely on written regulations and formalized procedures to ensure operational efficiency. While smaller firms often depend on informal communication and verbal agreements, larger ones implement detailed rules and process descriptions to govern task execution (Aguilar-Fernández & Otegi-Olaso, 2018). This difference affects not only decision-making processes but also daily operations: in large corporations, processes are typically more regulated and hierarchical, while in smaller firms, adaptability and simple coordination are key to efficiency.

Company size and organizational structure are closely linked. Large corporations usually adopt more advanced work organization and digitalization strategies, whereas small and medium-sized enterprises (SMEs) often rely on less standardized workflows and slower technological diffusion (Bauer et al., 2018). For example, in the Spanish construction sector, SMEs are less likely to adopt innovations compared to large companies, which possess greater financial and technological capacity. Large enterprises also tend to implement new work methods more rapidly due to the presence of organizational and managerial structures that facilitate effective change management (Cruces Aguilera & de la Fuente Sanz, 2024). Korcsmáros (2018) also points out that the smaller the company's workforce, the more frequently it employs atypical forms of employment, likely due to cost-efficiency considerations.

The question of where we work - and how this affects performance - is gaining increasing attention. With the rise of remote and hybrid work models, researchers are increasingly examining how the location of work influences productivity (Battisti et al., 2022). Some studies suggest that remote work can enhance individual productivity, particularly when employees can work at their own pace in a calm environment. However, other research emphasizes that the lack of teamwork and direct communication may reduce efficiency, especially in collaboration-intensive tasks (Paredes-Saavedra et al., 2024).

The shift in the location of work, especially through the spread of teleworking, has had a major impact on work organization and productivity (Hassard & Morris, 2024). As digitalization advances, research is increasingly focusing on how the location of work influences efficiency (Hesselbarth et al., 2024). Work organization processes are significantly affected by new information and communication technologies, which enable employees to work from geographically diverse locations (Ficapal-Cusí et al., 2023). The COVID-19 pandemic highlighted the necessity for organizations to adapt to changing conditions and to find new ways of maintaining efficiency in remote environments (Giovannini & Giauque, 2024).

Managerial-level telework represents an intriguing area of study, as remote work does not always increase efficiency among managers. They often struggle with the challenges of remote leadership, particularly when it comes to motivating and monitoring their teams (Hassard & Morris, 2024). Workflow reorganization is also a crucial element of modern work organization strategies. Studies indicate that an organization's success largely depends on its ability to adapt to organizational changes and restructure processes to enhance efficiency (Renard et al., 2021).

Corporate culture and organizational structure play vital roles in how employees perceive their work environment and its impact on performance (De Leede, 2017). Work environments that support reorganized workflows can positively influence employee engagement and satisfaction (Rudolph & Zacher, 2024). Modifying work organization and introducing new management practices can have both positive and negative effects.

Workflow transformation leads to efficiency gains only when supported by appropriate organizational culture, managerial support, and technological infrastructure. In social enterprises, for example, decentralized work organization and collaborative decision-making have been shown to enhance employee satisfaction and engagement while improving organizational performance (Joutard et al., 2024). However, a key question remains whether workflow restructuring genuinely produces measurable improvements in efficiency. The introduction of automation and digital technologies has brought revolutionary change in some companies, creating entirely new ways of working. In others, however, traditional, well-established structures remain dominant, as they provide stability and transparency (Amore & Minichilli, 2018).

In recent years, non-traditional ("atypical") forms of employment have gained increasing ground, offering flexible and personalized working conditions for employees and providing multiple advantages for employers as well (Poór et al., 2017). However, due to regulatory gaps or uncertainties, worker vulnerability may also increase, especially when company size or organizational structure fails to ensure adequate workplace protection and transparency (Weibel et al., 2023).

Hevenstone (2010) examined the issue at the national level, pointing out that the definition of atypical employment varies by country. Researchers use diverse terms such as part-time work, self-employment, fixed-term contracts, temporary work, and freelancing. Lipták (2011) further expanded this list to include telework and outsourcing. Pérez Guerrero et al. (2008) also classify part-time, temporary, and fixed-term employment as atypical forms. Experts disagree on whether atypical employment stabilizes or destabilizes the labor market in the long run, but they concur that organizational adaptability and flexibility in work organization play a decisive role in ensuring efficiency (Kotulovski & Laleta, 2020; Poór et al., 2017).

3. Materials and Methods

The aim of the research presented in this article is to analyze the preparedness of organizations for the challenges arising from current economic and social changes, as well as those affecting the uncertain environment of small and medium-sized enterprises (SMEs). The evaluation may contribute to the development of new work organization processes that are essential in today's volatile economic context. These processes are necessary to enhance organizational performance, which is one of the key factors determining the survival of companies.

The summarized results of the study analyze the characteristics of work organization within a complex research process, considering various aspects. The findings form part of a broader analysis entitled "Examination of the Impact of a Turbulently Changing Economic Environment on the Current Organizational Processes in Practice among Small and Medium-Sized Enterprises."

The theoretical foundation of the research was established through a systematic literature review. Using deductive logic, the main research questions and hypotheses were formulated, and both univariate and multivariate statistical methods were applied for their validation.

4. Results

4.1. Research Question and Sample Description

In recent years, several circumstances have repeatedly tested the adaptability of companies. During the latest public health restrictions, organizations were compelled to ensure that employees could perform their duties from home. While some companies have since returned to their traditional, on-site work arrangements, others recognized the benefits of remote work.

Simultaneously, a new generation is entering the labor market - one that actively seeks alternative forms of employment that allow for greater freedom and flexibility in managing work and personal life together. In addition to these shifts, the rapid development of digitalization and the growing integration of artificial intelligence into everyday corporate operations have created new challenges not only for employees but also for company leaders.

Taking these developments into account, our research aimed to answer the following questions:

- What is the relationship between company size and work organization?
- Is there a relationship between the location of work and work efficiency?
- Has the reorganization of workflows resulted in greater work efficiency?

Based on these research questions, we formulated the following hypotheses:

- H1: There is a difference between company size and the applicability of remote work as a form of employment.
- H2: There is a difference between the location of work and work efficiency.
- H3: Workflow reorganization has led to greater work efficiency.

The examined sample consisted of approximately one-third micro-enterprises, while the proportion of large companies was also relatively high (21.3%). The majority of the surveyed enterprises were limited liability companies (51.6%), followed by sole proprietors (20%).

4.1.1. Work Organization

When examining work organization, we analyzed which forms of work were most commonly applied among the surveyed companies. Based on the respondents' answers, the four most frequently used forms of work, in descending order, were as follows:

- Flexible working hours,
- Part-time employment,
- Job sharing, and
- Fixed-term employment contracts.

Nearly half of the respondents (147 individuals) indicated that they had not yet encountered platform work as a form of employment. This type of work arrangement is typically used by medium-sized and large enterprises and is more characteristic of respondents engaged in intellectual work.

Regarding the location of work, 60.84% of the surveyed enterprises supported on-site work, 32.36% supported a combination of on-site and remote work, and only 6.80% supported work performed entirely outside the workplace.

4.1.2. Hypothesis Testing

Since the variables we examined were measured on a nominal scale, we conducted cross-tabulation analysis to test the hypotheses and applied the Cramer's V test to determine the strength of the relationships between variables. Hypothesis testing was performed at a 5% significance level.

For our first hypothesis - There is a difference between company size and the applicability of remote work as a form of employment - we examined the relationship between company size and work arrangement.

After performing the cross-tabulation analysis, we applied the Chi-square test at a 5% significance level to determine whether there was a statistically significant relationship between company size and the applicability of remote work. The results of our research are summarized in Table 1.

The table shows that the significance level is less than 5%, indicating a statistically significant relationship between the two variables - in other words, company size and the applicability of remote work are correlated.

After confirming the existence of this relationship, we examined the strength of the association between the two variables, as shown in Table 2.

Table 1. Chi-Square Tests to H1 hypothesis (source: based on collected data)

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	35,929a	4	,000
Likelihood Ratio	39,116	4	,000
Linear-by-Linear Association	23,767	1	,000
N of Valid Cases	281		

As shown in Table 2, both the Cramer's V and the Contingency Coefficient values indicate a moderately strong and statistically significant relationship between the two variables. Based on these results, it can be concluded that there is a moderately strong significant correlation between company size and the applicability of remote work. There-fore, with regard to our first research hypothesis, it can be stated that as company size in-creases, the use of remote work becomes more characteristic of enterprises.

Table 2. Symmetric Measures to H1 hypothesis (source: based on collected data)

	Value	Approximate Significance
Nominal by Nominal Phi	,358	,000
Cramer's V	,358	,000
Contingency Coefficient	,337	,000
N of Valid Cases	281	

Next, we focused on testing our second hypothesis, which examines whether there is a difference between the location of work and work efficiency.

The results are presented in Table 3. As shown, the observed value of the indicator is 2.820, which - at a two-tailed significance level of 0.244 - does not exceed the threshold value. Therefore, the significance level is higher than our chosen 0.05 level. This indicates that the null hypothesis is accepted, meaning that there is no relationship between the location of work and work efficiency. Consequently, work efficiency develops independently of the place of work and is not influenced by where the work is performed.

Table 3. Chi-Square Tests to H2 hypothesis (source: based on collected data)

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	2,820a	2	,244
Likelihood Ratio	2,846	2	,241
Linear-by-Linear Association	1,937	1	,164
N of Valid Cases	200		

Finally, we tested our third hypothesis, which stated that the reorganization of workflows has led to greater work efficiency. Table 4 presents the results of the two variables together in a cross-tabulation.

Table 4. Crosstab to H3 hypothesis (source: based on collected data)

		We have reorganized the workflows		Total
		yes	no	
We have reorganized the workflows	yes	78	30	108
	no	59	33	92
Total		137	63	200

After examining the cross-tabulation, the Pearson Chi-square test (see Table 5) was used to determine whether a relationship exists between the two variables. In this case as well, the significance level is greater than 5%, which means that the null hypothesis is accepted. Therefore, it can be concluded that the reorganization of workflows has no significant effect on work efficiency.

Table 5. Chi-Square Tests to H3 hypothesis (source: based on collected data)

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	1,508a	1	,220
Likelihood Ratio	1,505	1	,220
Linear-by-Linear Association	1,500	1	,221
N of Valid Cases	200		

5. Discussion

The purpose of this research was to explore how company size, work location, and work-flow reorganization are related to issues of work organization and work efficiency. The hypothesis tests conducted during the analysis yielded mixed results.

The examination of the first hypothesis revealed a significant and moderately strong relationship between company size and the applicability of remote work. This indicates that larger companies tend to implement remote work arrangements more frequently and deliberately, while smaller enterprises are less likely to adopt such practices. This finding suggests that larger organizations are generally more capable of responding flexibly to work organization challenges, and that their available resources allow them to provide the necessary conditions for remote work.

The results of the second hypothesis show that there is no statistically significant relationship between the location of work and work efficiency. This implies that efficiency is not necessarily influenced by the physical location of work but rather by other factors - such as organizational culture, individual motivation, technological infrastructure, or the quality of leadership.

Similarly, the third hypothesis test found no significant relationship between workflow reorganization and increased work efficiency. This suggests that restructuring processes alone is not sufficient to improve performance unless accompanied by appropriate change management, training, or motivational measures.

Overall, the research highlights that while company size may be a determining factor in the adoption of modern work organization forms - such as remote work - the improvement of efficiency and performance is a complex, multifactorial process.

It is not merely a structural or organizational issue but also a cultural and managerial challenge that requires an integrated and adaptive approach.

6. Conclusions

The labor market of the 21st century is undergoing a radical transformation shaped by technological progress, digitalization, globalization, and social and cultural changes. Work organization, as a key element of organizational functioning, has become not only an economic issue but also a matter of strategic and human resource management. The aim of this study is to explore how companies respond to structural changes in the world of work, with particular attention to the relationships between company size, the location of work, and the reorganization of work processes, as well as how these factors influence work efficiency.

Over the past decades, models of work organization have changed significantly. The Fourth Industrial Revolution and the rise of artificial intelligence have created new opportunities, but also serious challenges for both employees and companies. The COVID-19 pandemic has especially accelerated the spread of alternative forms of employment - such as remote work, hybrid work, and platform-based work - which have fundamentally re-defined the spatial and temporal dimensions of work. At the same time, this flexibility has given rise to new inequalities and uncertainties, such as the blurring of work-life boundaries, digital overload, and the weakening of employee loyalty.

In the empirical part of the research, we analyzed data from 281 companies to examine the relationships between work organization practices and efficiency. The results indicate a moderately strong, statistically significant relationship between company size and the applicability of remote work: in large companies, remote work has become much more integrated into the organizational structure, while smaller enterprises tend to rely primarily on traditional employment forms. However, no statistically significant relationship could be established between the location of work and efficiency, suggesting that performance is influenced much more by organizational culture, employee motivation, and the quality of leadership practices. Furthermore, the reorganization of work processes does not automatically guarantee increased efficiency if the changes are not accompanied by appropriate human and knowledge management strategies.

Based on the findings, it can be concluded that the efficiency of work organization today is the result of a complex, multifactorial system in which technological development is only one component. Managerial competencies, organizational culture, communication, and employee well-being play equally important roles. The greatest challenge for organizations in the future will be integrating digital

innovations with human-centered organizational functioning. Artificial intelligence and automation are taking the division of labor to a new level but are also reshaping the role of human work: creative, problem-solving, and interpersonal skills are becoming increasingly valuable, while routine tasks are being taken over by machines.

Therefore, the future of work organization is not only a technological but also a social and ethical issue. Trends toward flexible employment, hybrid work, and lifelong learning demand a new managerial mindset capable of balancing productivity, sustainability, and human well-being. The most successful organizations will be those that recognize that efficiency does not merely result from the optimization of work processes, but from supporting employees' autonomy, development opportunities, and psychological safety.

In conclusion, the study highlights that the future of work organization lies in the integration of technological innovation and human factors. For companies, the most important task is to develop a flexible, learning, and adaptive organizational culture that can respond to the challenges of an uncertain economic environment while preserving the value and sustainability of human work.

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The Effect of Herding Behavior and Fear of Missing Out (FOMO) on Investment Performance of Retail Investors in Indonesia

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Abstract

This study aims to examine the influence of herding behavior and fear of missing out (FOMO) on the investment performance of retail investors in Indonesia. Using a quantitative approach, primary data were collected through an online questionnaire distributed to active retail investors. A total of 178 responses were analyzed using the Partial Least Squares Structural Equation Modeling (PLS-SEM) technique via SmartPLS 3.2.9. The results show that herding behavior has a positive and significant effect on FOMO, and FOMO, in turn, has a positive and significant effect on investment performance. Additionally, herding behavior also shows a positive and significant direct effect on investment performance. Mediation analysis confirms that FOMO mediates the relationship between herding behavior and investment performance. These findings reveal that psychological and social factors—especially the tendency to imitate others and the fear of missing investment opportunities—play an important role in shaping investment outcomes. Emotional-driven decisions, often triggered by herding and FOMO, can significantly influence retail investors' portfolio performance.

Keywords: Herding behavior, Fear of Missing Out (FOMO), Investment performance, Retail investors, Behavioral finance

1. Introduction

Traditional finance theories, such as the Efficient Market Hypothesis (EMH), assume that investors behave rationally and make decisions solely based on risk–return optimization, guided by complete information and logical analysis. Within this framework, markets are viewed as efficient mechanisms that reflect all available information, and investors are expected to act independently to maximize their utility. However, empirical evidence has consistently shown that real-world investors often deviate from rationality due to psychological and emotional influences that shape

their perceptions, judgments, and behaviors. Behavioral finance, therefore, emerged as an interdisciplinary field that integrates insights from psychology, sociology, and economics to explain how cognitive biases and affective states lead to irrational or suboptimal financial decisions. Emotions such as greed, fear, and anxiety, as well as social dynamics such as imitation and peer influence, have been found to significantly distort investors' ability to assess risk and value accurately. Retail investors, in particular, tend to be more susceptible to these behavioral biases because they often possess limited access to sophisticated financial information, analytical tools, and professional guidance. Consequently, their decisions are more likely to be driven by emotions, heuristics, and social cues rather than by fundamental analysis.

In Indonesia, the number of retail investors has grown rapidly over the past five years, fueled by the rise of digital trading platforms, easier access to online investment applications, and the pervasive influence of social media. The democratization of finance has indeed opened new opportunities for public participation in the capital market; however, it has also intensified emotional and social factors in decision-making. Online investment communities, social media influencers, and viral stock discussions on digital platforms such as Instagram, X (formerly Twitter), and TikTok have created a culture of constant information flow and social comparison. Many investors make decisions based on prevailing trends, peer recommendations, or collective sentiment rather than conducting adequate financial analysis. This behavioral shift has heightened the prevalence of psychological biases such as herding behavior—the tendency to follow the majority's actions—and the fear of missing out (FOMO)—the anxiety of being excluded from potentially profitable opportunities. Both biases can lead to impulsive trading, overreaction to market news, and misjudgment of asset value, which may ultimately impact investment performance either positively or negatively depending on market conditions.

Against this background, understanding the behavioral underpinnings of retail investment decisions becomes increasingly important, especially in emerging markets like Indonesia where social influence and emotional engagement are strong cultural forces. This study aims to examine the effects of herding behavior and FOMO on the investment performance of retail investors in Indonesia. Specifically, it seeks to analyze (1) the effect of herding behavior on investment performance, (2) the effect of herding behavior on FOMO, (3) the effect of FOMO on investment performance, and (4) the mediating role of FOMO in the relationship between herding behavior and investment performance. By exploring these relationships, the study intends to contribute to a deeper understanding of how psychological and social mechanisms interact to shape investment outcomes in the modern digital era. Furthermore, the findings are expected to provide insights into how emotional regulation, financial literacy, and rational analysis can be strengthened to improve investment discipline and enhance portfolio performance among Indonesia's growing population of retail investors.

2. Literature Review and Hypothesis Development

2.1 Behavioral Finance

Behavioral finance is a field of study that integrates insights from psychology and economics to explain why and how investors sometimes make irrational financial decisions. Unlike traditional finance, which assumes that individuals act rationally and markets are efficient, behavioral finance recognizes that investors are influenced by emotions, cognitive biases, and social pressures that lead to deviations from rationality (Thaler, 2015; Kahneman, 2011).

Traditional finance theories such as the Efficient Market Hypothesis (EMH) assume that all available information is instantly reflected in prices, and that investors act logically to maximize utility. However, real-world market phenomena—such as speculative bubbles, overreactions, and panic selling—demonstrate that investors often deviate from rational expectations. Behavioral finance seeks to explain these anomalies by identifying the psychological and social mechanisms that drive them.

Key concepts within behavioral finance include heuristics, overconfidence, loss aversion, mental accounting, herding behavior, and FOMO (Fear of Missing Out). These factors influence how investors perceive information, assess risk, and make investment choices. For instance, loss aversion describes the tendency of individuals to prefer avoiding losses over acquiring equivalent gains (Kahneman & Tversky, 1979), while overconfidence leads investors to overestimate their knowledge and control over outcomes.

Behavioral finance provides a more realistic framework for understanding financial decision-making, especially among retail investors who may lack professional expertise or access to in-depth market data. Retail investors often rely on emotional and social cues rather than fundamental analysis, making them particularly susceptible to biases such as herding and FOMO. In this sense, behavioral finance bridges the gap between psychological tendencies and market outcomes, offering valuable insights into why investors act as they do and how these actions affect overall market dynamics.

In the context of emerging markets like Indonesia, behavioral factors play a significant role due to the rapid growth of digital investment platforms, social media influence, and financial democratization. These developments have made investing more accessible but also more emotionally driven, amplifying the relevance of behavioral finance in explaining retail investor behavior.

2.2 Herding Behavior

Herding behavior refers to the inclination of individuals to imitate the actions of a larger group rather than relying on their own independent analysis or judgment (Bikhchandani & Sharma, 2000). In financial markets, this phenomenon occurs when investors collectively follow the trends of others—buying when the majority buys and selling when the majority sells—without fully assessing the fundamental value of assets. This imitation can lead to the overvaluation or undervaluation of securities and contributes to the formation of market bubbles and crashes.

From a behavioral finance perspective, herding is a deviation from the assumption of rationality in classical finance theory. Traditional models such as the Efficient Market Hypothesis (EMH) suggest that investors act independently based on available information. However, real-world evidence shows that individuals are heavily influenced by the behavior of others, especially in uncertain or volatile market conditions. When faced with ambiguity or limited information, investors perceive the collective actions of the crowd as a form of "social proof," assuming that others possess superior information or analytical skills. This psychological shortcut reduces cognitive effort but increases the risk of systematic errors in judgment (Banerjee, 1992).

Herding can be informational or behavioral in nature. Informational herding arises when investors infer private information from the actions of others, believing that the market majority must possess valuable insights. Behavioral herding, on the other hand, results from emotional and psychological pressures such as the need for conformity, fear of social isolation, or a desire to avoid regret (Devenow & Welch, 1996). In both cases, the outcome is a collective movement that amplifies market trends beyond what fundamentals justify.

Empirical research shows that herding behavior often intensifies during periods of market uncertainty or high volatility. Investors tend to follow the majority to minimize the discomfort associated with making independent but potentially incorrect decisions. This phenomenon, sometimes referred to as "safety in numbers," offers temporary emotional security but can result in long-term financial inefficiency. When market sentiment shifts, herding can quickly reverse direction, causing sharp corrections that exacerbate market instability (Chiang & Zheng, 2010).

In emerging markets such as Indonesia, herding behavior is particularly pronounced among retail investors. Limited access to high-quality information, lower levels of financial literacy, and a strong collectivist culture enhance the tendency to rely on social cues. The widespread use of online trading platforms and investment communities further reinforces this behavior, as investors observe and emulate the trading patterns of others in real time. Social media and influencer culture also

magnify the visibility of investment trends, making herding not only a cognitive shortcut but also a social phenomenon that provides a sense of belonging and validation (Siganos et al., 2017).

While herding can occasionally improve investment performance in the short term—particularly when collective behavior aligns with favorable market movements—it generally undermines performance in the long run. Investors who follow the crowd often enter markets too late, buying at high prices during euphoric periods or selling at a loss during panic phases. This reactive pattern reduces the ability to exploit undervalued opportunities and leads to greater exposure to market reversals.

Understanding herding behavior is essential for improving decision-making discipline and market stability. Financial education that promotes analytical reasoning, diversification, and awareness of psychological biases can help investors resist the emotional pull of the crowd. In addition, fostering individual accountability and long-term investment perspectives can mitigate the negative effects of herding on both personal portfolios and the broader financial system.

2.3 Fear of Missing Out (FOMO)

Fear of Missing Out (FOMO) refers to the pervasive apprehension that others might be having rewarding experiences or opportunities from which one is absent (Przybylski et al., 2013). Within the context of financial markets, FOMO manifests as an emotional and cognitive bias that drives investors to act impulsively out of fear that they will miss potential profits or market opportunities seized by others. This psychological pressure often overrides rational analysis, causing investors to make decisions based on emotion rather than informed judgment.

FOMO is particularly intensified in the digital age, where information spreads rapidly through social media, online investment communities, and financial influencers. Retail investors are constantly exposed to stories of others' success — such as individuals gaining large returns from emerging stocks, cryptocurrencies, or trending assets — which amplifies the perception of missed opportunities. This exposure creates an emotional imbalance characterized by anxiety, restlessness, and urgency, leading investors to buy assets at inflated prices or enter markets without adequate analysis. Such actions frequently result in overvaluation, poor timing, and heightened exposure to volatility, ultimately harming investment performance (Taj, 2021).

Psychologically, FOMO is driven by anticipated regret — the discomfort associated with imagining oneself missing a profitable opportunity that others have taken. To avoid this regret, investors may engage in speculative trading, excessive diversification, or frequent portfolio adjustments. These behaviors can increase

transaction costs, reduce long-term returns, and undermine strategic investment planning. Empirical studies have shown that FOMO correlates with increased trading volume during market booms, where social sentiment and media attention reinforce the illusion of guaranteed profits (Kaur & Arora, 2021).

FOMO also interacts with other behavioral biases such as herding, overconfidence, and loss aversion. For instance, an investor influenced by FOMO may follow the crowd (herding) or overestimate their ability to time the market (overconfidence). Simultaneously, loss aversion — the tendency to fear losses more than valuing equivalent gains — may cause the same investor to hold on to underperforming assets longer than rational analysis would suggest, hoping to recover missed opportunities. This combination of biases can create cycles of emotional investing that destabilize portfolio performance.

In emerging markets such as Indonesia, where retail participation has increased significantly due to digital trading platforms, FOMO has become a defining feature of investor behavior. The rapid spread of investment-related content through social media channels, such as Instagram, TikTok, and online trading groups, fosters a competitive atmosphere where financial success is publicly displayed and compared. This social influence not only heightens the psychological pressure to participate but also reduces the perceived importance of fundamental analysis and risk assessment. Consequently, many retail investors engage in short-term trading behavior that prioritizes social validation over long-term wealth accumulation.

From a behavioral finance perspective, FOMO exemplifies how emotional impulses can distort rational investment decision-making. Instead of focusing on intrinsic asset value or financial fundamentals, FOMO-driven investors are guided by external cues — primarily the actions and achievements of others. This often leads to overreaction in bullish markets and panic selling during downturns, both of which contribute to market inefficiency and personal financial losses.

Therefore, managing FOMO is critical for improving investment discipline and performance. Financial education, emotional regulation, and awareness of cognitive biases can help investors resist the urge to chase market trends impulsively. Understanding FOMO's psychological mechanisms enables investors to shift from reactive decision-making to more deliberate, strategy-driven behavior — ultimately enhancing portfolio stability and long-term returns.

2.4 Investment Performance

Investment performance refers to the measurable results of an investor's decisions in managing their portfolio, encompassing both financial outcomes and psychological satisfaction. Traditionally, performance is evaluated through quantitative indicators such as portfolio returns, capital gains, and risk-adjusted metrics (e.g., the Sharpe ratio,

Treynor ratio, or Jensen's alpha). However, in the behavioral finance perspective, performance is not solely determined by objective financial results but is also shaped by subjective perceptions of success and satisfaction (Barber & Odean, 2001).

Investment performance reflects how effectively investors manage risk, allocate assets, and time their entry or exit from the market. Retail investors, who often have limited access to financial information and lower levels of analytical expertise compared to institutional investors, tend to rely more heavily on heuristics and emotional cues. These behavioral tendencies can lead to biases that either enhance or reduce investment performance. For instance, investors driven by optimism or overconfidence may take excessive risks, whereas those influenced by fear or loss aversion may become overly cautious, both of which can result in suboptimal performance.

From a behavioral standpoint, emotional factors such as herding behavior and fear of missing out (FOMO) are closely related to performance outcomes. Investors who engage in herding may experience temporary gains when market trends align with the crowd but are also exposed to sharp losses when the trend reverses. Similarly, FOMO can drive investors to enter markets at peak prices or chase speculative assets, leading to poor timing and diminished long-term returns. These behaviors reflect a departure from rational decision-making and demonstrate how psychological impulses can directly affect portfolio performance.

Moreover, perceived investment performance—the investor's subjective evaluation of how well their investments are performing—is equally important. Research in behavioral finance emphasizes that individuals often assess their performance not only through absolute returns but also through relative comparison with peers or market benchmarks. This social comparison can trigger feelings of satisfaction or regret that further influence subsequent investment decisions (Shefrin & Statman, 2000). For instance, an investor who perceives that others are earning higher returns may feel dissatisfied even when their portfolio is objectively performing well, which could lead to impulsive adjustments driven by emotion rather than analysis.

In the context of Indonesia's growing retail investor base, investment performance is strongly affected by the psychological and informational environment. Social media platforms, investment communities, and financial influencers play a major role in shaping expectations and perceptions of success. Retail investors exposed to sensationalized market news or peer success stories may feel compelled to replicate others' actions to achieve similar performance outcomes, reinforcing both herding and FOMO tendencies.

Therefore, investment performance is not merely a product of analytical capability but also of emotional discipline and behavioral control. Investors who can recognize and regulate biases such as herding and FOMO are more likely to achieve stable and

consistent performance over time. Conversely, those who succumb to market sentiment and emotional triggers risk making short-term, reactive decisions that can undermine long-term portfolio growth.

In summary, behavioral biases significantly influence investment performance through their impact on decision quality, timing, and risk management. A deeper understanding of these psychological mechanisms is essential for improving financial literacy and fostering more resilient investment behavior among retail investors.

2.5 Hypothesis Development

- H1: Herding behavior has a positive and significant effect on investment performance. (Direct Effect)
- H2: Herding behavior has a positive and significant effect on FOMO.
- H3: FOMO has a positive and significant effect on investment performance.
- H4: FOMO mediates the relationship between herding behavior and investment performance. (Indirect Effect)

3. Research Methodology

3.1 Research Design

This study uses a quantitative approach with a survey design. Data were collected through an online questionnaire distributed to active retail investors in Indonesia. A total of 178 valid responses were analyzed using PLS-SEM with SmartPLS 3.2.9.

3.2 Respondents' Characteristics

Age Category	Frequency	Percentage (%)
18–25 years	104	58,4%
26–35 years	51	28,7%
36–45 years	23	12,9%
Total	178	100,0%

Tabel 1. Respondent Characteristics

Among the 178 respondents, 56.7% were female and 43.3% were male. The majority were between 18 and 25 years old, held a bachelor's degree, and had 3 months to 1

year of investment experience. The data reflect a young, digitally active investor population typical of Indonesia's retail market.

3.3 Data Analysis Procedure

The analysis included:

1. Measurement Model (Outer Model): Assessing validity and reliability using factor loadings, Cronbach's Alpha, Composite Reliability, and AVE.
2. Structural Model (Inner Model): Testing hypotheses via bootstrapping, assessing R^2 , F^2 , and Q^2 values for predictive relevance and model fit.

4. Results and Discussion

4.1. Measurement Model (Outer Model)

The evaluation of the measurement model aims to assess the relationships between the indicators and their corresponding latent constructs, ensuring that each measurement item demonstrates adequate validity and reliability. In this study, the outer model was tested using several indicators, including convergent validity, discriminant validity, and reliability, analyzed through the Partial Least Squares (PLS) Algorithm.

4.1.1 Convergent Validity

Convergent validity assesses the extent to which multiple indicators of a construct are highly correlated, thus representing the same underlying concept. An indicator is considered valid if its loading factor is positive and greater than 0.70. A higher loading value indicates that the indicator strongly reflects its corresponding latent variable.

Based on the results generated by SmartPLS version 3.2.9, all indicators for the variables FOMO, Herding Behavior, and Investment Performance exhibit loading factor values above 0.70. Therefore, all indicators are deemed valid as measures of their respective latent constructs.

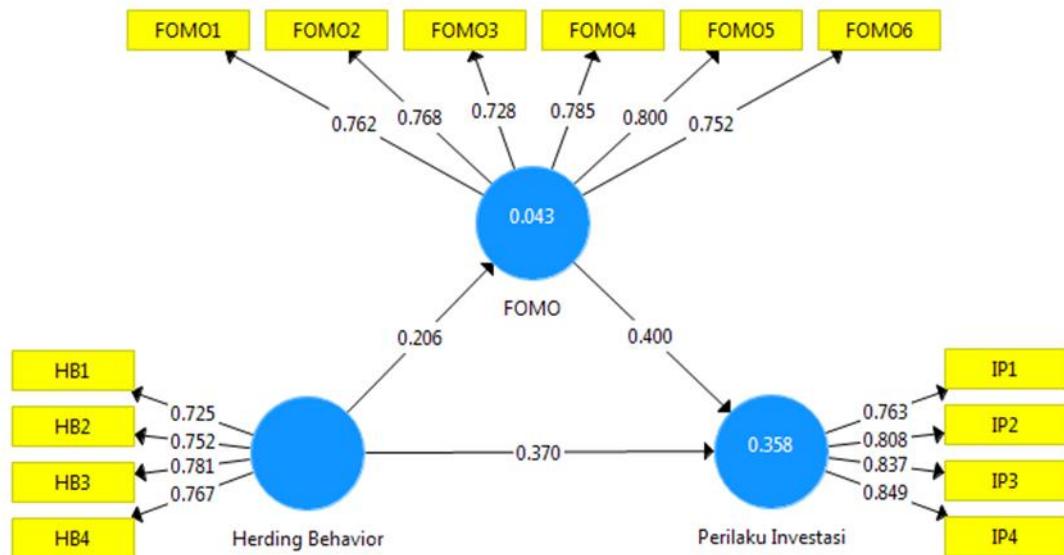


Figure 4.1.1. (Source:Hasil Output SmartPLS (v.3.2.9))

Table 4.1.1. Convergent Validity (Source: Hasil Output SmartPLS (v.3.2.9))

Variable	FOMO	Herding Behavior	Investment Performance
FOMO1	0,762		
FOMO2	0,768		
FOMO3	0,728		
FOMO4	0,785		
FOMO5	0,800		
FOMO6	0,752		
HB1		0,725	
HB2		0,752	
HB3		0,781	
HB4		0,767	
IP1			0,763
IP2			0,808
IP3			0,837
IP4			0,849

IP3	0,837
IP4	0,849

4.1.2 Discriminant Validity

Discriminant validity tests whether a construct is truly distinct from other constructs within the model. This assessment was carried out using two approaches: the Fornell–Larcker Criterion and Cross Loadings. The Fornell–Larcker results show that the square root of the Average Variance Extracted (AVE) for each construct is greater than its correlations with other constructs. This indicates that each construct better explains its own indicators than those of other constructs.

Similarly, the cross-loading analysis reveals that all items have the highest correlation with their respective constructs compared to other constructs, with all values exceeding 0.70. Hence, the results confirm that the discriminant validity criteria are satisfactorily met.

Table 4.1.2 Nilai Fornell-Larcker Criterion (Source: Hasil Output SmartPLS (v.3.2.9))

Variable	FOMO	Herding Behavior	Inv. Perf.
FOMO	0,766		
Herding Behavior	0,206	0,756	
Perilaku Investasi	0,476	0,453	0,815

Table 4.1.3 Cross loading (Source: Output SmartPLS (v.3.2.9))

Item	FOMO	Herding Behavior	Inv. Perf.
FOMO1	0,762	0,156	0,351
FOMO2	0,768	0,210	0,383
FOMO3	0,728	0,159	0,369
FOMO4	0,785	0,079	0,313
FOMO5	0,800	0,183	0,416
FOMO6	0,752	0,136	0,335
HB1	0,096	0,725	0,348
HB2	0,078	0,752	0,339
HB3	0,229	0,781	0,374
HB4	0,202	0,767	0,303
IP1	0,324	0,327	0,763

IP2	0,377	0,399	0,808
IP3	0,414	0,339	0,837
IP4	0,429	0,404	0,849

4.1.3. Reliability Analysis

Reliability testing was conducted to evaluate the internal consistency of indicators within each construct. The reliability was assessed through Cronbach's Alpha and Composite Reliability (CR).

The results show that all variables have Cronbach's Alpha and Composite Reliability values above 0.70, while AVE values exceed 0.50. These findings confirm that each construct possesses a high level of internal consistency, meeting the reliability thresholds recommended by Hair et al. (2021). Consequently, all constructs are considered reliable and suitable for further analysis.

Table 4.1.3.Reliability Testing (Source: Output SmartPLS (v.3.2.9))

Variable	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
FOMO	0,860	0,895	0,587
Herding Behavior	0,751	0,842	0,572
Investment Performance	0,831	0,888	0,664

4.1.4. Multicollinearity Test (VIF)

The Variance Inflation Factor (VIF) test was conducted to detect potential multicollinearity among indicators. The analysis indicates that all VIF values are below the threshold of 5, suggesting that there is no serious multicollinearity problem in the model. This implies that the indicators do not produce distortions in significance estimation or weight estimation. Therefore, the data can be considered free from high collinearity issues.

Table 4.14 Nilai VIF (Source: Output SmartPLS (v.3.2.9))

Item	VIF
-------------	------------

FOMO1	2,005
FOMO2	1,726
FOMO3	1,601
FOMO4	2,148
FOMO5	2,041
FOMO6	1,872
HB1	1,416
HB2	1,486
HB3	1,457
HB4	1,502
IP1	1,617
IP2	1,729
IP3	2,032
IP4	2,032

4.1.5. Heterotrait–Monotrait Ratio (HTMT)

The final step in evaluating the measurement model involves testing the Heterotrait–Monotrait Ratio (HTMT), which is a modern criterion for assessing discriminant validity. The results show that all HTMT values among constructs are below the recommended threshold of 0.90. This indicates that no excessive correlations exist among constructs, and each construct is conceptually distinct. Therefore, the HTMT analysis further supports that the discriminant validity of the model is satisfactory.

Table 4.1.5. HTMT Test (Source: Output SmartPLS (v.3.2.9))

Variable	FOMO	Herding Behavior	Perilaku Investasi
FOMO			
Herding Behavior	0,248		
Perilaku Investasi	0,554	0,568	

Overall, the results of the outer model evaluation demonstrate that all indicators exhibit sufficient convergent and discriminant validity, as well as high reliability.

Accordingly, the analysis proceeds to the structural model evaluation to test the relationships among the latent constructs.

4.2. Structural Model (Inner Model)

After confirming that the measurement model meets the validity and reliability requirements, the next step is to evaluate the structural model (inner model). This analysis aims to examine the relationships among latent constructs and assess the model's predictive power and overall fit. The evaluation of the inner model was performed through the examination of R-square (R^2), F-square (F^2), and Predictive Relevance (Q^2) values using SmartPLS version 3.2.9.

4.2.1. R-Square (R^2)

The R^2 value represents the proportion of variance in the dependent variable explained by the independent variables. The results show that the R^2 value for FOMO is 0.043, indicating that 4.3% of the variance in FOMO can be explained by the independent variables, while the remaining 95.7% is influenced by other factors not included in the model.

Meanwhile, the R^2 value for Investment Performance is 0.358, suggesting that 35.8% of the variance in investment behavior can be explained by FOMO and Herding Behavior. According to the criteria proposed by Hair et al. (2021), these fall within the moderate explanatory power category.

Table 4.1.6. Tabel R^2

Variable	R-Square	R-Square Adjusted
FOMO	0,043	0,037
Investment Performance	0,359	0,351

4.2.2. F-Square (F^2)

The F^2 test is used to measure the effect size of each exogenous construct on the endogenous construct. The results show that the F^2 value for the relationship between FOMO and Investment Behavior is 0.239, while the effect of Herding Behavior on Investment Performance is 0.204. These values indicate moderate effect sizes, meaning both independent constructs contribute meaningfully to explaining the variation in investment performance.

Table 4.1.7. F Square

Variable	FOMO	Herding Behavior	Inv.Perf.
FOMO			0,239
Herding Behavior	0,044		0,204
Inv.Perf.			

4.2.3. Predictive Relevance (Q-Square)

The predictive relevance (Q^2) test, conducted using the blindfolding procedure, assesses how well the model predicts observed data. The obtained Q^2 values are greater than zero ($Q^2 > 0$), demonstrating that the structural model has acceptable predictive relevance. This implies that the model's parameter estimates are capable of producing accurate and meaningful predictions of the observed values.

Tabel 4.1.8 Predictive Relevance

Variable	$Q^2 (=1-SSE/SSO)$	Desc.
FOMO	0,021	Indicates predictive relevance
Investment Performance	0,230	Indicates predictive relevance

Source: Output SmartPLS (v.3.2.9)

4.2 Hypothesis Testing

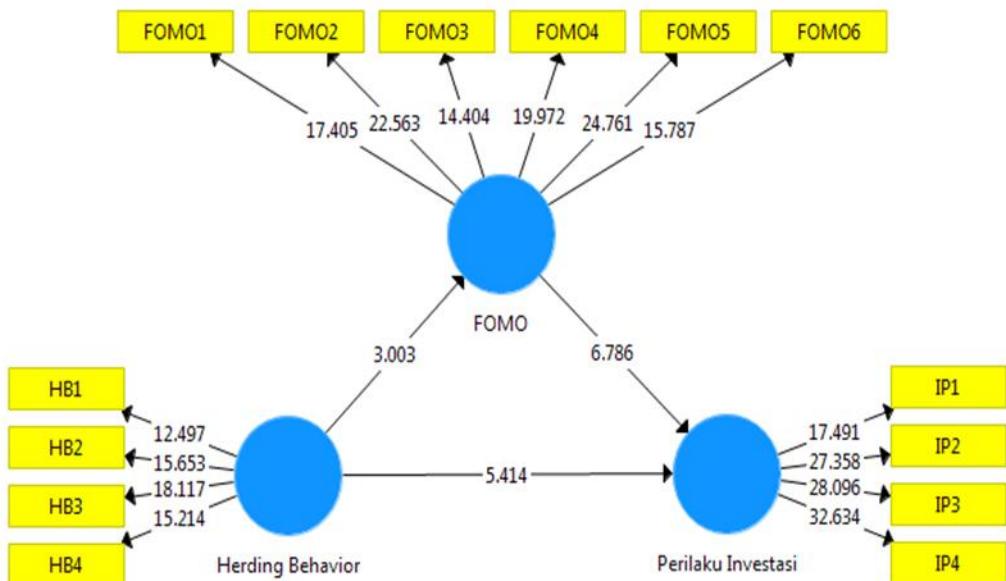


Figure 4.2. SmartPLS Output

Figure 4.2 illustrates the structural model showing the relationships among Herding Behavior, FOMO (Fear of Missing Out), and Investment Performance. The measurement model indicates that all observed indicators (HB1–HB4, FOMO1–FOMO6, and IP1–IP4) have strong and significant factor loadings, demonstrating good indicator reliability and validity for each construct. The structural model further reveals that Herding Behavior exerts a significant positive effect on both FOMO ($t = 3.003$) and Investment Performance ($t = 5.414$). Similarly, FOMO has a significant positive influence on Investment Performance ($t = 6.786$). These findings suggest that investors who tend to follow others' actions are more likely to experience FOMO, which in turn drives them to engage more actively in investment decisions that enhance performance.

Moreover, the mediation test confirms that FOMO partially mediates the relationship between Herding Behavior and Investment Performance ($t = 2.831$; $p = 0.005$), indicating the presence of an indirect effect alongside the direct path. This result highlights that the emotional bias of FOMO serves as a psychological channel

through which social influences, represented by herding tendencies, affect investors' decision-making outcomes. Overall, the figure underscores the interconnected roles of social and emotional factors in shaping investment performance, reinforcing the behavioral finance perspective that investor decisions are not purely rational but are significantly influenced by psychological and social dynamics.

Tabel 4.2. SmartPLS OutPut

Path Relationship	Path Coefficient	T-Statistic	P-Value	Result
Herding Behavior → Investment Performance	0,37	5,41	0,00	Supported
Herding Behavior → FOMO	0,21	3,00	0,00	Supported
FOMO → Investment Performance	0,40	6,79	0,00	Supported
Herding Behavior → FOMO → Investment Performance	0,08	2,83	0,01	Supported

Table 4.2. presents the results of the path analysis, showing that all hypothesized relationships are statistically significant and supported by the data. Each path coefficient, t-statistic, and p-value is described in detail below.

First, the relationship between Herding Behavior and Investment Performance shows a positive and significant effect, with a path coefficient of 0.370, t-statistic of 5.414, and p-value of 0.000. This result indicates that herding behavior enhances investment performance. In other words, when investors tend to follow the decisions of the majority, they may benefit from collective market movements, which can improve their overall performance. This finding aligns with prior behavioral finance literature suggesting that under certain conditions, following crowd behavior may provide informational advantages and strengthen investors' confidence in their decisions.

Second, Herding Behavior has a significant positive effect on FOMO (Fear of Missing Out), with a path coefficient of 0.206, t-statistic of 3.003, and p-value of 0.003. This implies that investors who exhibit stronger herding tendencies are more likely to experience FOMO. The social and informational influence from others triggers anxiety about missing profitable opportunities, motivating investors to act quickly to avoid being left behind. This supports the notion that herding behavior can amplify emotional biases, particularly those related to fear and social comparison in investment contexts.

Third, FOMO significantly influences Investment Performance, as shown by a path coefficient of 0.400, t-statistic of 6.786, and p-value of 0.000. The result suggests that investors driven by FOMO tend to make more proactive or risk-taking decisions, which, in some cases, lead to better performance outcomes. Although FOMO is often associated with impulsive or emotionally driven decisions, this finding indicates that the motivational aspect of FOMO can also encourage investors to seize opportunities promptly, thereby enhancing their investment results.

Finally, the mediating analysis reveals that Herding Behavior affects Investment Performance through FOMO, with a path coefficient of 0.083, t-statistic of 2.831, and p-value of 0.005. This indicates a significant indirect effect, confirming that FOMO partially mediates the relationship between herding behavior and investment performance. In essence, investors influenced by herding are more susceptible to FOMO, which subsequently drives their investment actions and performance outcomes.

Overall, all hypotheses are supported, confirming the theoretical framework that behavioral biases—specifically herding behavior and FOMO—play a crucial role in shaping retail investors' decision-making and investment outcomes. These findings highlight that psychological and social factors can meaningfully influence financial behavior, suggesting that understanding emotional and cognitive biases is essential in predicting and explaining market dynamics among retail investors.

5. Conclusion and Implications

5.1 Conclusion

1. Herding behaviour positively and significantly affects investment performance.

This finding indicates that collective investor actions—where individuals imitate the majority's decisions—can influence market outcomes and portfolio performance. In the short term, following the crowd may lead to gains when market momentum is positive, as collective optimism drives asset prices upward. However, such gains are often unsustainable and subject to reversal once market sentiment changes. The positive and significant relationship observed suggests that, within the Indonesian retail investment context, herding may occasionally enhance returns when market trends align with the majority view. Nevertheless, excessive reliance on crowd behavior undermines independent analysis, making investors vulnerable to bubbles and sharp corrections. This result aligns with previous studies by Chiang and Zheng (2010) and Bikhchandani and Sharma (2000), who emphasize that herding can distort market efficiency while temporarily amplifying returns.

2. Herding behavior positively and significantly affects FOMO.

The relationship between herding and FOMO highlights the psychological mechanism linking social influence with emotional response. When investors observe others profiting from specific assets or market trends, they experience heightened anxiety about missing out on similar opportunities. This social comparison process reinforces emotional contagion, where collective enthusiasm spreads rapidly within investor communities. In Indonesia's increasingly digitalized financial environment—

where information circulates through social media and online trading platforms—herding intensifies FOMO by amplifying perceived opportunities. Investors who witness others' success are likely to imitate their behavior, not necessarily because of rational evaluation, but to reduce the discomfort associated with exclusion. This finding confirms the interdependence of cognitive and emotional factors within behavioral finance, as described by Przybylski et al. (2013) and Taj (2021).

3. FOMO positively and significantly affects investment performance.

This result suggests that emotional anxiety—while often associated with impulsive behavior—can also act as a motivator for market participation. Investors experiencing FOMO are driven by the desire to capture potential gains, which may increase their activity levels and willingness to assume risk. When market conditions are favorable, such proactive engagement can translate into higher returns. However, the quality of these returns largely depends on timing and market stability. While FOMO can increase participation and short-term profitability, it may also result in excessive risk-taking and poor decision quality when markets turn volatile. Thus, the positive effect of FOMO on performance may be context-dependent, reflecting the dual nature of emotional motivation in investment behavior.

4. FOMO mediates the relationship between herding behavior and investment performance.

The mediation effect of FOMO underscores the emotional pathway through which social influence translates into performance outcomes. Herding alone may not directly determine investment success; instead, it activates emotional responses—particularly the fear of missing out—that drive investors toward immediate action. When FOMO is high, investors are more likely to join market trends aggressively, magnifying both potential gains and losses. The mediating role of FOMO highlights that psychological states serve as a bridge between social imitation and economic behavior. This finding supports the argument that emotional regulation plays a critical role in moderating the effects of social influence on financial outcomes (Kaur & Arora, 2021).

5.2 Implications

Theoretical Implications

This study contributes to the development of behavioral finance theory by highlighting Fear of Missing Out (FOMO) as a significant mediating psychological mechanism between herding behavior and investment performance. While classical behavioral finance focuses on cognitive biases such as overconfidence or loss aversion, this research extends the framework by incorporating social-emotional dynamics that drive investor behavior in digital and information-saturated markets. The finding that herding influences FOMO, which in turn affects investment outcomes,

underscores that investors' decisions are not solely shaped by rational expectations but are also conditioned by affective and social contagion processes. Thus, this study advances theoretical understanding by integrating emotional contagion and social influence into existing behavioral finance models, offering a more holistic view of how collective behavior translates into financial outcomes.

Practical Implications

From a practical standpoint, these findings suggest that financial advisors, policymakers, and regulators should take into account the emotional dimension of investor decision-making. Behavioral biases such as herding and FOMO can lead to short-term speculation, overreaction to market trends, and suboptimal portfolio management. Therefore, investor education and behavioral training programs are crucial to help retail investors recognize emotional triggers and mitigate impulsive decision-making. Financial literacy campaigns—particularly those emphasizing emotional regulation, critical evaluation of market information, and long-term investment discipline—can significantly reduce the adverse effects of behavioral biases. Additionally, regulators can design early warning systems or sentiment monitoring tools to detect herding waves in retail markets, thereby promoting financial stability and investor protection.

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Theoretical Perspectives on AI in Risk Management: The Role of Risk Managers in Facilitating AI Integration

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Abstract

This study aims to explore the role of risk managers in facilitating the integration of Artificial intelligence (AI) within organizational risk management frameworks by identifying the important factors influencing their strategic operational motivation. The research explains how trust leadership communication, organizational culture and data quality management exhibit AI adoption behaviors. The study adopts a theory-driven conceptual methodology based on an integrative framework that combines the Technology Acceptance Model (TAM) and the Diffusion of Innovation (DOI) theory. A thematic literature review was conducted to extract core constructs such as perceived usefulness, ease of use (PUEOU), organizational enablers, and technical barriers. These constructs were synthesized into a novel conceptual model explaining how risk managers act as facilitators of AI integration, with special attention to emerging variables such as AI-trust and algorithm complexity. The proposed model identifies trust in AI, leadership communication, organizational culture, data quality management, and algorithm complexity as pivotal factors influencing behavioral intention to adopt AI in risk management. The study reveals that adoption is not solely determined by technical considerations but is strongly shaped by managerial perceptions and contextual enablers. As a conceptual investigation, this study does not present empirical validation but offers a theoretical foundation for future research. It calls for empirical testing using structural equation modeling and encourages sector-specific applications to assess model generalizability. It also spotlights the need to account for contextual variables such as industry type, digital maturity, and perceived risk. This study contributes to the literature by extending classical technology adoption models through the inclusion of organizational and human-centric constructs. It repositions risk managers as strategic actors in digital transformation processes and provides a multidimensional framework for understanding AI integration. The findings offer valuable

outcomes for researchers, practitioners, and policymakers aiming to foster responsible and effective AI adoption in risk-sensitive environments.

Keywords: AI , Risk managers, AI adoption, Technology Acceptance Model (TAM) , Diffusion of Innovation (DOI), Conceptual Model, Theoretical Research

1. Introduction

In the 21st century, advances in hardware and computational power have driven numerous breakthroughs in Artificial Intelligence (AI). The development of algorithms, support vector machines had made AI implementation viable across diverse industries. Therefore, Artificial intelligence explained as "a system's ability to correctly interpret external data, to learn from such data and to use those learnings to achieve specific goals and tasks through flexible adaptation" (Kaplan & Haenlein, 2019b, p. 17), this concept has captivated an immense attention among business managers, entrepreneurs, scientists, academics and politicians, consequently it interests all the community members.

In the current context, there is growing attention on the potential of artificial intelligence (AI) to transform business measurement and reporting practices. At the same time, concerns are being raised about the risks associated with delayed or incomplete adoption, which could lead to the persistence of outdated systems that become increasingly ineffective over time (Akinsola et al., 2022; Bagnoli et al., 2019; Cobianchi et al., 2022; Cong et al., 2018; Žigienė et al., 2019).

Indeed, AI particularly through its core machine learning techniques is transforming, and will continue to revolutionize, our approach to risk management. As emerging technologies and information systems become increasingly integral to modern digitalized societies, their associated risks have gained significant scholarly attention (Bandyopadhyay, Mykytyn, & Mykytyn, 1999). Integrating AI into risk management empowers managers to generate more informed forecasts, identify optimal decision-making strategies, and anticipate outcomes with greater precision than traditional methods allow.

In the domain of risk management, a growing body of research features the benefits of integrating AI technologies. Scholars and practitioners alike have brought to attention how AI is reforming the role of risk managers. Copulsky (2011) argues that this role is evolving toward a more strategic function, moving beyond traditional technical tasks. As AI adoption expands, the profession is increasingly focused on interpreting and understanding complex risk dynamics (Taarup-Esbensen, 2019). Supporting this shift, a Deloitte (2019) survey reveals that risk management departments are progressively utilizing technology to enhance efficiency by reducing redundancies and simplifying governance structures. However, despite these

promising developments, the implementation of AI tools remains limited in many organizations (Deloitte, 2021).

The problematic arises from today's complex and dynamic organizational environment; risk managers face heightened uncertainties and diverse risk that require accurate forecasting. To address this issue, many organizations around the world are turning to AI driven tools, which offer powerful capabilities for predicting and managing potential risks. Nevertheless, the implementation of these tools is not straightforward, it requires careful alignment with organizational goals, processes, and culture.

This paper aims to explore the theoretical perspectives emerging from recent research, with a particular focus on the role of managers as facilitators of AI integration. While the topic has gained attention in the literature, there remains a lack of empirical studies within my specific context. By building a strong theoretical foundation, this study seeks to contribute to future empirical investigations.

The study addresses the following central research question: **How do risk managers facilitate the integration of AI tools into organizational risk management frameworks?** To frame this inquiry, a deeper theoretical understanding is required, one that moves beyond general adoption models. This paper proposes a theoretical exploration grounded in two intertwined models: The Technology Acceptance Model (TAM) (Davis, 1986) which emphasizes perceived ease of use and perceived usefulness as key determinants of technology acceptance, and the Diffusion of Innovation (DOI) theory (Rogers, 2003) which explains how, why and at what rate new technologies spread within a system. According to Rogers (2003, p. 5), diffusion is "the process by which an innovation is communicated through certain channels over time among the members of a social system." Researchers, theorists, and practitioners from many fields have been interested in DOI within and across organizations, including organization theory, management, education, health care and public health, information technology, and sociology. A review of the literature on the diffusion and sustainability of innovations (Greenhalgh, Robert, Macfarlane, Bate, & Kyriakidou, 2004) identified 13 major research traditions.

These frameworks offer a conceptual base to study the managerial behaviors, beliefs, perceptions and contextual factors that determine the integration of AI in risk management processes.

2. Methodology

This research endorses a theoretical and conceptual approach aimed to exploring how managers facilitate the integration of AI into organizational risk management frameworks, rather than conducting empirical research, the paper extracting

epiphanies from an existing body of literature to construct a theoretical foundation to grasp the managerial role in AI integration.

To do so, we employ a theory driven analytical method grounded in critical review of recent scholarly discoveries about AI adoption, risk management and managerial roles. Our deep analysis is structured around two previous theoretical models: The technology of acceptance (TAM) and the Diffusion of innovation (DOI) theory. These models were selected for their materiality, relevance and applicability in explaining technology adoption at both the individual and organizational levels, as for their complementarity perspectives.

The research first identifies vital theoretical constructs related to managerial facilitation, such as perceived usefulness, ease of use, compatibility and complexity, whilst these constructs are afterward conceptually mapped to the context of AI integration in risk management. Although by juxtaposing these models the study offers a synthesized theoretical standpoint that underscore the active role of managers in influencing adoption processes, supporting organizational change, and mediating between technological potential and strategic implementation.

A narrative literature review was conducted using databases such as Scopus, Web of Science and Google Scholar to build a robust theoretical foundation the search focused on identifying the most cited articles within the last five years from 2019 to 2025, specifically addressed themes such as AI adoption, risk management, managerial roles in digital transformation, and technology adoption. Priority was given to highly cited, peer-reviewed journal articles to ensure the inclusion of influential and contemporary theoretical contributions. The reviewed literature was analyzed thematically, focusing on identifying (1) the role of risk managers in digital transformation (2) the barriers to and facilitators of AI adoption and (3) theoretical exploration from these barriers.

This methodological approach was chosen to rigorously synthesize recent high impact scholarly contributions and address the identify theoretical gap, particularly in light of limited availability of context specific empirical studies.

3. Results

This theoretical investigation results in a novel conceptual framework that bring to light the strategic role of risk managers as enablers of AI integration in risk management framework. Therefore, by merging the Technology Acceptance Model (TAM) with the Diffusion of Innovation (DOI) theory, the study transcends traditional models concentrated solely on user acceptance. Whilst it proposes a synthesized approach that dissect how managerial perceptions, behaviors and contextual variables relate to influence AI adoption.

Despite the number of the recent conceptual works addressing AI in risk management domain, there is limited theoretical and empirical literature on the topic. Yet, this study repositions risk managers as operative and active intermediaries who could translate AI potential into actionable strategies, hinder resistance, and align AI with organizational objectives and risk culture.

The framework introduces specific extended constructs such as: (1) Organizational culture (2) Trust in AI (3) Managerial Strategic usefulness (4) Leadership (5) AI Algorithm complexity (6) Data quality Management. These constructs determine real hindrances in organizations that classic models TAM and DOI might overlook. Moreover, they make the framework more applicable and precise. Furthermore, these extended constructs encompass technical, human, organizational and managerial dimensions, furthermore this multidimensional approach constitutes a distinctive contribution to the literature. Additionally, the theoretical synthesis also demonstrates a notable gap in current literature by providing a structured foundation for future empirical studies, especially in contexts considered by limited empirical data or nascent digital transformation processes, such as those observed in Morocco.

4. Discussion

The integration of extended constructs into the TAM and DOI models has yielded a holistic comprehension of AI adoption in the field of risk management. The results exhibit that technical, organizational, managerial, and human factors must be intertwined to fully grasp the intricacies bordering AI integration. In parallel with our initial motivation, to grasp what facilities or inhibits the adoption of AI tools by risk managers, this study confirms that classical models are insufficient in isolation, especially in this era.

In particular, the construct of Organizational culture serves as the pioneer factor in facilitating AI integration into risk management, as fundamentally sets the internal tone for how innovations are perceived, accepted and operationalized within an organization. Referring to the DOI model the Social System represents the context in which an innovation is introduced, essentially interpreted through external environmental influences, for example the market dynamics, industry maturity, industry ecosystems. However, in this study, we expand this dimension by outlining the internal social system of the organization, its culture, values, norms, and shared beliefs as a critical determinant of AI adoption, as collectively demonstrate employees' attitudes and behaviors towards Innovation.

We argue that an organizational culture that promotes experimentations, continuous learning, and collective problem-solving creates a fertile ground for AI integration, in such environment's employees' are not only trained to adapt to digital

transformation but also developed a shared cognitive and behavioral disposition, as it framed in this study a collective mindset toward AI'. This level state of mind accelerates technological shift, and strengthen organizational resilience in managing risks. On the other hand, we argue that organizational culture, as an expression of the internal social system, is an indispensable complementary construct to the Technology Acceptance Model (TAM) in understanding AI adoption within risk management frameworks.

While TAM explains a strong individual level explanation, demonstrating perceived usefulness and perceived ease of use as fundamental predictors of technology acceptance, it often overlooks the broader organizational context in which these perceptions are formed. In this research, we extend the model by positioning organizational culture as a structural and social environmental determinant that inhibits these TAM constructs. Notably, an organizational culture that stimulates learning, experimentation, psychological safety, and openness to innovation nurtures conditions in which individuals are more likely to perceive AI tools as useful and user friendly. We will return to the notion of 'the collective mindset' underscores that AI adoption is not merely the result of individual decisions, but rather reflects a shared organizational commitment framed by commons values, norms and strategic alignment.

In essence, while TAM explains how individuals come to accept technology, organizational culture explains why and under what conditions these perceptions are likely to emerge and be sustained across the organization. This integrative standpoint offers a more apprehension to AI adoption, especially in complex domains like risk management, where organizational norms, readiness, and shared beliefs significantly impact digital transformation processes.

Among the extended constructs proposed in this framework is AI-trust, as has emerged as an important factor in aggregating both perceived usefulness and the intention to adopt, thus warranting special attention. While traditional models TAM and DOI account for variables like ease of use, usefulness and innovation attributes (e.g. compatibility or complexity), they fall short in addressing the relational and psychological dimensions of human-AI interaction, particularly in risk management, where decision making authority is central. Recent work by Rizzo, Bagna, and Tuček (2023), where they addressed a special question "Do Managers Trust AI? directly engages with this gap. Their findings showed that even though AI systems are increasingly recognized and valued, the study's results reveal that managers still tend to prefer advice given by humans rather than advice coming from AI. However, the analysis also shows that managers who have a low tendency to compare themselves with others (low social comparison orientation) are more open or willing to accept advice from AI systems. This relational trust becomes even more sensitive in domains like risk management, where the stakes of delegation judgment to AI are high, and

where risk managers may perceive AI tools as either a strategic aid or a threat to their role.

In this light, trust in AI should be conceptualized as a standalone, complementary construct in the era of AI technology, it appends a human centered approach to the adoption process, acknowledging that even highly integrated systems could confront resistance if users do not feel confident or aligned with the AI's outputs and eventually logic. In contrast to the previous studies of TAM model that focused on perceived usefulness which noticeably concentrates on performance expectations, or ease of use which concerns system interaction, trust in AI reflects a deeper cognitive and affective appraisal, stemming perceptions of transparency, fairness, explainability and shared control.

Therefore, integrating AI-trust corresponds to a growing body of literature calling for context adaptation of classical adoption models (e.g., Wirtz et al., 2022; Davenport & Ronanki, 2018). Additionally, AI-trust constructs align with the managerial realities of AI deployment, where adoption is not just a matter of Utility, but of Identity, authority and confidence in algorithm reasoning. This construct becomes especially relevant in contexts like Morocco, where digital transformation is still evolving and where managerial hesitation may be amplified by a lack of experience or systemic support for AI decision-making.

(3) Leadership presents a critical role in framing the successful adoption and integration of AI technologies within organizational frameworks. It is understood as a broad and dynamic domain, as we conceptualized it, leadership unfolds in a sequential process rather than a static construct. Consequently, this research focuses specifically on one critical aspect of leadership, the communication style of the risk manager. Effective communication by leadership is essential to ensure that collaborators comprehend the purpose, benefits and limitation of AI technologies, such clarity is important because AI adoption trigger uncertainty and fear among employees, including concerns about job security and loss of control. The risk manager plays a role of a proactive leader, by addressing these concerns at the early stage through transparency and consistent communication. This approach mitigates resistance, foster trust and facilitate shared organizational understanding of AI as a strategic enabler rather than an impediment. In this sense, communication acts as a bridge between technological innovation and human factors, supporting constructs such as organizational culture and AI-trust.

In risk management context, where decisions must be transparent, justifiable, accountable, leadership communication also captures how AI outputs are interpreted and used by managers (López-Cabarcos et al., 2022). Leaders who actively encourage and support the sharing of knowledge about AI help risk managers become more capable and confident in using AI tools. This leadership approach

accelerates the spread (diffusion) of AI technologies within the organization and helps make AI a regular, established part of how organization works.

In addition to above variables, data quality management (DQM) is important in risk management domain, where decision accuracy and reliability are paramount. As Data can takes various forms numbers, text, images or even sensory inputs. Data is representation of any object or event in some physical medium. The value of data is in its ability to convey something about the object that we care to know. By using data, rather than interacting directly with the object itself, we can be more efficient and effective (R. Weber., 1997). in a recent study by Roman Lukyanenko (2025) which aimed to clarify and consolidate the definition of data quality, the author defines Data quality (information quality) is the characteristic of data that impacts the appropriateness of decisions and actions taken based on data. High Data quality is characterized by accuracy, completeness, consistency and timeliness, these elements are indispensable for AI systems to generate trustworthy predictions.

From a managerial perspective we argue that effective outputs emerge from an organizational environment determined by well-established processes, robust governance structures, and a culture that prioritizes data accuracy and integrity. This aligns closely with the construct of environmental culture, wherein organizational culture norms and values support meticulous data handling and continuous process improvement. Moreover, DQM influences trust in AI, as risk managers 'confidence in AI outputs depends strongly on the perceived reliability of underlying data. In the absence of robust Data quality practices, AI-generated recommendations may be questioned or dismissed, undermining adoption efforts.

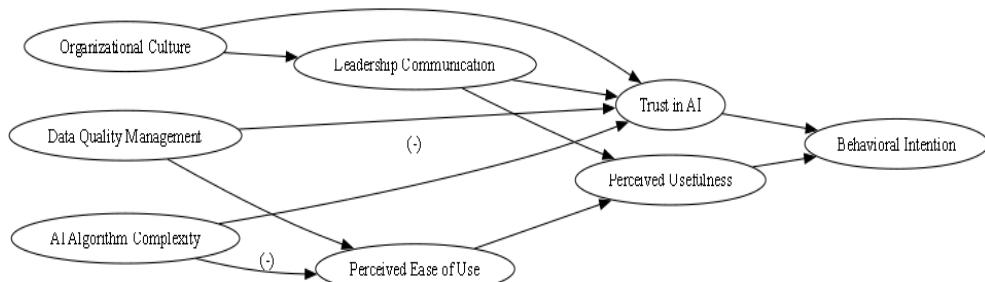
The role of risk manager's team managing data behind the scenes also demonstrate the human dimension rooted within DQM. This hypothetically linked to change management initiatives as that foster training, accountability, and continuous feedback information to ensure data standards are upheld over time.

AI algorithm complexity is perceived as a technical opacity the evaluation and supervision of its algorithm have become important issues in AI risk management. A recent study presented by Wenyi Xu et al. (2025) at the 2023 International Conference on Big Data, Artificial Intelligence and Risk Management (ICBAR '23), argued that the complexity of AI models, especially black box algorithms has become one of the principal barriers to managerial trust and adoption. Their findings indicate that when algorithmic decision processes are not transparent or easily explainable, managers tend to either defer to human judgment or reject the AI system altogether, regardless of its technical performance. This synchronizes with TAM model, particularly in its construct of perceived ease of use, which is negatively impacted be the perceived incomprehensibility of AI algorithms. Moreover, excessive complexity can erode trust

in AI, especially when risk managers are incapable to trace the rationale behind AI generated results, thereby increasing perceived risk and reducing acceptance.

The implications of AI complexity also extend to Data Quality Management. As Wenyi Xu et al. argue, high algorithmic complexity often requires exceptionally clean, well-structured data—making the presence of mature data governance practices essential. Even well-trained models can produce unreliable outputs if data integrity is compromised, especially when the algorithm's internal workings are not readily interpretable.

AI algorithm complexity is not only a technical construct, but a concern that moderates the relationships between functional adoption drivers, mainly trust and ease of use, making it an important addition to any extended AI adoption framework in risk management. Building upon the TAM and DOI models, this study proposes a conceptual research model (figure 1) that integrates both technological and



organizational dimensions influencing the adoption of AI in risk management context.

Figure 5. Conceptual model of AI adoption integrating organizational and technological constructs.

This model suggests several interrelated constructs that are grounded from organizational behavior and information system. Organizational culture is perceived as the internal social system that form collective beliefs, openness to innovation and receptivity to AI. It exerts an important influence on both trust in AI and leadership communication, thus, leadership communication style is positioned as a driver of both trust and the perceived usefulness (PU) of AI systems. It illustrates how leaders communicate about AI initiatives, foster transparency, and reduce uncertainty. Whereas, trust in AI emerges as central construct which is affected by both technical factors (AI complexity, Data quality) and social/organizational ones (Culture/leadership). Hypothetically, AI algorithm complexity has a negative impact on trust and perceived Ease of use (PEOU), it explains that complexity may hinder acceptance.

Additionally, DQM is conceptualized as essential for fostering PEOU and building trust, especially in risk-sensitive situations where data integrity is non-negotiable. Furthermore, Perceived Ease of Use (PEOU) and Perceived Usefulness (PU) remain

bone TAM constructs. Their positioning maintains consistency with the established model while being hypothetically influenced by both technical (e.g., complexity, DQ) and organizational factors. Eventually, behavioral intention to adopt AI is influenced directly by both trust in AI and PU, representing the risk manager's intent to facilitate the integration of AI.

Despite the model's contributions, it is not without limitation. It focuses primarily on the organizational and technological factors, overseeing contextual and environmental variables that may influence adoption of AI, not only this, while the model includes core constructs such as trust, culture, and leadership, it oversimplifies complex psychological and social processes that may vary individual or industry, which calls the necessities to include moderators, such as industry context, user experience, perceived risk, digital maturity. Eventually, future research may empirically validate this model using structural equation modeling (SEM) or partial least squares (PLS) approaches and explore the moderating roles.

5. Conclusion

This study aims to explore the intricacies interplay of factors influencing the adoption of AI tools in organizational risk management frameworks. Referring to the Technology Acceptance Model (TAM) and enriched by organizational and information system perspectives, the research proposes a thorough conceptual model incorporating models such as organizational culture, Leadership Communication, Trust in AI, Data Quality Management (DQM) and AI Algorithm complexity.

The core argument of the model is that AI adoption is not exclusively a technological decision, but one embedded within the social and organizational fabric of the firm. In particular, trust in AI is formulated as an indispensable construct, influenced by either technical determinant (e.g., algorithm complexity and data quality) and socio organizational enablers (e.g., Leadership communication and culture). The model retains and expands TAM's core constructs Perceived Ease of Use (PEOU) and Perceived Usefulness (PU) connecting them to Behavioral Intention to use AI.

Furthermore, the results achieved through this conceptual framework are theoretical and explanatory in nature. As a result, the model offers:

1. A multi-dimensional view of AI adoption, integrating organizational behavior, information systems, and technology acceptance literature;
2. A re-centering of trust as a cognitive mechanism that spans technological complexity and user intention;
3. Enlightenment into how organizational leadership and data governance practices create the cultural and informational conditions necessary for AI acceptance.

This model thereby contributes to existing scholarship by:

1. Expanding the TAM to include other determinants, social, cultural, and technical antecedents that are exclusively relevant to AI and risk management;
2. Spotlight the role of internal organizational drivers, often overlooked in techno-centric models in demonstrating user's perception and acceptance of complex technologies;
3. Offering a foundation for empirical validation, which can provide a development of context specific strategies for AI integration;

Concerning the future directions for research, forthcoming studies can extend this study in several directions:

1. An empirical testing and validation are required, using Structure Equation Modeling (SEM) or Partial Least Square (PLS), one of these can validate the model's constructs and causal relationships in interviewed organizations;
2. The model has to be contextualized, it could be tested across different sectors (e.g., Finance, Logistics) to evaluate whether the proposed relationships hold in diverse risk environments;
3. The model could take into consideration the temporal and dynamic factors or include longitudinal designs to showcase how trust in AI, leadership approaches and perceived usefulness progress over time as organizations evolve in their digital transformation;
4. The model could be expanded to include either moderators or mediators to refine the understanding of AI adoption pathway;
5. Each context is different when it comes to AI adoption, therefore, the model could be tested via comparative studies on how organizational culture and leadership styles differentially affect AI adoption results in various socio-economic and institutional context.

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Beyond Expertise: Leadership Style as a Catalyst for Effective Consulting Relationships

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Abstract

Consulting plays an increasingly important role in the modern business environment, which is characterized by dynamic change, growing competition, and the rising complexity of business processes. Organizations are relying more and more on the expertise of consultants to ensure sustainable growth, enhance efficiency, and adapt to global market trends. In this context, the relationship between the consultant and the client represents the cornerstone of a successful consulting engagement. The quality of this relationship is measured not only by project outcomes but also by how the consultant manages the collaboration, fosters mutual trust, and builds a genuine partnership. The subject of this paper is the analysis of the role of leadership style in building and maintaining trust between consultants and their clients. The focus is placed on examining consultants' perceptions of their own leadership styles and how they assess the development of trust within the consulting relationship. The research results have both theoretical and practical significance. They contribute to a deeper understanding of the connection between leadership and trust, while also providing valuable guidance for consultants seeking to improve their approaches to working with clients.

Keywords: leadership, consulting, effective relationship, leadership style

JEL Classification: M12, L84, D23, M54, C83

1. Introduction

Leadership in consulting services should be viewed as a dynamic and multidimensional process in which interpersonal skills, ethical conduct, and professional credibility are equally important as technical competence. The subject of this paper is the analysis of the role of leadership style in building and maintaining

trust between consultants and their clients. The focus was placed on examining consultants' perceptions of their own leadership styles and the ways in which they assess the development of trust within the consulting relationship. The aim of the paper was to explore which dimensions of leadership contribute most significantly to the creation of trust, how consultants establish partnership-based relationships with clients, and in what ways trust affects the long-term nature and quality of collaboration. The research results have theoretical value in terms of providing a better understanding of the connection between leadership and trust, as well as practical significance, as they can serve as guidelines for consultants seeking to enhance their approaches to working with clients.

2. Distinctive Features of Leadership in Consulting Organizations

Changes in contemporary business have also shaped theoretical approaches to leadership, leading to the development of a number of models collectively referred to as contemporary leadership theories. Their fundamental feature is the greater involvement of employees in decision-making processes, with an emphasis on participation and collaboration compared to the hierarchical and authoritarian styles of earlier theories. These models differ in the emphasis they place on motivation, vision, the leader's personality, or interaction with the environment, but they share a common goal, to increase organizational effectiveness under dynamic conditions.

Leadership in professional services emerges as a complex and multidimensional phenomenon that differs from traditional forms of leadership characteristic of industrial or bureaucratic systems. Professional services, such as those provided by lawyers, doctors, consultants, or university professors are based on specialized knowledge, a strong professional identity, and a relatively high degree of autonomy among experts. These very characteristics influence the form and dynamics of leadership within such organizations, making it less hierarchically determined and more focused on mutual influence and coordination (Empson and Langley, 2015). In this context, leadership is not reduced to formal power or positional authority, but rather to the ability to shape a shared direction of action through professional credibility and interpersonal skills (Ford et al., 2015).

The role of the leader in professional services is often manifested through three interrelated aspects: demonstrating expertise and professional knowledge, engaging in political interaction with colleagues, and setting a personal example that embodies professional values (Langley and Empson, 2015). This highlights that leadership is not always individualized but is often collective, where several individuals jointly participate in shaping norms and the strategic direction of action. Such a form of leadership becomes particularly important in contexts where formal control has limited reach and the professional autonomy of employees remains high (Empson and Langley, 2015).

Traditional leadership theories, such as the trait or behavioral theories, have proven insufficient for explaining the specificities of professional services. Organizations of

this type function as professional bureaucracies in which leadership must simultaneously respect individual autonomy and align activities with the organization's mission (Dennison and Shenton, 1990). Therefore, more relevant are contemporary approaches that emphasize contextuality and social interaction, such as distributed leadership or leadership-as-practice. Distributed leadership assumes that leadership roles are not limited to formal positions but can also be assumed by professionals through everyday interactions, knowledge sharing, and mutual recognition of competencies (Dalli and Thornton, 2020). This form of leadership contributes to both stability and innovativeness, particularly in academic and consulting organizations (Simpson, 2004).

Given the complexity and uncertainty that characterize professional services, leaders must develop competencies that go beyond technical expertise. They need emotional intelligence, ethical responsibility, and the ability to facilitate collaborative processes. In this context, authority stems from professional credibility and reputation, while the power of formal position is of secondary importance. A successful leader must be recognized as an expert, a trusted individual, and someone capable of aligning individual and collective interests with the goals of the organization (Kelly, 2023).

Leadership in professional services is largely based on negotiation, consensus, and the management of informal networks of influence. It is less oriented toward command and control, and more toward facilitation and inspiration (Simpson, 2004). Consequently, it often takes the form of collective leadership that arises from mutual trust, expertise, and the reputation of team members (Empson and Langley, 2015). This form of leadership enables flexibility and participation in decision-making and relies on social mechanisms of control such as norms, rituals, and professional codes. These mechanisms guide behavior without formal intervention, and their strength lies in socialization and mentorship, through which younger professionals adopt values and behavioral patterns by observing senior colleagues (Ford et al., 2021).

The professional identity of experts strongly shapes how they perceive and accept leadership. In professional services, leadership is often seen not as the imposition of authority, but as collaboration among equals (Empson and Langley, 2015). This requires leaders to possess well-developed communication and interpersonal skills, empathy, and the ability to facilitate joint decision-making. Such a logic of leadership implies that, in professional organizations, leaders often operate in the background as catalysts of change and supporters of teamwork rather than as figures who dominate processes. Many professionals demonstrate a certain resistance to traditional managerial models, perceiving them as distancing from the essence of their profession. Therefore, successful leaders must align their authority with the professional values of the community while simultaneously ensuring progress and innovation (Dalli and Thornton, 2020).

Furthermore, the development of leadership in professional services is strongly linked to education and experience. Many professionals enter leadership roles without formal preparation; however, research indicates that structured training programs can

enhance their abilities in planning, decision-making, and team leadership (Dennison and Shenton, 2016).

Despite its numerous advantages, leadership in professional services faces specific challenges. One of these is the resistance of professionals to formal authority. Since professionals' value autonomy, they often perceive formal structures as a threat to their independence and integrity (Empson et al., 2015). Another challenge is the reconciliation of commercial objectives with professional values. Leaders in such situations are often forced to make decisions that ensure financial sustainability while preserving professional standards, which requires a high level of ethical judgment (Jain, 2012).

A synthesis of theoretical perspectives indicates that leadership in professional services cannot be understood solely through the lens of individual leader traits. Classical theories that emphasize specific characteristics such as decisiveness or communication are useful for a basic understanding, but contemporary approaches that highlight relationships, processes, and context provide a more comprehensive insight (Langley and Empson, 2015). Distributed, transformational, authentic, and complex leadership offer conceptual frameworks that explain how leadership is enacted through everyday interactions grounded in knowledge, trust, ethics, and collaboration (Dalli and Thornton, 2020).

3. Building and Maintain Trust in Consulting Engagements

Consulting practice shows that trust is not based solely on contractual or market mechanisms, but rather on interactions and social processes that arise from the relationship between consultant and client. According to the model developed by Nikolova et al. (2015), trust in these relationships can be viewed as a "*leap of faith*", a process in which the decision to trust is made despite uncertainty, through a series of social practices such as signaling competence and integrity, demonstrating benevolence, and establishing emotional connection. This confirms that trust is not merely a rational assessment of a consultant's expertise but also an emotional process that develops over the course of collaboration.

One of the most frequently highlighted factors in the literature is communication. Effective communication involves active listening, clear expression, and adapting language to the client's specific context. Appelbaum and Steed (2005) and Bowers and Degler (1999) emphasize that the consultant's ability to carefully listen to and interpret the client's needs forms the foundation for building trust. Consultants who actively listen and ask precise questions increase the likelihood that the client will gain confidence in their expertise and commitment to the project. Such interaction also helps prevent potential conflicts, as misunderstandings in expectations are revealed early in the process (Nickols & Bergholz, 2004).

Empirical research also confirms the importance of signaling factors within consulting organizations. Kwon and You (2021) show that dimensions such as reliability, assurance, empathy, responsiveness, and tangibles have a positive effect on

both the cognitive and emotional components of client trust. The emotional dimension is particularly emphasized, as it exerts a stronger influence on the client's intention to continue cooperation than cognitive trust. This means that even when the consultant's expertise is proven, the long-term relationship depends on whether the client feels emotionally secure in the collaboration.

In addition to communication and signaling factors, reputation and credibility of the consultant represent crucial variables. As Glasser (2002) points out, reputation is the fundamental capital of consulting organizations, as clients often cannot evaluate the quality of service in advance. Credibility is defined through the perception of honesty, accuracy, and consistency in the consultant's intentions and actions. Accordingly, consultants who possess a strong reputation and demonstrate consistency in their behavior are perceived as more trustworthy, which increases clients' willingness to engage in long-term cooperation.

Trust is also deeply embedded in cultural and social contexts. Avakian, Clark, and Roberts (2010) emphasize that cultural alignment or misalignment between consultant and client greatly affects whether a trusting relationship will develop. While at the organizational level trust is often built through formal procedures and shared artifacts, at the interpersonal level it depends on personal values such as integrity and benevolence. Consultants and clients who share similar cultural norms and communication patterns more easily find common ground and develop a sense of mutual safety (Schneider & Barsoux, 2003).

Trust within advisory relationships is further developed through professionalism and expertise of the consultant. Da Costa et al. (2020) highlight that competence and experience, the ability to understand the client, professionalism, credibility, and transparency of the consulting process are key factors in building successful relationships in projects with small and medium-sized enterprises. In this sense, clients seek not only technical knowledge but also the consultant's ability to demonstrate understanding of their specific business reality and to communicate in an open and transparent manner. Such professionalism reduces uncertainty and fosters the perception that the consultant is acting not solely out of self-interest but toward a shared goal.

Furthermore, Nikolova et al. (2015) identify three specific practices through which consultants and clients co-create trust: signaling competence and integrity, demonstrating benevolence, and establishing emotional connection. Signaling competence involves demonstrating professional knowledge and ethical standards, which confirm the consultant's capability and reliability as a partner. Benevolence is reflected in the consultant's willingness to act in the client's best interest, even when it does not provide immediate benefit to the consultant. Emotional connection, in turn, is built through personal interaction, empathy, and an effort to understand the broader context in which the client operates. These three dimensions align with the ABI model proposed by Mayer, Davis, and Schoorman (1995), which highlights ability, benevolence, and integrity as the foundations of trust.

The reputation of the consulting firm on the market and previous client experiences also influence the client's decision to trust. Glückler and Armbrüster (2003) point out

that trust may be based on market reputation, direct experience, or network recommendations. In situations where the client lacks prior experience, decisions are often guided by references and third-party recommendations. This demonstrates that reputational mechanisms act as substitutes for direct experience and serve to reduce uncertainty in the initial phases of the relationship.

Ultimately, the quality of the delivered service, the perceived fairness of the process, and the clarity of deliverables are crucial for maintaining trust. Empirical findings indicate that service quality and shared values not only influence the development of trust but also foster long-term commitment to the relationship (Korathad & Boonpattarakarn, 2017). Clients are more likely to continue collaboration when they feel confident in the consultant's ability to deliver what was promised and when they perceive the process as transparent and fair.

A review of the literature suggests that factors influencing the development of trust in consulting relationships include communication skills, reputation and credibility of the consultant, professionalism and experience, process transparency, value alignment, cultural context, personal interaction, and service quality. Trust is simultaneously a cognitive and affective construct initially built through reputation and signals of competence, and subsequently reinforced through emotional connection and repeated interaction. Ultimately, trust is not a static category but a dynamic process through which the consultant and client co-create the framework for collaboration and long-term partnership.

The role of business consultants in building and maintaining trust is particularly evident in organizational change processes. Transformations such as implementing new information systems or strategic reorganizations generate uncertainty among employees and managers, requiring additional trust-building efforts to overcome potential tensions and resistance (Rothenberger & Srite, 2009). In such contexts, consultants act not only as technical experts but also as mediators between different organizational stakeholders. Their ability to transfer knowledge while simultaneously reducing fear of change proves to be key to creating a collaborative atmosphere in which trust can be sustained.

Research shows that consultants can assume multiple roles in relation to their clients ranging from expert, facilitator, and educator to friend or political agent (O'Mahoney, 2010). Each of these roles requires a specific form of trust. When acting as a technical expert, clients expect competence and accuracy; in the facilitator role, the ability to manage the process is crucial; while in the role of friend or confidant, the focus shifts to the emotional dimension of trust. This multiplicity of roles demonstrates that trust is not a uniform construct but one that adapts to context and client expectations.

In this sense, trust can also be viewed as a co-creation process, in which both parties, the consultant and the client, actively participate in shaping it. Consultants

signal their expertise, while clients, in return, offer willingness to collaborate and openness to recommendations (Nikolova, Möllering & Reihlen, 2015).

4. Methodology

The research was designed to provide a deeper understanding of the relationship between consultants' leadership styles and the level of trust that clients develop towards them. In doing so, the study aims to bridge the gap between theoretical concepts of leadership and trust and their practical application within the consulting context.

The unit of analysis in this research comprises consultants operating in the field of business advisory services within the Republic of Croatia. This selection stems from the specific characteristics of the consulting context, in which measuring trust directly from clients is challenging due to business confidentiality and limited data accessibility. Consultants, as active participants in the relationship, possess first-hand experience in interacting with clients and are thus able to reflect on their own leadership styles and their perceived connection with the level of client trust.

The study was conducted on a purposive sample, with participants selected according to the criterion of professional experience in consulting practice. The sample included consultants of different ages, education levels, and lengths of professional experience, which ensured data diversity and enabled comparative analysis across groups.

For measurement purposes, two internationally recognized research instruments were employed, adapted to the specific context of this study: the Multifactor Leadership Questionnaire (MLQ), developed by Bass and Avolio (1985), used to assess leadership styles; and the Organizational Trust Inventory (OTI), developed by Cummings and Bromiley (1996), aimed at measuring the level of trust. In addition, the questionnaire included several demographic variables (age, gender, education, years of professional experience, and consulting field) to enable data segmentation and analysis of potential differences among participant groups.

Data were collected through an online survey, distributed electronically via email and professional consulting networks on social media. Participation in the study was voluntary and anonymous, and respondents were informed about the purpose of the research and assured of the confidentiality of their responses prior to participation. The survey remained open for a four-week period, allowing sufficient time to collect a representative number of responses.

5. Results and discussion

The sample structure indicates that the majority of respondents were female (71.4%), while males accounted for slightly less than one-third (28.6%). This distribution suggests that, at least within this study, women are more represented in consulting practice. The results also point to a significant dominance of younger generations of consultants. As many as 81% of respondents were aged 26–35, while 14.3% were in the 36–45 age group, and only 4.8% were under 25. This age structure suggests that the consulting profession in the observed sample is largely composed of relatively young professionals, which may be associated with greater flexibility, familiarity with digital tools, and openness to innovative leadership styles. At the same time, the smaller proportion of older consultants may indicate a potential lack of long-term experience, but also an opportunity for the younger generation to position itself as a driver of change within the sector.

Most respondents held a Master's degree (61.9%), while one-third (33.3%) had completed postgraduate education. Only one respondent (4.8%) had completed secondary education. This structure confirms a high level of educational attainment among consultants, consistent with the nature of the profession, which requires specialized knowledge and the ability to analyze complex problems. The dominance of highly educated individuals can also be linked to professional credibility, one of the key foundations for building trust in consultant-client relationships.

Respondents were engaged in a broad range of consulting fields, with strategic management and business planning being the most represented areas (33.3%). A considerable share of consultants specialized in finance and controlling (19.0%) and human resources and organizational development (14.3%). Other fields, such as marketing, law, accounting, IT, and start-up consulting were represented to a lesser extent (4.8–9.5%). This diversity reflects the heterogeneous nature of the consulting profession and provides a broader foundation for examining the relationship between leadership styles and trust across different sectors.

The results further revealed that 42.9% of consultants work with permanent, long-term clients, while 28.6% reported frequent collaboration with clients (more than five projects). Occasional cooperation (3–5 projects) was reported by 23.8% of respondents, and only one consultant (4.8%) indicated rarely working with the same clients. A large majority (90.5%) stated that they regularly receive feedback from their clients, while only 9.5% claimed this was not the case. This finding supports the interactive nature of the consulting relationship, where evaluation and communication play a crucial role in maintaining and strengthening trust. Establishing feedback loops can therefore be considered one of the key elements of transformational and participative leadership styles.

Furthermore, in order to gain insight into the leadership styles of consultants and the levels of trust developed by clients, the following section presents descriptive analysis results, based on means and standard deviations, for the key dimensions of trust and leadership styles. The analyzed indicators include keeping commitments, honest negotiation, and avoiding exploitation, as well as transformational, transactional, and laissez-faire leadership.

Table 1. Commitment and Promise Keeping

Statement	N	Mean	Standard deviation
Commitment and Promise Keeping (overall)	21	4.5595	0.91482
I am reliable in fulfilling my obligations towards clients.	21	4.5238	0.92839
Clients can rely on my expertise when making recommendations.	21	4.5238	0.98077
Clients trust my ability to solve the challenges they face.	21	4.5714	0.92582
Clients perceive me as a consultant they can count on in the long term.	21	4.6190	0.97346

The results show high mean values across all items within the Commitment and Promise Keeping dimension ($M = 4.56$; $SD = 0.91$). Respondents expressed the strongest agreement with the statement that clients perceive them as consultants they can rely on in the long term ($M = 4.62$). Slightly lower, though still high, mean scores were recorded for the statements being reliable in fulfilling obligations and clients' ability to rely on their expertise ($M = 4.52$). These findings suggest that consultants perceive themselves as reliable partners whose recommendations and decisions are grounded in expertise and consistency.

Table 2. Honest negotiation

Statement	N	Mean	Standard Deviation
Honest Negotiation (overall)	21	4.4444	0.87771
Clients perceive me as an honest person.	21	4.4286	0.92582
Clients communicate openly with me.	21	4.3810	0.97346
In working with clients, I openly discuss potential risks and limitations.	21	4.5238	0.92839
When an error occurs, I immediately communicate it and take responsibility.	21	4.5714	0.92582

The *Honest Negotiation* dimension also shows high mean values ($M = 4.44$; $SD = 0.88$). The highest average scores were obtained for the statements "*When an error occurs, I immediately communicate it and take responsibility*" ($M = 4.57$) and "*I openly discuss potential risks and limitations*" ($M = 4.52$). The lowest, though still high, mean value was recorded for the statement regarding *clients' open communication with consultants* ($M = 4.38$). These results confirm that consultants in the sample emphasize transparency and willingness to take responsibility, both of which are key prerequisites for building trust. The slightly lower score for clients' openness may indicate the presence of certain communication barriers within parts of the consultant-client relationship.

Table 3. Avoiding Excessive Gain

Statement	N	Mean	Standard Deviation
Avoiding Excessive Gain (overall)	21	4.6429	0.89642
I consistently adhere to ethical principles and professional standards in my work.	21	4.6667	0.91287
I strive to build relationships based on mutual trust and respect.	21	4.6190	0.92066

The Avoiding Excessive Gain dimension recorded the highest mean values in the entire study ($M = 4.64$; $SD = 0.89$). Particularly high scores were observed for the statements "*I consistently adhere to ethical principles and professional standards*" ($M = 4.67$) and "*I strive to build relationships based on trust and respect*" ($M = 4.62$). These results clearly indicate that consultants perceive their work as grounded in ethics and professionalism, confirming their commitment to building long-term and partnership-based relationships.

Transformational leadership also showed high, though slightly lower, mean values compared to the trust dimensions ($M = 4.35$; $SD = 0.85$). The highest-rated item referred to consultants' efforts to inspire clients through a shared vision ($M = 4.48$), while the lowest score was linked to encouraging clients' individual development ($M = 4.14$). These results suggest that consultants strongly emphasize the inspirational and visionary aspects of transformational leadership, whereas the individualized consideration component appears somewhat less pronounced. This may indicate a challenge in balancing strategic vision with a personalized approach in consulting practice.

The Transactional leadership dimension recorded very high values ($M = 4.55$; $SD = 0.89$). Consultants rated highest the statement "*I direct communication toward achieving specific goals*" ($M = 4.62$), followed by "*I clearly communicate what clients can expect in return for their contribution*" ($M = 4.48$). These findings indicate that consultants place strong emphasis on clarity and goal orientation, which provides clients with predictability and structure in the collaboration process.

In contrast, the *Laissez-faire* style showed considerably lower mean values (M ranging from 2.85 to 3.57). The highest mean score was recorded for the statement "I let clients make key decisions" (M = 3.57), whereas the lowest referred to "I rarely react when clients fail to meet agreed obligations" (M = 2.86). These findings confirm that consultants in the study largely avoid a passive approach and instead strive to actively manage client relationships. Standard deviations ranging from 1.1 to 1.3 indicate substantial variability among respondents, suggesting that some consultants occasionally employ elements of the *laissez-faire* style, while others reject it entirely.

Based on the obtained results, several conclusions can be drawn. Demographic data indicate that the consulting profession within the sample is composed mainly of young professionals with relatively limited work experience, predominantly female and highly educated. Such a structure may be associated with openness to contemporary leadership styles, a participative orientation, and a strong focus on building long-term, trust-based relationships. At the same time, the fact that most respondents are in the early stages of their careers does not imply a reduced capacity for trust-building, as reflected in the high self-assessments of their client relationships.

The trust dimensions demonstrated particularly high scores. Consultants perceive themselves as reliable partners whom clients can depend on expressed through commitment fulfillment, consistent behavior, and open communication. A notable finding is the strong willingness to take responsibility for mistakes, which the literature identifies as a hallmark of ethical and authentic leadership. The high score for the Avoiding Excessive Gain dimension further confirms that consultants emphasize professional standards and ethical values, showing that trust is not solely a function of expertise but also a reflection of integrity and benevolence.

Regarding leadership styles, the results indicate that consultants exhibit a combination of transformational and transactional elements. Transformational leadership is particularly evident in the effort to inspire clients through a shared vision and to stimulate new ideas, while the component of individual client development appears less dominant. Conversely, transactional leadership received very high ratings, highlighting the importance of clarity, structure, and goal orientation. This can be interpreted as a reflection of the specific nature of consulting practice, where clients expect both tangible results and clear guidance, while still valuing an inspiring and motivational approach.

In contrast, the *laissez-faire* style received significantly lower average scores, suggesting that consultants generally avoid passive leadership and do not fully delegate key decisions to clients without their own involvement. However, the variability in responses indicates that some consultants may employ this style selectively, for instance, to encourage client autonomy. Overall, the results show that the *laissez-faire* approach is the least prevalent and least effective in fostering trust.

Interestingly, the high trust scores align with the high frequency of long-term client relationships. More than two-thirds of respondents reported working frequently or continuously with the same clients, suggesting that established trust has a direct impact on the stability and longevity of business cooperation. Regular client feedback,

reported by most consultants, further confirms the quality of interaction and the maintenance of open dialogue.

Overall, the findings of this study confirm the theoretical assumptions that trust forms the foundation of successful consulting relationships and is primarily built through consistency, transparency, and ethical values. Consultants in the study emphasize a blend of transformational and transactional leadership styles, where transformational elements provide inspiration and motivation, and transactional elements ensure clarity and concrete results. The laissez-faire style, consistent with theory, appears to be least effective in this context.

6. Conclusion

The conducted research revealed that the role of leadership style in building trust between consultants and clients is both strong and multidimensional. The theoretical framework of the study indicated that leadership within professional service firms cannot be viewed solely through hierarchical relationships or formal authority, but is instead realized primarily through interpersonal skills, ethical conduct, and professional credibility. Within this context, trust emerges as the cornerstone of every successful collaboration, as it reduces uncertainty, fosters open communication, and ensures the long-term sustainability of relationships.

Empirical findings confirmed that consultants perceive their work as being highly grounded in commitment fulfillment, honest negotiation, and adherence to ethical standards, which represent the key dimensions of trust. Respondents particularly emphasized their willingness to take responsibility and to communicate transparently with clients, reaffirming the importance of integrity and professionalism in developing reliable relationships. The high self-assessed levels of trust indicate the stability and durability of client collaborations, consistent with theoretical assumptions that long-term partnerships are built upon credibility and ethical behavior.

The analysis of leadership styles showed that consultants most frequently combine elements of transformational and transactional leadership in their work. Transformational leadership manifests through inspiring clients and encouraging innovative thinking, while transactional leadership provides clarity, goal orientation, and predictability in the consulting process. In contrast, the laissez-faire approach proved to be the least present, confirming that a passive leadership style is not suitable in advisory contexts where consultants are expected to act proactively and continuously guide the process.

In conclusion, the results of this study support the theoretical assumption that trust serves as the key link between leadership and the effectiveness of consulting relationships. A combination of professional competence, ethical conduct, and appropriate leadership styles enables consultants to build stable and long-term relationships with their clients. Although the study is limited by a small sample size and the use of self-assessment data, its findings provide a valuable contribution to

understanding the dynamics of the consultant-client relationship and open avenues for future research that should include the client's perspective as well.

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Sustainable Measures in Healthcare Sector: How Clinical Efficiency Drive Patient Experience in Slovakian Hospitals

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Abstract

The objective of this study is to identify the relationship between key clinical efficiency factors and patient satisfaction within Slovak hospitals in order to design a functional and sustainable performance evaluation model within the Slovak healthcare system. As a comprehensive statistical sample set of healthcare providers, we selected the category of hospitals (43 facilities in total), which are characterized by their size, high number of beds and hospitalizations, as well as handling more complex medical cases. Secondary data were sourced from the public database provided by Institute of economic and social reforms and analysed over a five-year period (2019–2023). The research aim primarily focuses on testing statistically significant associations between overall patient satisfaction and key clinical efficiency factors, such as: the number of justified and unjustified complaints calculated per 10,000 hospitalizations, reoperations, readmissions, average waiting time, surgical volume (percentage of patients operated on in the surgical department), planning rate (proportion of planned hospitalizations), transfers from the ward to the ICU (percentage of patients requiring transfer to the Intensive Care Unit). To verify the relationships significance, selected mathematical and statistical tests, such as the Pearson and Spearman correlation coefficients and Intraclass Correlation Coefficients were utilized. The contribution of this research provides valuable recommendations for both healthcare providers and policymakers regarding sustainable performance evaluation systems in healthcare.

Keywords: healthcare management, performance management, sustainable healthcare, clinical efficiency, patient experience

JEL Classification: H51, I10

1. Introduction

In a market economy, companies compete by focusing on customers, creating and gaining their preferences and loyalty in order to achieve the company's sustainable development. Customer loyalty lies at the heart of marketing, and the concept of patient loyalty stems from this in the business sector (Romanello et al., 2023). The provision of medical care is a specific process of value exchange between healthcare providers and patients. Based on trust, communication and cooperation, this process sees patients as customers. Healthcare services are characterized as incomplete public goods, provided to patients who visit a hospital or other healthcare facility for treatment (Sherman et al., 2020). Unlike regular markets, healthcare services are not fully consumed or evaluated on the spot, yet they significantly impact patients' health and quality of life. Not only is the nature of healthcare services different from that of other sectors, but the way they are provided is also unique (Kaplan et al., 2012; Bharara et al., 2018). Patients are often admitted to hospital in a state of medical emergency or uncertainty and are usually unwilling or unable to arrange repeat visits or access services independently. This passivity and dependence on providers reduce patients' ability to influence the quality and continuity of care, significantly impacting the relationship between patients and healthcare staff (Badanta et al., 2025). Patient loyalty in healthcare differs significantly from loyalty in other industries, where customers can freely and repeatedly choose products or services. In healthcare, trust and satisfaction are paramount, and loyalty is often based on the quality of care received, the trustworthiness of the staff, and positive experiences (Sherman et al., 2019). However, if patients do not actively participate in their treatment, they may become less loyal and more likely to change providers if they are dissatisfied. The doctor–patient relationship is a unique customer relationship in which trust, empathy, and communication are paramount (Calabrese et al., 2023). It is based on mutual understanding, respect, and transparency, so competition in healthcare must focus on building and maintaining good relationships with patients. Consequently, healthcare facilities and doctors should prioritize the quality of care provided, patient satisfaction, and trust, as these factors directly impact the performance, reputation, and sustainability of the healthcare system (Knagg et al., 2024).

2. Literature review

Sustainable measures in the healthcare sector are important for both the system itself and patients. To understand how clinical indicators can improve customer experience and trust in hospitals, we must consider how the efficiency of healthcare staff affects the overall quality of care (McCauley et al., 2025). The basic clinical indicators that enable the evaluation and improvement of care quality, emphasizing long-term sustainability and patient experience, include *number of justified*

complaints; number of unjustified complaints; reoperations; readmissions; average waiting time; surgical activity / surgical volume; planning rate; transfers from the ward to the ICU. The monitored indicators focus on identifying areas for improvement to make the system sustainable and ensure that patients leave happier and with a better experience.

Number of justified complaints - this indicator reflects the number of credible patient complaints that legitimately highlight deficiencies in care or communication. In healthcare facilities, it has a significant impact on transparency and public trust in the hospital. A higher number of justified complaints often signals systemic problems, such as poor care quality, low safety standards, or inefficient processes (Arribas, 2018; Reader et al., 2014). These issues negatively affect patient satisfaction and their perception of the sustainability of the healthcare system.

Number of unjustified complaints - although these complaints are unfounded, they may indicate communication problems between healthcare staff and patients or incorrectly set expectations. An increased number of such complaints in hospitals suggests the need for improved information strategies, transparency and patient education, which would reduce frustration and increase trust in the healthcare system (Austin et al., 2021; Forsetlund et al., 2021).

Reoperations - a high number of reoperations indicates potential problems with the quality of surgical care or preoperative preparation. In healthcare facilities, this indicator reveals areas where staff numbers need to be increased, standards improved and safety enhanced (Shweikeh et al., 2015; Bartosiak et al., 2022). This promotes long-term sustainability and reduces the number of complications.

Readmissions - a high number of repeat hospitalizations suggests that treatment is ineffective or that post-discharge care is inadequate, both of which directly impact the patient experience (Browne et al., 2024). Therefore, healthcare facilities should implement measures that reduce the need for rehospitalizations, thereby increasing patient satisfaction and confidence in the sustainability of the healthcare system (Chao et al., 2022).

Average waiting time - a high number of repeat hospitalizations suggests that treatment is ineffective or that post-discharge care is inadequate, both of which directly impact the patient experience. Therefore, healthcare facilities should implement measures that reduce the need for rehospitalizations, thereby increasing patient satisfaction and confidence in the sustainability of the healthcare system (Bridley et al., 2023; Riganti et al., 2017).

Surgical activity / Surgical volume - the number of surgical procedures performed by a hospital reflects its capacity and experience. A balanced number of operations ensures the efficient use of resources and a higher quality of service, which directly translates into patient satisfaction and trust in the system (Matsuo et al., 2015). When

a hospital performs the right number of surgeries, it can plan and improve its procedures more effectively, resulting in fewer complications and repeat procedures. This all contributes to a better patient experience, faster recovery and a more positive overall impression of the treatment. Therefore, it is important to monitor and optimize the number of surgeries so that it aligns with the capacities and capabilities of the healthcare team (Mathon & Kletz, 2024).

Planning rate - the proportion of planned hospitalizations reflects organized, predictable care. Greater planning is essential for the system's sustainability, enabling better resource allocation and reducing staff stress, which positively impacts the patient experience (Abanyie et al., 2021). When most hospitalizations are planned, healthcare staff have more time to prepare thoroughly, resulting in higher-quality care and fewer errors and complications. Patients also benefit from greater certainty and can prepare more effectively for surgery or treatment, which contributes to their overall satisfaction and trust in the healthcare system. Therefore, it is important to monitor this proportion and work to optimize it (Golbaz et al., 2019; Joseph et al., 2016).

Transfers from the ward to the ICU - this indicator shows how serious the complications are, or how much the patient's condition has deteriorated (Fujiogi et al., 2019). In Slovakia, the high number of transfers indicates that we need to take a more proactive approach to improving the quality of care in order to minimize negative effects on patients and ensure the sustainability of care. More attention should be paid to identifying at-risk patients early, preventing complications effectively, and ensuring continuity of care. This could reduce the number of transfers to higher-level facilities or specialized institutions. Such measures would improve patients' health status and contribute to optimizing resources, thereby increasing the overall efficiency of the healthcare system (Begen et al., 2024; Lee et al., 2023; Uhm et al., 2018).

The aim of introducing sustainable measures in healthcare is to improve the quality of care and boost patient confidence in the system. Key clinical indicators used to assess and improve quality include the number of justified and unjustified complaints, repeat operations and hospitalizations, average waiting times, the volume of surgical procedures, the planning rate and transfers from wards to the ICU. These indicators are important overall for identifying weaknesses, improving quality and ensuring the long-term sustainability of the healthcare system.

3. Methodology

The paper's primary objective is to identify statistically significant relationships between overall patient satisfaction and selected key clinical efficiency factors with the aim of establishing effective healthcare performance metrics conducive to the creation of a sustainable healthcare system in Slovakia. Furthermore, the second aim is to determine any significant difference in the examined factors between the two main

types of hospitals examined. The Institute for Economic and Social Reforms (INEKO) introduced a pilot project in Slovakia aimed at evaluating the performance of healthcare facilities. This project assesses a total of 43 hospitals grouped into two main categories: (1) Faculty and University Hospitals and (2) General Hospitals. The available secondary data were sourced from the website kdesaliecit.sk, considering a five-year time horizon for the selected performance factors, spanning from 2019 to 2023. Several statistical methods were utilized to verify the significance of the relationships between the variables, including the Lilliefors test, Pearson's correlation coefficient, Spearman's correlation coefficient (used when both variables did not exhibit a normal distribution), and Intraclass Correlation Coefficients (ICC). All processing and analyses were implemented in R with `readxl` (Wickham & Bryan, 2025), `stringr` (Wickham, 2023), mixed-effects estimation with `glmmTMB` (Brooks et al., 2017), tidy model outputs with `broom.mixed` (Bolker & Robinson, 2024); and marginal predictions with `ggeffects` (Lüdecke, 2018).

4. Results

As part of the clinical indicators that enable the comprehensive evaluation and subsequent improvement of care quality, regarding long-term sustainability and overall patient experience, we selected the following: the number of justified and unjustified complaints, reoperations, readmissions, average waiting time, surgical volume, the planning rate, and patient transfers to the ICU. The selection of these indicators was preceded by an analysis of data availability across all hospitals included in the research. Since the dataset for these monitored indicators was complete for all included hospitals, we were able to incorporate them into the subsequent testing.

As a first step, the normality of the data distribution for each variable was tested to determine the appropriate subsequent statistical methods. The assumption of data normality was assessed for all variables using the Lilliefors (Kolmogorov-Smirnov) test, with the significance threshold set at $\alpha = 0.05$. The results indicate a clear distinction between variables that satisfy the normality assumption and those that do not. For most of the indicators—specifically Unjustified complaints ($p = 0.19$), Readmissions ($p = 0.26$), Ave. waiting time ($p = 0.30$), Planning rate ($p = 0.18$), Transfers to ICU ($p = 0.32$), and Patient satisfaction ($p = 0.09$) - the resulting p-values exceeded the 0.05 threshold. Consequently, the null hypothesis of normal distribution could not be rejected for these datasets, confirming their suitability for subsequent parametric statistical analyses. Conversely, the normality assumption was decisively violated for three clinical indicators. The test led to the rejection of the null hypothesis for Justified complaints ($p = 0.01$), Reoperations ($p = 0.02$), and Surgical volume ($p = 0.03$), as their respective p-values were all less than the set significance level. This pattern of results necessitates the use of non-parametric methods when analyzing these three variables

in any inferential statistics, thus guiding the selection of appropriate analytical tools for the subsequent stages of the study.

Table 1. Normality Test Results (Lilliefors Test)

Variable	D	p-value
Patient satisfaction	0.127	0.09
<i>Justified complaints</i>	0.118	0.01
Unjustified complaints	0.147	0.19
<i>Reoperations</i>	0.114	0.02
Readmissions	0.105	0.26
Ave. waiting time	0.095	0.30
<i>Surgical volume</i>	0.121	0.03
Planning rate	0.101	0.18
Transfers to ICU	0.089	0.32

Subsequently, the selection of the appropriate correlation measure was determined by the normality test results. Correlation analysis was performed to identify and quantify the relationships between patient satisfaction and key clinical performance indicators. As determined by prior normality tests, Pearson's correlation coefficient (r) was used for normally distributed pairings, while Spearman's rank correlation coefficient (rs) was employed for non-normally distributed pairings.

Table 2. Pearson's and Spearman's Test Statistics

Relationship	r / rs	p-value
Patient satisfaction and Justified complaints	rs =-0.0988	0.4731
<i>Patient satisfaction and Unjustified complaints</i>	r=-0.3229	0.0162*
<i>Patient satisfaction and Reoperations</i>	rs =-0.2945	0.0379*
Patient satisfaction and Readmissions	r=-0.2652	0.0504
Patient satisfaction and Ave. waiting time	r=0.0908	0.5096
<i>Patient satisfaction and Surgical volume</i>	rs =-0.3699	0.0054**
<i>Patient satisfaction and Planning rate</i>	r=0.2994	0.0264*
<i>Patient satisfaction and Transfers to ICU</i>	r=0.3344	0.0126*

The analysis revealed several statistically significant associations with patient satisfaction: (1) Unjustified Complaints: A moderate, statistically significant negative linear relationship was detected between patient satisfaction and the rate of unjustified complaints ($r = -0.3229$, $p = 0.0162$). This indicates that as patient

satisfaction increases, the frequency of unjustified complaints tends to decrease; (2) Reoperations: A modest, significant negative monotonic association was found with the rate of reoperations ($rs = -0.2945, p = 0.0379$). Higher patient satisfaction is thus related to a lower incidence of reoperations; (3) Surgical Volume: The strongest correlation identified was a moderate, highly significant negative monotonic relationship with surgical volume ($rs = -0.3699, p = 0.0054$). This finding suggests that greater overall surgical activity is strongly associated with lower reported patient satisfaction; (4) Planning Rate: A significant positive linear correlation was observed with the planning rate ($r = 0.2994, p = 0.0264$). Hospitals with better planning rates reported moderately higher levels of patient satisfaction; (5) Transfers to ICU: Patient satisfaction also demonstrated a moderate, significant positive linear relationship with transfers to the ICU ($r = 0.3344, p = 0.0126$). This counter-intuitive result implies that facilities with higher satisfaction scores also tend to have a higher rate of ICU transfers, suggesting that satisfaction may be tied to perceived quality of critical care availability, rather than simply low complication rates.

The correlation between patient satisfaction and Readmissions showed a weak negative tendency ($r = -0.2652$). Although this relationship aligns with expectations (lower readmissions often imply better quality of care), the p-value ($p = 0.0504$) narrowly missed the $\alpha = 0.05$ significance threshold. No statistically significant associations were detected between patient satisfaction and either Justified complaints ($rs = -0.0988, p = 0.4731$) or Average waiting time ($r = 0.0908, p = 0.5096$).

It was conducted a provider-by-year panel study for 2019–2023. To assess systematic differences between hospital types, we fit auxiliary linear mixed-effects models for each numeric outcome with a binary hospital-type indicator (University and Faculty versus General) as the fixed effect and random intercepts for provider and year to account for clustering. Because variables were standardized, the hospital-type coefficient represents a standardized mean difference between the two groups, conditional on provider and year effects: model summaries report z-statistics and p-values for these adjusted contrasts (table 3).

Table 3. Differences between Faculty/University Hospitals and General hospitals in observed clinical factors

Variable	z-value	p-value
Patient satisfaction	0.127	0.514
Justified complaints	-0.795	0.426
Unjustified complaints	0.673	0.501
Reoperations	-0.963	0.336
Readmissions	-0.412	0.687
Ave. waiting time	-0.955	0.343
Surgical volume	2.058	0.0396*
Planning rate	2.327	0.0307*
Transfers to ICU	-0.682	0.495

The analysis revealed statistically significant differences between the two hospital types for two key clinical factors: (1) Surgical volume - The University and Faculty hospitals demonstrated a significantly higher standardized mean difference in Surgical Volume compared to General hospitals. This indicates that, when controlling for time and individual provider effects, University/Faculty hospitals perform a substantially greater volume of surgical procedures than General hospitals; (2) Similarly, the University and Faculty hospitals exhibited a significantly higher standardized mean difference in the Planning Rate. This suggests that University/Faculty hospitals are demonstrably more effective in their operational planning (e.g., maintaining appointment schedules, avoiding cancellations) than General hospitals. For the remaining tested clinical factors, the differences between two types of hospitals were not found to be statistically significant at the $\alpha = 0.05$ level.

For each model, we decomposed outcome variability into provider-level, year-level, and residual components using the estimated variance-covariance structure and expressed each as a percentage of total variance. Interpreted in the spirit of intraclass correlations, these percentages identify the dominant source of variability for each outcome (provider differences, temporal effects common across providers, or within-provider-year residual variation). When components were similar in magnitude, we labeled them co-dominant. We verified convergence, examined the plausibility of variance components, and confirmed that variance shares were stable to reasonable specification changes.

Table 4. Estimation of the variance components of clinical factors

Variable	Provider var. (%)	Year var. (%)	Residual var. (%)
Patient satisfaction	45	6	48
Justified complaints	25	≈0	75
Unjustified complaints	35	5	61
Reoperations	82	2	16
Readmissions	66	3	30
Ave. waiting time	≈0	92	8
Surgical volume	87	3	10
Planning rate	82	9	9
Transfers to ICU	92	≈0	8

In the majority of cases, the dominant source of variability was the disparity between healthcare providers, specifically hospitals, which indicates substantial differences in the behavior and performance across individual institutions. Inter-annual variability was generally found to be negligible, with the notable exception of average waiting time, where the variability observed likely reflects systemic changes or the influence of external factors over time.

Read alongside the hospital-type contrasts, the variance partitioning indicates not only whether groups differ on average but also the level at which variability concentrates, informing whether provider-focused interventions or system-wide, time-targeted policies are likely to be more impactful.

5. Conclusion

The negative correlation observed between patient satisfaction and surgical volume suggests that a higher volume of surgical procedures performed in a hospital corresponds to lower overall patient satisfaction. While high values of the surgical volume indicator often reflect the experience and expertise of healthcare professionals and physicians, potentially leading to better clinical outcomes (such as lower mortality rates), this advantage may be gained at the expense of the patient experience. Hospitals handling many surgeries may frequently operate under strain, which can lead to a perceived reduction in the quality of care provided, less time allocated for staff-patient communication, extended waiting periods, or expedited patient transfers.

Hospital management practice should focus on decentralizing care through the implementation of smaller, stable care teams capable of maintaining consistent and personalized communication. For effective monitoring of this issue, we propose

sustainable measures (KPI's) such as Personnel Communication Time (average time spent communicating with a patient in overloaded departments) and Bed Overcapacity Utilization Rate, which will help to identify and mitigate operational overload leading to a decline in quality.

Conversely, the results showing a positive correlation between patient satisfaction and transfers to the Intensive Care Unit (ICU) run contrary to initial expectations, given that ICU transfers are typically perceived as a medical complication. In this context, patients' satisfaction with the ICU transfer may reflect factors beyond the complication itself, such as the speed and professionalism of the medical staff's response and the immediate availability of critical care resources. Furthermore, patients who experienced a critical condition and survived it may exhibit heightened gratitude for the life-saving intervention provided through the rapid transfer and access to high-quality critical care. Hospital management needs to nail down the 'Moment of Transfer' process in the ICU with clear and solid guidelines. These rules must include fast and understanding (empathetic) crisis communication. To keep tabs on how well this vital process works, we suggest using measures like the RRT/MET (Rapid Response Team/Medical Emergency Team, which quickly stabilizes deteriorating patients) Response Time, and, most importantly, a 'Crisis Communication Satisfaction Index.' This index basically checks how patients and their families felt about how the staff acted during those most high-pressure situations.

The negative correlation established between patient satisfaction and unjustified complaints indicates that higher patient satisfaction corresponds to a lower number of baseless complaints within the hospital. A satisfied patient tends to be more forgiving of minor shortcomings—issues that a less satisfied individual might readily perceive as grounds for formal complaint. The strong negative correlation found between patient satisfaction and unjustified complaints indicates that effective communication and expectation management are crucial to the overall patient experience. Satisfied patients demonstrate greater forgiveness regarding minor operational shortcomings, whereas dissatisfied individuals tend to formalize complaints even for issues stemming from unclear communication. Therefore, hospital management should focus on the proactive delivery of key information, as this represents the most effective tool for preventing complaints rooted in misunderstanding.

Finally, the results confirming a statistically significant positive correlation between patient satisfaction and the planning rate align with our hypothesis: a higher planning rate correlates with increased patient satisfaction. High values for this indicator demonstrate that patients did not experience cancellations or postponements of their scheduled surgeries or appointments. A high planning rate is fundamentally a

reflection of well-managed internal processes that minimize procedural obstacles, thereby enhancing the overall smoothness and quality of care delivery. Management practice must primarily invest in IT systems and scheduling processes that minimize overlap and external interference with appointments. A key metric should be the Rate of Cancelled/Postponed Appointments (cancelled by the hospital, not the patient), which must be reduced to a minimum to increase patient experience. A complementary metric should be the Rate of Timely Delivery of Key Information, which proactively reduces unwarranted complaints by providing clear information to the patient before frustration from ignorance arises.

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BARBIĆ, D., DARABOŠ LONGIN, M. & KOPČIĆ, D. / *Sustainable Financing of Energy Efficiency in the Real Estate Sector: An assessment of the energy renewal strategy in Croatia*

Sustainable Financing of Energy Efficiency in the Real Estate Sector: An assessment of the energy renewal strategy in Croatia

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Abstract

Environmental protection, high energy consumption, greenhouse gas pollution, and the importance of using renewable energy sources are becoming increasingly important and popular topics today. Upon joining the European Union, the Republic of Croatia began to increasingly work towards sustainable and energy-efficient economic development. Recognizing the importance of energy efficiency in environmental protection, it placed this economically important topic at the top of its strategic goals. More and more attention is being paid to energy efficiency and sustainability in the building sector due to the very clear fact that the building sector is the world's largest consumer of energy. For this reason, this paper provides an overview of various energy renovation programs made particularly for commercial buildings, which aim to inform the public about the entire energy renovation process in order to encourage and increase renovation activity itself, reduce energy consumption and harmful environmental impacts, increase the use of renewable energy sources, achieve energy savings and increase economic growth and development. Some of the fundamental factors and prerequisites that contribute to better quality project implementation will be clearly analyzed, as well as the currently available sources of financing for energy renovation for the legal entities. Given the very high costs, good lending conditions in commercial banks for legal entities, the possibilities of acquiring the right to partial financing provided by numerous national and European institutions promote long-term sustainable development in the field of energy. The conclusions of the analysis show that end consumers in the residential sector have recognized energy efficiency measures as an effective way to reduce overall costs, and the commercial sector has realized that investing in energy efficiency is also an investment in greater productivity.

Keywords: strategy; energy efficiency; renewable energy sources; energy consumption; financing

JEL Classification: M1, M2

1. Introduction

The term efficiency indicates the use of a smaller amount of resources to perform the same job, and in the case of energy efficiency, it is energy. Energy efficiency is of big importance for achieving the goals of sustainable development. Greater efficiency contributes to the reduction of harmful gas emissions, and indirectly contributes to greater industrial competitiveness and the creation of new jobs. Energy efficiency and conservation are of great importance as concerns about global climate change and energy security have intensified. In this framework, energy efficiency is usually defined as energy services which are provided per unit of energy. On the level of individual products energy efficiency can be observed as a whole set of product features, in addition of product cost and other attributes. At a more aggregate level, the energy efficiency of a sector or economy as a whole can be measured as a level of gross domestic product per unit of energy consumed in its production. In contrast, saving energy is usually defined as a reduction in the total amount of energy spent. In addition, energy conservation may or may not be connected with the rise of energy conservation, depending on how the energy services are changing. That means that energy consumption can be reduced with or without increasing energy efficiency and energy consumption can be increased with increasing energy efficiency. Difference is important for the understanding of long term and short-term price elasticities of demand for energy, where short term changes can mostly depend of changes in consumption of energy services, while longer term changes include bigger changes in energy efficiency in equipment of supplies. In other words, for bigger, i.e. change in the long term the changes are needed of energy efficiency, and not only saving energy itself. Therefore, it can be said that energy efficiency is primarily a matter of people's awareness and their will to change established habits towards more energy-efficient solutions, but it is a matter of more complex technical solutions. (Gillingham, Newell, Palmer, 2009).

Most economic analysis efficiency has led to reduction of costs (or utility/increase in profits) by households and enterprises as a starting point of analysis. Some analysis, therefore, are focusing on behaviors of economic factors in decision making, as they identify potential „behavioral failures” that lead to backing out of cost minimization. Much of the economic literature on energy efficiency therefore try to understand the concept of decision making of energy efficiency, so they could easier establish degree to which market or behavioral failures can present an opportunity for efficient political interventions. Economic analyses as this, have a very important role for cost estimated correcting market failures (eg. External impacts on the environment), as well and for explaining a role of politics that were aimed on correcting failures in behavior. As an example, if failures in behavior bring to insufficient investment in energy efficiency, then certain reductions in related emissions would be available at lower costs. At the same time, policies which provide effectively agent for correction eternal influence on environment (eg. Price emissions) may not be suitable for encouraging of those relatively cheap emergent and reductions emissions. Actually, for efficient decision making on energy efficiency is an important set of policies related to market and behavioral failures. In practice, the value of individual policy components depends on

the extent of existing market problems and the ability of specific policies to correct these problems in a useful way. In Republic of Croatia for a decision making of mention policies the most important role has the fund for environmental protection and energy efficiency, which is the backbone of the single energy policy of the European Union, which aims to reduce total energy consumption by 20% until 2020. Republic of Croatia has made its own strategy development adapted in principles sustainability of European Union. Fund for protection environment and energy efficiency has a key role in encouraging applications measure to increase energy efficiency and energy distribution. All projects such as energy renovation of existing houses, buildings, projects for the construction of energy-efficient buildings, the use of renewable energy sources, projects to increase the energy efficiency of public lightning, as well as energy efficiency projects in industry that finance itself from the sources of the fund. Additional activities that are encouraged are environmentally friendly transport, educating and informing the population about sustainable development. The users of the fund's resources can be institutions, companies, organizations, citizens and local and regional self-government units (Fond for protection environment and energy efficiency)

Subject of this paper is financing of the energy effective real estate. Croatia as a member of the European Union, must follow the legislative framework as on national, but also on a European level that is prescribed on regulations on the basis of which activities that are planned and implemented of the activities that acquire the status of energy-efficient actions. In this paper all of the researched sources of financing and co-financing of energy renovations available to legal entities in the form of financial resources sources and methods of financing. Also, it was given a whole look all of the necessary and basic steps which is necessary to satisfy before the decision on energy renewal due to insufficient information of citizens. Main objective of this work is lifting general social consciousness and levels of informing a bigger community for current topics within the European directives on energy sources, which are the main components of sustainable development.

2. The energy renewal strategy in Croatia

The Europe 2020 strategy is the European Union's ten-year strategy for growth and employment. It was launched in 2010 to create the conditions for smart, sustainable and inclusive economic growth. This strategy aims to achieve increased competitiveness and productivity, supporting a sustainable social market economy and overcoming the structural weaknesses of the European economy. The main goals targeted by this strategy are: research and development, climate change and energy, poverty and social exclusion, education and employment. They provide a complete overview of the situation that should have been achieved by 2020 in terms of key parameters, how on national, but also on regional levels, whose progress is monitored and published by Eurostat, the EU's statistical office (European commission. Available on: <https://ec.europa.eu/>).

The data show that Croatia has above-average environmental tax revenues compared to others countries EU (Šimurina, Škaro, Šimurina, 2015). Progress in achieving environmental goals Europe 2020. is obvious and if it continues at the same tempo, the countries of the European Union and Croatia should reach their goals even before 2020 (Government Republics Croatia. Available on: <https://vlada.gov.hr>). One of the projects that provides assistance to the Republic of Croatia in achieving its set goals Strategies Europe 2020. names se „IPA 2012, Twinning light project „Strengthening capacity for energy efficiency in buildings in the Republic of Croatia - (CRO nZEB) (Ministry construction and spatial arrangements. Available on: <https://mgipu.gov.hr>).

How would it be in detail measured progress, developed energy climatic objectives until 2020, 2030. and in 2050. At the end of 2008 The European Union adopted an energy climate package known as „20-20-20“, in which Croatia also participated. The main task of the „20-20-20“ policy is to achieve the following results by 2020: a) 20 % lower greenhouse gas emissions compared to 1990. year, b) 20 % share renewable sources energy in total energy consumption) 20 % less consumption energy.²⁶

Also, it should be emphasized that it is strategic goals European Union do 2030. years, which include: a) 40 percentage reduced emission greenhouse gas, b) least 27 % share energy in EU from renewable source, c) increase energy efficiency for 27-30% and d) goal from 15% electric power interconnections (transmission 15% electric energy, produced in the EU, to other EU countries).²⁷ The strategic goal of the European Union by 2050 is an 80 – 95 percent reduction in greenhouse gases compared to 1990 according to the Energy plan for 2050.²⁸

The Croatian market is in the absence of professionally trained workforce for energy renovation and construction, and the need for education, specialization and improvement of the same has been noticed. Croatia applies certain allowances of the type of deduction from the base for the costs of scientific research projects and education, as well as education and training of workers (Šimović, 2008). Energy policy objectives are achieved through European legislation, by linking regional, national and international stakeholder, intersectoral cooperation, EU projects and encouraging research in energy. Member States that have achieved significant achievements in the field of energy the results claim that it is almost impossible to achieve on a national energy efficiency goals without key national implementing institutions (Ministry construction and spatial arrangements. Available on: <https://mgipu.gov.hr>).

Area energy efficiency includes several law u competences more ministries, and implementation is the responsibility of several institutions. Energy Efficiency Law is the basic law for the provisions Directives on energy efficiency. It brings the plans at the local, regional and national level for improving energy efficiency and their implementation, measures and obligations of energy efficiency, edits energy service activity, proves saving energy, rights of consumer in the implement of measure energy efficiency and other measurements connected to the consumption of energy and energy efficiency.

3. The financing sources of energy renewal

The maximization of profits and the constant tendency to lower operating costs in business are the key principles in the management of the commercial sector. Interest that is related to the energy-efficient renovation of commercial buildings is reflected in investments that result in a reduction of expenditures and that open up the possibility of returning invested funds in a short period of time. In favor, favorable sources of financing are crucial for the successful realization of energy renovation of buildings in the commercial sector. Financial institutions are developing models of affordable requirements of loan for projects of energy efficiency, but the role of state institutions is still crucial on this specific issue as well as for achieving ambitious energy goals. A large number of member states of the European Union invest efforts in significant activities to develop financial mechanisms with the aim of motivating entrepreneurs to invest in the energy efficiency of buildings. They open special funds that are in favor for the financing of reconstruction projects, the funds of which come from specially intended tax giving, the state budget or the funds of structural instruments of the European Union allocated for an individual member state. A few financial programs, preferential loans, grants and subsidies refer to new ones, while the majority is focused on already existing buildings that need renovation. The largest share of financial incentives refers to the funds needed for reconstruction envelopes buildings and installation for more efficient technical equipment. Important is to note as residential buildings are much more represented in the implementation of incentives for energy renovation than commercial buildings for the reason that they prevent distortion of competition on the market by placing certain economic entities in a more favorable position (Official Gazette, 2014).

Encouraging the energy renovation of commercial sector buildings is manifested through financial mechanisms that are divided into: non-refundable loans, loans, guarantees and technical assistance in project preparation and implementation. Non-refundable loans are the most common form of support in the preparatory and implementation phase, which is characterized by longer payback periods and very high costs, and provides investors with a higher level of profitability of the investment. They most often appear in the form of one-time financial assistance granted through state funds established primarily for this purpose and through various programs of competent ministries. The rule that applies on direct non-refundable funds are going under the name de minimis which assumes how amounts state help that are lower than 200,000 euros received by the company within three financial years does not create market distortions, but, it does not increase its competitiveness in such a way as to disrupt equal market competition. Height de minimis grants has been revised over the years, given the Commission's very ambitious goals for the renovation of residential buildings in the period 2014.- 2020, it is to be expected that this amount will increase in order to increase the profitability of energy efficiency projects in buildings (Official Gazette, 2014).

Loans, as a classic form of financing, are offered by foreign commercial and development banks through their specific products intended for investing in the energy improvement of buildings. They are characterized by a longer repayment pay, a lower interest rate and the possibility of waiting for repayment, but with pre-set energy savings requirements. Entrepreneurs who do not own much assets or financial power in the startup phase are needed guarantees from foreign business or development banks, and serve as an instrument to secure part of the principal amount of the loan for the investment. With only financial resources themselves, entrepreneurs need professional and technical assistance. Technical assistance programs are intended to improve the quality and implementation of the project itself, which provide financial resources for the external advisory services of experts regarding the creation of the project documentation, supervision and verification achieved energy project savings renovations. They include a making investment study, study feasibility, study influence on the environment, creation of the idea and the main project itself (Official Gazette, 2014).

Operational program „Competitiveness and cohesion 2014-2020.“ intended to improve competitiveness in The Republic of Croatia co-finances itself from European fund for regional development and Cohesion Fund. The strategy of the program is based on the concentration of investments in the nine thematic goals of the common strategic framework and their specific investment priorities, with a further focus on the specific goals that need to be achieved. Within priority axis 4 „Promotion of energy efficiency and renewable source energy“ launched is call under the name of „Increasing energy efficiency and the use of renewable energy sources in the service sector (tourism, trade)“. The main goals of this call are to encourage more efficient and sustainable use of energy by the private service sector of tourism and trade, to reduce the share of fossil fuels in total energy consumption, and to introduce new technologies for the use of energy from renewable sources. The call refers to the private service sector, therefore, to activities in the sectors tourism (accommodation, preparation and serving food and drinks, passenger agencies, tour operators (tour operators) and other reservation services) and shops (wholesale and retail motor trade vehicles and motorcycles, repair motor vehicles and motorcycles, shop wholesale and retail trade, except trade in tobacco and tobacco products). At the invitation published by the Ministry of Environment and Energy in May 2018, 75 project proposals met the conditions for awarding grants. The amount of funds increased from HRK 76 million, due to the large number of quality project proposals, and the total value of grants awarded was HRK 174.5 million for projects worth HRK 311.5 million (European structural and investment funds).

After the implementation of the planned activities encouraged by this call, CO emissions will be less by 3,705.89 tons per year. By investing in energy efficiency measures in the tourism sector and shops need for energy will reduce for 5,5 million kWh/year and it is expected that it will from newly installed capacities energy production from renewable sources energy increase by 9.7 million kWh/year (Fund for protection environment and energy efficiency).

The maximum degree of co-financing of eligible project costs from grants from the European Regional Development Fund, depending on the size of the company and the categories of activities, is calculated in the accordance with program state support for promotion energy efficiency and renewable energy sources in companies and the Small Value Grant Program (de minimis aid) for the promotion of energy efficiency and renewable energy sources in enterprises (European structural and investment funds). Detailed amounts are given in the following table.

Table 1. Maximum support intensity ERDF by size enterprises (Source: Ministry of Protection environment and energy)

Category activities /type of support	Micro and small business	Medium-sized enterprise	Large company	Related Program typology awards
Preparation documentation project proposal and others project-technical documentation	85% acceptable costs	85% acceptable costs	85% acceptable costs	Award program support small values
Measures of energy efficiency	65% acceptable costs	55% acceptable costs	45% acceptable costs	State aid allocation programme
Measures for high efficiency cogeneration	80% acceptable costs	70% acceptable costs	60% acceptable costs	State aid allocation programme
Measures for promotion energy from renewable source of energy	80% acceptable costs	70% acceptable costs	60% acceptable costs	State aid allocation programme
Management project and administration and promotion and visibility	85% acceptable costs	85% acceptable costs	85% acceptable costs	Award program support small values

The Ministry of Regional Development, European Union funds and the Croatian Bank for Reconstruction and Development signed the Financing Agreement on the occasion of the launch of the new financial instrument „ESIF Loans for energy efficiency for entrepreneurs“. Financial instruments co-finance in the frame European structural and investment fund, but they will implement through commercial banks as financial intermediaries that HBOR will choose through public procurement, which will provide HRK 245 million in private capital. The goal of the program is to reduce the consumption of delivered energy by the production industry and the service sector through the implementation of energy efficiency measures and measures for

the use of renewable energy sources, which in production facilities bring a minimum reduction of 20 % in the consumption of delivered energy by the production industry reference delivered energy, that is in a relationship on consumption delivered energy before the implementation of those measures (Eko vjesnik).

The program is intended to all micro, small, medium and large private entrepreneurs registered to perform the activities of the manufacturing industry and service activities (tourism and trade). To entrepreneurs it will be given of amount from 68 million euro, that is 511 million kuna, individually in the range from 25,000.00 euro do 10,000,000.00 euro, with low interest rate which will be determined according to the development index of the local self-government unit in whose territory the project is implemented. The repayment date will be up to 17 years, including up to 4 years in start period with exemption from all fees. In addition to the new and simpler access to EU funds, this financial instrument is also characterized by reuse after return, that is, when they are returned to the state budget, the Republic of Croatia will use them for the same purposes, which makes the money we invest in financial instruments used several times. Considering these benefits, it can be concluded that these loans represent a truly available and favorable source of financing for achieving energy savings and raising the competitiveness of entrepreneurs (Croatia bank for restoration and development).

Another ELENA project worth more than 2 million euros is announced, which would be financed external experts who will create project documentation for investment in energy efficiency and renewable energy sources for eligible users. Also, the implementation of a financial instrument that would put Croatian entrepreneurs and the public sector into action was initiated on disposition total 4,2 billion of kuna, that is more from 550 million euro, for financing of their investment projects by the Ministry of Regional Development and European Union funds (Croatia bank for restoration and development).

The European Bank for Reconstruction and Development (EBRD) offers a range of products and services entitled to each client, while small and medium companies offer financial funds through intermediaries. Future clients must demonstrate that the proposed project or business meets the minimum requirements to be considered for EBRD participation. EBRD funding for private sector projects typically ranges from \$5 million to \$250 million, in the form of loans or equity. The average investment of the EBRD is 25 million dollars. Smaller projects can be financed through financial mediator or special programs for smaller direct investments in less developed countries (European bank for restoration and development).

Two new financial instruments coming to Croatia are the Modernization Fund and PF4EE: Financing energy efficiency with private capital. The fund is intended for member states EU, and his purpose is to cover big needs for investments in energy efficiency and modernization of energy systems. The fund will be filed through the greenhouse gas emissions trading system. In the period from 2021 to 2030, 2% of emission quotas will be allocated (about 310 million in total), and the European Commission estimates the value of these quotas at about EUR 8 billion. The PF4EE

instrument is implemented through the European LIFE program as a joint agreement between EIB and European commissions, and his main goal is to increase access adequate and favorable commercial financing for investments in projects to increase energy efficiency. The instrument is intended for financial institutions that apply directly to the European Investment Bank with which they conclude a financing agreement. Aims for small investments in range from 40,000 to 5 million euro, a potential users credit line they can be small and medium-sized enterprises, natural persons or units of local/regional self-government (Regional energy agency).

Loan and financial incentives (grants) for private companies offers and Western Balkans Sustainable Energy Financing Facility (WeBSEFF) in the amount of up to 2,000,000 euros for investment in modern technologies that reduce energy consumption or CO₂ emissions² for at least 20%, renewal and optimization of buildings, with the condition that at least 30% higher energy efficiency will be achieved, and independent projects of renewable energy sources. The goal of the investment is to help companies reduce costs, make it more competitive, ensure the possibility of replacing old equipment and modernizing production, expand production or production range, and improve quality standards and meet the requirements of export markets. Companies will receive a financial incentive of 5% to 10% of the loan amount after successful completion and verification of eligible projects. Percentage of the incentives base on a basis influence project on the environment that calculates on a base of CO₂ emission reductions or the choice of technology (for projects in the building sector) (Western Balkans Sustainable Energy Financing Facility- WeBSEFF).

Financial institutions that supported the financing of the commercial sector are: Croatian Bank for Reconstruction and Development (HBOR), Fund for Environmental Protection and Energy Efficiency (FZOEU), Croatia agency for small business and investments (HAMAG INVEST), European bank for reconstruction and development (EBRD), European Investment Bank (EIB), Western Balkans Sustainable Energy Financing Facility II (WeBSEFF II) and CroPSSF Green energy. Today is very little available financial funds for energy restoration commercial building than what this was before and the sources listed above are available (Official Gazette, 2014).

Projects can also be financed through energy performance contracts „Energy Performance Contracting“ which is specific implementation form investments because the entrepreneur plans, and ESCO – „Energy Service Company“ company finances, performs and guarantees energy savings on a renovated building or energy system. The goal of each EPC project is to reduce the cost of energy and maintenance by installing new, more efficient equipment and optimizing energy systems, which ensures the repayment of the investment through realized savings over a period of several years depending on the client and the project. The ESCO company provides guarantees and, as a rule, assumes the risk of making savings. During the repayment of the investment for energy efficiency, the client pays equal amount for costs energy like before implementation project that shares on a real (reduced) cost for energy and also a cost for repayment investments. After repayments investments, ESCO Company exits from the project and all benefits are

handed over to the client, and the client achieves positive cash flows during the repayment period and long-term savings. Users of the ESCO service can be private and public companies, institutions and local self-government units (Incitement energy efficiency in Croatia).

Figure 1. Scheme for achieving savings by applying ESCO model (Source: Solar Project Croatia – ESCO models and financing)

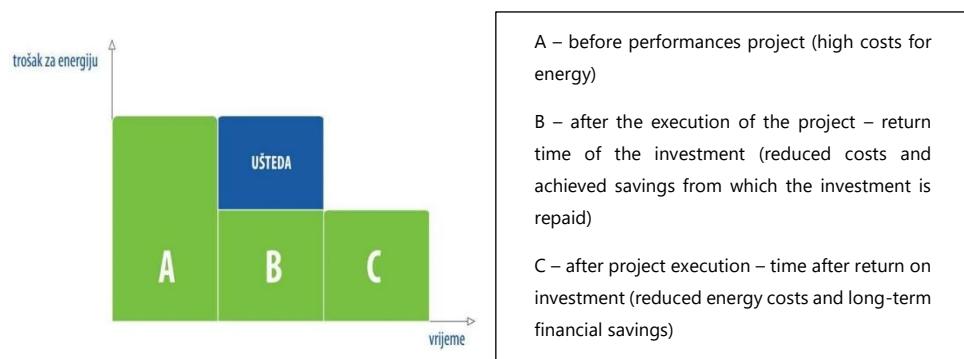


Table 2. Comparison EPC with own energy implementation renovations (Source: European Energy Service Initiative (2014) Guide for intermediaries for energy Performance Contracting (EPC))

Advantages / Disadvantages	EPC	Own restoration
Warranty savings	ESCO guarantees energy savings in the EPC contract	Without guarantees savings
Maximization of energy savings	ESCO is highly motivated to maximization energy savings	Relatively little motivation, possibility returnable effect
Maximization of financial savings	Level financial savings are guaranteed by ESCO via EPC contract	Financial savings could be higher code own renewals, provided that the client allocates sufficient funds/involves external experts in carrying out extensive savings measures of energy in his own buildings
Technically risk	ESCO	Client
Technical responsibilities for new systems (Costs substitutes (parts) of the system/guarantee)	ESCO throughout its duration contract (one contact)	External design/installation entities only during the duration of the guarantee (usually 2 years), after the expiration of the guarantee, the responsibility rests with the client

Financial risk	ESCO	Client
Costs financing		They could be lower, provided the client has a budget for implementation measure or options financing with low interest
Levels comforts	Optimization of energy consumption on defined comfort levels	Complete flexibility level comforts
Process design	Coordinates ESCO	Coordinate client and external designers
Return effect	ESCO is highly motivated to avoid all possible returnable effects	Usually coming down increases in energy consumption after the application of measures (refundable effect)

The Croatian Agency for Small Business and Investments (HAMAG INVEST) provides support in the operations of small and medium-sized entrepreneurs, enabling them to develop more easily and quickly at the national level. The measures by which HAMAG-INVEST can help small and medium-sized enterprises in increasing the energy efficiency of their own facilities are as follows:

- **Guarantee programs** – The agency issues guarantee for investments in fixed assets as part of the program „Lets grow together“. The guarantees cover up to 50% of the total investment, or up to HRK 7.5 million.
- **Consulting services** – The Agency co-finances (up to 75%) consulting services that include the preparation of feasibility studies and the implementation of energy audits.

In addition to the possibilities of co-financing that are mentioned, there are also various loans intended to improve energy efficiency. The offer of Croatian Postal loans was cited as an example bank. Croatia postal bank in cooperation with the European bank for restoration and development offers loans for energy efficiency business subjects. Its credit intended financing working capital, financing the purchase of products, materials and equipment that meets the set technical requirements of energy efficiency. The program is intended for suppliers, manufacturers, installers or sellers of energy-efficient products. Also, there is a free technical help consultant which includes all of the explanations about energy-efficient equipment, savings that can be achieved, optimal combination of energy efficiency measures, necessary project documentation and all implementation steps (Croatia postal bank – Real estate).

Table 3. Conditions of the credit (Source: Croatian postal bank)

Date of repayment	To 5 years
Start	To 12 months

Amount of credit	from 4.000,00 EUR to 2.500.000,00 EUR
Usage of credit	To 12 months

4. Conclusion

The European Union has recognized energy efficiency as one of the key ways to achieve the goals of sustainable energy development, so taking care of energy efficiency is one of the essential components of the sustainable development of the Republic of Croatia. The main goals are to ensure sustainable use of renewable sources, protection and care of the environment, and increase efficient use of energy and to achieve energy significant savings. One of the ways of achieving goals is through energy renovation in the building sector, which is analyzed in detail in the paper.

All processes in energy restoring building, starting from energy reviews and making of the energy certificate, the creation of project documentation and the execution of works with expert supervision until the final energy renovation, have to be professionally managed and implemented with high quality in order to achieve the set goals and favorable financing conditions. Experience has shown that the implementation of many projects energy renovations building shows big potential energy saving in the existing sector. The conclusions of the analysis show that end consumers in the housing sector recognized energy efficiency measures as an effective way to reduce overall costs, and commercial one's sector saw it is that is investment in energy efficiency also and investment in the bigger productivity.

Considering the very high costs, all current possibilities and conditions of financing and co-financing were explored energy renovations of physical and legal persons and also the public sector available on the market, which increased significantly upon joining the European Union. Available data and comparison of new programs co-financed from funds EU with the previous one's programs they indicate on a extremely increasing public interest and greater incentive when making investment decisions. For this reason, it is extremely important to implement continuously information to the public of the whole procedure, necessary conditions and ways of implementation in energy renovations of institutions and also about all available possibilities financing and co-financing in order to continue the growth of energy-efficient real estate.

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How Gen Z deals with money: A snapshot of financial behavior in Croatia

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Abstract

Generation Z is emerging as a financially active demographic, yet its financial literacy and financial behavior remain a subject of increasing concern for educators, policymakers, and financial institutions. This paper aims to provide an overview of financial behavior among members of Generation Z in Croatia, based on data from a survey conducted in 2021. Understanding the financial behavior of Generation Z is increasingly relevant as they enter adulthood which assumes increased financial independence and making their own financial decisions. The analysis is based on self-reported financial behavior data. We surveyed young adults at 229 high schools and universities in Croatia and a total of 895 respondents born between 1995 and 2010 were included in the analysis. Descriptive statistics and subgroup comparisons were used to examine behavioral trends. Results show varied financial behavior. A portion of Gen Z respondents demonstrate responsible financial habits, however many still lack basic budgeting and long-term financial planning skills. The findings provide insights for the creation of targeted financial education programmes that can support young people in developing sound money management habits.

Keywords: financial behavior, financial habits, Generation Z, young, Croatia

JEL Classification: X00, X01, X02, X03, X04, X05 [Max 5 Classifications]

1. Introduction

According to Zemke et al. (2000) people may be classified into one of the following generations: Baby Boomer generation, Generation X, Generation Y, Generation Z, and Generation Alpha. The generational gap between them is mostly the result of digitalization (Fistrić, 2019). According to Wibowo and Ayuningtyas (2024) as cited in Nuresa (2023) digital technology and its development had a strong influence on almost every aspect of human life, including the financial behavior of modern society.

Generation Z includes individuals born between 1997 and 2012, known as the "digital-native generation" (Nuresa, 2023). It represents the generation that starts to take financial responsibility and make independent financial decisions. They grow up in the changing social and economic environment, characterized by an unstable labor market, technological innovations and changes in values and lifestyle. As a result of that, they are confronted with specific financial challenges, including difficulties in long-term financial planning and limited awareness of future financial needs. These are individuals in early adulthood that will now (or very soon) enter the labor market as a new workforce. Generation Z on the global level has become a key force in many areas of life, influencing and encouraging economic growth through e-commerce, gig work and tech start-ups (Nuresa, 2023). Due to this, many researchers have shown interest in analyzing their behavior. Scientists study their financial habits, especially their behavioral patterns (Rupčić, 2021). Understanding the way that young people behave and make money decisions is a crucial step towards strengthening their financial literacy, resilience and overall wellbeing.

The financial situation of youth is shaped by the combination of demographic, social and economic factors, but also by their financial habits and behaviors. As a result of that, financial goals and available resources differentiate from one individual to another. Comprehending the financial behavior of youth is essential in helping them procure a safe and successful future in adulthood. In the early stages of their financial independence, young people start to make financial decisions that significantly influence their current and future wellbeing. In time, those choices, from everyday consumption to taking out a loan, can have serious long-term financial consequences. When compared to older age groups, young adults are financially more vulnerable due to variable income and limited financial experience (Lachance, 2012). This vulnerability highlights the importance of developing strong financial habits in the early age, since poor financial choices made in youth may accumulate and follow them in their adult life.

Generation Z has grown up in a digital era where information is easily available and financial products and services are only a few clicks away. Unlike their predecessors, they have been living in a fully digital environment since they were born, where smartphones, social media, and financial technologies are a part of their everyday life. So, they are not just "digital natives," but also "mobile natives," meaning they use technology on the go, mostly due to smartphones (Rupčić, 2021). Their financial behavior and habits are shaped by the unique combination of digital development, changing social norms and economic instability. They use internet platforms and mobile apps to manage their finances, which allows them to make financial decisions more independently and faster. However, this kind of digital comfort also creates certain risks, including impulsive spending, exposure to disinformation and vulnerability to internet and financial frauds. OECD (2023) and Hanfa (2022) highlight that even though young people are digitally skilled, their financial and digital literacy often remain low which results in difficulties in differentiation of reliable from unreliable financial information. In Croatia, where saving patterns of the households is still mainly determined by short-term deposit (CNB, 2023), this generational shift towards digital finance requires better

understanding of the ways that internet habits and technological environment shapes financial behavior of the youth. Today's devices offer huge amounts of content which is interesting, new, useful, or a mix of all that (Rupčić, 2021) and Gen Z consumes this content faster than any previous generation, but they do not always stop to think about it or check if it's reliable, especially if they do not already know much about the topic, which is especially dangerous when it comes to personal finance matters.

There is an expanding body of research examining the variations in financial literacy and financial behavior among different generations. Beck and Garris (2019) investigated various attitudes on personal finances and how these attitudes differ among generations. They found that Gen Z is significantly more oriented towards their own financial future and potential economic risks that might affect them, compared to other generations that were much more concerned about the financial decisions of future generations. Rosdiana (2020) found significant distinctions between Gen Z and Millennials in the level of financial literacy, motivations, social factors and interest to invest. In the Croatian context, research of Pavković et al. (2024) showed that Gen Z accomplishes a higher level of financial literacy than Millennials. However, they concluded that the level of financial knowledge does not necessarily reflect their long-term financial resilience. Even though young people successfully use digital platforms to conduct everyday money decisions, their understanding of risk, investment and long-term planning is still rather limited. Their results are in line with international literature that emphasizes the "knowledge - behavior gap among the youth.

This study aims to explore how Generation Z in Croatia manages money and to identify the patterns and characteristics of their financial behavior. It focuses on everyday financial practices, including saving, spending, budgeting and using financial products and services, in order to better understand the extent to which young people demonstrate responsible financial behavior. Although the research sample is not nationally representative, it provides indicative insights into the financial habits and resilience of young people in Croatia. Using the empirical data collected among high school and university students, the study seeks to contribute to the existing literature on financial behavior and financial literacy, offering evidence-based implications for the design of financial education programs and public policies aimed at improving financial capability of Generation Z.

2. Theoretical Background

Financial behavior includes various ways that people manage their money in order to make the most of their available resources (Hilgert et al, 2003; Xiao, 2008). Responsible financial behavior refers to informed money management, such as budgeting, saving, thoughtful investing and making prudent financial decisions (Atkinson et al., 2006; Barbić et al., 2018). It usually includes creating, maintaining and monitoring budgets, creating emergency funds and long-term planning (Lučić et al., 2023). Financial behavior therefore does not only reflect only the way that

individuals manage their money, but also the way they make financial decisions. According to Dew and Xiao (2011) and Lučić et al. (2023), behaviors such as maintaining a savings buffer and identifying personal financial goals are crucial for the accomplishment of long-term financial security. On the other hand, irresponsible financial behavior includes poor money management practices that might result in serious financial consequences, such as overspending, high level of indebtedness, lack of savings and the absence of financial planning (Lučić et al., 2023).

Literature often emphasizes the positive effects of financial literacy on responsible financial behavior, especially in the domains such as saving, budgeting and investing (Rodriguez et al., 2024; Atkinson et al., 2006; Barbić et al, 2018). According to Hilgert et al. (2003), financial planning represents the practical outcome of financial literacy and financial decision-making process. Still, knowledge alone does not automatically translate into behavior. This "knowledge–behavior gap" is one of the main challenges for financial education, as it highlights the need to focus not only on cognitive understanding but also on habit formation and behavioral change.

EU (2023) conducted a survey of financial literacy in EU-27 and concluded that on average in EU-27 prevails responsible financial behavior, including assessing affordability and tracking expenses, while long-term financial planning is somewhat less developed. About nine in ten respondents across the EU agree that before they buy something, they consider whether they can afford it (51% "completely agree" and 41% "somewhat agree"). A similar proportion of respondents report that they keep track of and monitor their expenses (49% "completely agree" and 43% "somewhat agree"), while about seven in ten agree that they set long-term financial goals and strive to achieve them (21% "completely agree" and 50% "somewhat agree") (Figure 1).

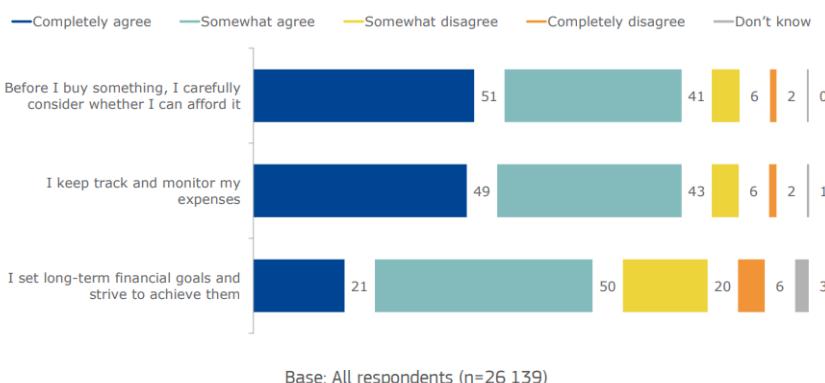


Figure 1: Financial behavior in EU-27 (source: EU, 2023)

According to CNB (2023), the average score for financial behavior in Croatia is 4.73 out of 9 points (53%), with those younger than 19 receiving the lowest average

score (4.4). The research also revealed that 91% of citizens make everyday decisions about their own money independently or together with someone else, 86% always or often pay their bills on time, 70% always or often think carefully before making a purchase, 68% carefully manage their financial affairs, 63% personally manage household finances and have a household budget, 56% monitor their spending, 55% set aside money for bills separately from everyday spending, and 47% set long-term financial goals and strive to achieve them. In the area of digital financial behavior, however, the situation is reversed; the average score for Croatian citizens is 2.22 out of 4 (56%), while respondents younger than 19 achieved the highest score (2.7).

Generation Z, born and raised in the digital era, is stepping into financial independence under significantly different circumstances than previous generations. This generation has been shaped by digitalisation, societal transformation, and economic volatility. Growing up surrounded by smartphones, social media, and financial technologies, they gravitate toward digital tools such as mobile banking, instant payments, and real-time expense tracking (OECD, 2020). At the same time, the world they live in is marked by uncertainty; political instability, rising living costs, short-term employment contracts, and increased exposure to online financial content and financial frauds. Although it is often assumed that young people due to their digital competencies make prudent financial decisions, recent research has shown that this is not necessarily the case. Muat et al. (2024) point out that, among Gen Z, digital financial literacy on its own rarely leads to improved financial outcomes. The authors concluded that financial behavior acts as a key mediator between financial knowledge and financial well-being and that digital and financial knowledge is being transformed into quality decision making only when it is accompanied with habits such as planning, budgeting, spending control and self-control. These findings confirm the importance of measuring and analyzing financial behavior of young people since it represents the most direct link between cognitive competencies and real financial outcomes. In Croatia, for example, many Gen Z investors mistakenly assume that crypto assets are regulated in the same way as traditional investments, revealing critical gaps in both knowledge and awareness (Hanfa, 2022).

According to Muat et al. (2024) financial behavior has been shown to be a stronger predictor of perceived financial well-being among Gen Z than either digital literacy or financial knowledge alone. A large portion of the existing research on young adults' financial behavior has focused on the use of credit cards. As credit cards are widely used among this age group, they offer a useful tool for assessing financial literacy and decision-making patterns (Breitbach & Walstad, 2016). For example, Lachance et al. (2006) examined the credit card habits of young individuals and found that those with greater knowledge about credit cards were more likely to own at least one card and also tended to carry more debt.

Other studies have explored different aspects of young adults' financial conduct. Findings show that young adults are less inclined to plan for retirement (van Rooij et al., 2011), invest in the stock market (van Rooij et al., 2011), or build emergency savings (Babiarz & Robb, 2014). Additionally, they are more likely to be underbanked, meaning they have limited or no access to traditional banking services

(Breitbach & Walstad, 2016). de Bassa Scheresberg (2013) claims that young people very often engage in risky financial behavior; taking on complex financial obligations such as student loans or other forms of high-interest debts, while demonstrating seriously low levels of financial literacy at the same time. The findings emphasized that the lack of basic financial knowledge is correlated with lower probability of creating an emergency fund and using expensive financial products. Collectively, these studies suggest that young adults often engage in financial behaviors that may endanger their long-term financial health.

Khairullah et al., 2024, as cited in Nuresa (2023) found that when it comes to Generation Z, they show very different consumption patterns compared to previous generations. They tend to value convenience and speed, which is reflected in their financial habits. The Harris Poll (2025) report showed that Gen Z representatives predominantly use digital forms of payment, which not only dominates their every day financial habits but also shapes their consumption patterns, often increasing their proneness to impulsive buying. According to Nuresa (2023), the consumption habits of Gen Z are shaped by digital media, values of sustainability and an increased sensitivity to social and environmental issues. Gen Z is more prone to emotional and impulsive consumption, but at the same time they show a high level of interest for price comparisons, reviews and "value-for-money" approach. It is evident that technology plays a dual role in this context. While it simplifies access to financial tools and fosters better budgeting, it also introduces risks such as impulsive spending, misinformation, and exposure to unregulated assets like cryptocurrencies and NFTs (Qamar et al., 2023; Hanfa, 2022).

The Harris Poll (2025) report showed that almost 50% of young people do not have more than a few hundred dollars of savings, pointing to the lack of financial resilience. However, despite their digital upbringing, they have not completely abandoned traditional financial practices. Recent studies show that many Gen Z still rely heavily on cash. Hanfa (2022) research showed that young people in Croatia mostly save by keeping their money at home (61%), and they are generally not inclined to invest, for example, only 4% of respondents invest in investment funds, and as many as 26% of respondents invest or plan to invest in the crypto market. Hybrid behaviors, such as the return of cash-envelope saving and budgeting ("cash stuffing") illustrate their desire for control and tangibility in uncertain times. This type of behavior among Gen Z might be connected to increasingly popular trend on TikTok, where clips with the hashtags "#cashstuffing", "#cashenvelopesystem" and "#cashenvelopes" have garnered more than 3 billion views combined (CNBC, 2025).

Generational experiences also play a role in shaping financial behaviors. Shaped by global events such as the 2008 financial crisis and the COVID-19 pandemic, Gen Z has become more cautious toward debt and tends to prioritize saving, especially for immediate or short-term needs (Milotay, 2020; Harris Poll, 2025) which also explains saving in cash.

3. Methodology and results

This study is based on data gathered from the survey that was conducted on a sample of youth in Croatia, which examined their financial competencies, attitudes, and behaviors. Data was collected using a web-based survey of a convenience sample of young people in 2021. All high schools and registered universities and colleges were contacted and invited to join the survey. The principles and professors were asked to coordinate the link distribution among students. Therefore, it is impossible to make any estimations of the exact response rate. Overall, 970 high school and university students participated in the survey, aged 15 to 25 years, while 895 of them completed the survey questions used for this paper and were defined as Generation Z. Most of the respondents were born in 2003 (20.3%). Out of all respondents, 55.4% were high school students and 44.6% were university students. Regarding gender, 26.4% were male and 73.6% were female respondents. Regarding the household type, most of the respondents live with their families (88.2%), 5.70% live with their roommate, 3.33% live with their partner, 1.95% live on their own, and 0.83% have other types of household structure. Parents' level of education points to the fact that most of the respondents' parents, (51.23% mothers and 54.15% fathers) have a secondary level of education.

In this paper, financial behavior is defined using 7 items (FB1-FB7) that measure various aspects of responsible financial behavior, including saving, monitoring spending, price comparison, budgeting, managing transactional accounts and being informed about financial products. Every item is evaluated on a seven point Likert scale (1- I completely disagree; 7 - I completely agree). After that, for every respondent the average combined value of financial behavior was calculated. The resulting score ranged from 1 to 7, with lower values indicating weaker and higher values indicating more responsible financial behavior. On the one hand, a score at the lower end of the scale (1.00) represents a respondent who does not have money set aside for future use, does not maintain an emergency fund, does not monitor their spending, does not compare prices before making a purchase, lacks control over the balance between income and expenses, and does not know how to choose a financial product for a specific purpose. On the other hand, a respondent with an average score close to 7 demonstrates a respondent with a high level of responsible financial behavior.

The conducted descriptive analysis shows that most respondents scored in the moderate-to-high range across most items. Table 1 presents item-level statistics, including means, standard deviations, and quartile values.

Table 1. Descriptive Statistics for Financial Behavior Items (N = 895)

Variable	Mean	Median	Mode	Std. Dev.	Sample Variance	Min	Mx	Sum	Coefficient of variation
FB1- I have money set aside for future use.	4.897	6	7	2.266	5.137	1	7	4383	46.282
FB2- I have an emergency savings fund ("for a rainy day").	4.034	4	7	2.459	6.046	1	7	3611	60.948
FB3- I carefully monitor how much money I spend.	4.983	5	7	1.721	2.960	1	7	460	34.528
FB4- Before buying something for myself, I compare the prices of similar items.	5.614	6	7	1.668	2.783	1	7	5025	29.713
FB5- In my budget, my income exceeds my expenses.	4.388	4	7	1.995	3.980	1	7	3923	45.464
FB6- I confidently manage deposits and withdrawals from my bank account.	4.487	5	7	2.125	4.516	1	7	4016	47.361
FB7- I know how to choose financial products for a specific purpose.	4.493	5	5	1.821	3.315	1	7	4022	40.516

The descriptive statistics provide an overview of Generation Z's financial behaviour across seven statements (FB1–FB7). The highest mean score was recorded

for FB4 – “Before buying something for myself, I compare the prices of similar items” ($M = 5.61$; $SD = 1.67$), indicating a strong tendency toward rational financial behaviour and price-conscious decision-making. This variable also exhibits the lowest variability ($V = 29.71$), suggesting a high level of agreement among respondents.

Relatively high mean values were also observed for FB3 – “I carefully monitor how much money I spend” ($M = 4.98$) and FB1 – “I have money set aside for future use” ($M = 4.90$). Both items reveal a solid level of self-control and planning orientation, with mode values of 7, implying that a large share of respondents demonstrate a consistent and disciplined approach to money management.

In contrast, the lowest mean value was recorded for FB2 – “I have an emergency savings fund (‘for a rainy day’)” ($M = 4.03$; $SD = 2.46$), highlighting a potential gap in financial preparedness and resilience among young individuals. The high variance ($V = 60.95$) further reflects considerable heterogeneity in respondents’ ability to maintain an emergency fund.

Moderate mean scores were found for FB5 – “In my budget, my income exceeds my expenses” ($M = 4.39$) and FB6 – “I confidently manage deposits and withdrawals from my bank account” ($M = 4.49$), suggesting an average to moderately positive level of financial management confidence and budgeting discipline. The dispersion in these items indicates diverse financial experiences and capacities within the sample.

Finally, FB7 – “I know how to choose financial products for a specific purpose” ($M = 4.49$; $SD = 1.82$) reflects a moderate level of perceived financial competence, pointing to the need for further improvement in financial literacy and informed decision-making regarding financial products.

As presented in Figure 2, mean scores for all seven financial behaviour items ranged from 4.03 to 5.61.

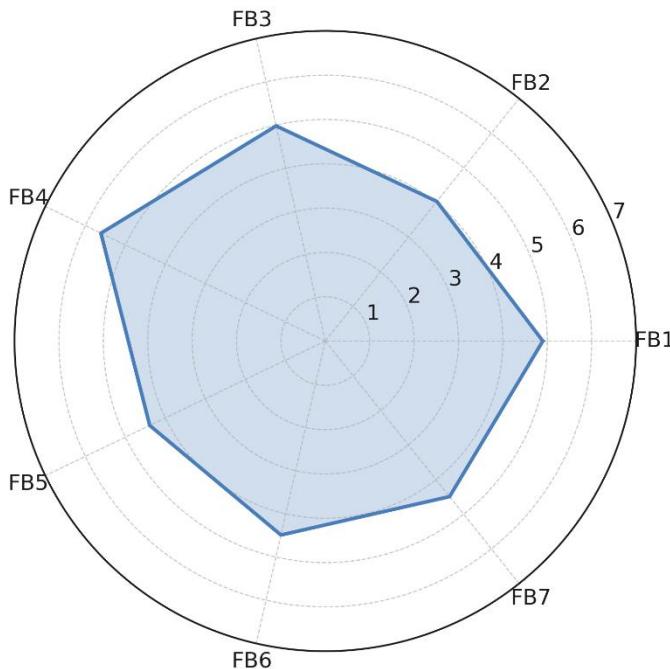


Figure 2: Radar chart of financial behavior

Internal consistency values were calculated for the scale's reliability. Internal consistency of the financial behavior scale (7 items) was assessed using Cronbach's alpha. The scale demonstrated acceptable reliability (Cronbach's $\alpha = 0.76$), indicating that the items capture a common underlying construct of financial behavior. According to commonly used guidelines (Gliem & Gliem, 2003), Cronbach's alpha values above 0.70 indicate acceptable internal consistency for research purposes, values above 0.80 reflect good reliability, while values above 0.90 are considered excellent but may also suggest item redundancy. Therefore, an alpha of 0.76 places this scale within the range of satisfactory and theoretically appropriate reliability for behavioral research, confirming that the scale is sufficiently consistent without being excessively homogeneous.

Table 2: Reliability indices of the scale.

Item	Mean	Std. Deviation	Cronbach's alpha if item deleted
FB1	4.90	2.27	0.71
FB2	4.03	2.46	0.71
FB3	4.98	1.72	0.73
FB4	5.61	1.67	0.76
FB5	4.39	1.99	0.73
FB6	4.49	2.13	0.76
FB7	4.50	1.82	0.74

To obtain the continuous measure with a categorical financial behavior variable, respondents were divided into three levels based on predefined cut-off points: low (1.00–3.49), moderate (3.50–5.49), and high financial behavior (5.50–7.00). This classification allowed identifying the patterns of financial behavior among Gen Z and comparison of different groups according to their demographic characteristics and financial habits.

Table 3: Levels of financial behavior

Levels	Financial behavior	Percentage
Low (1.00–3.49)	Inconsistent or weak financial behavior	19.44%
Moderate (3.50–5.49)	Moderately responsible behavior	48.72%
High (5.50–7.00)	Responsible and disciplined financial behavior	31.84%

The analysis showed that most of the respondents had a moderate level of financial behavior (48,72%), followed by high level of financial behavior (31,84%) and finally low level of financial behavior (19,44%).

These categories were used in further analysis with a purpose of understanding the differences in financial behavior among representatives of Gen Z in Croatia. A chi-square test was conducted to examine whether financial behavior categories differed by gender and by level of education.

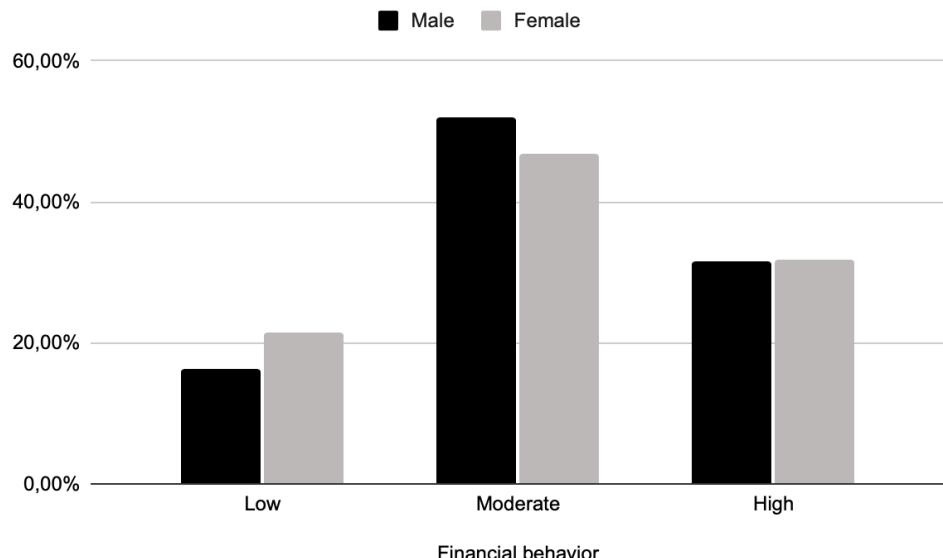


Figure 3: Financial behavior by gender

The results showed no statistically significant association between gender and financial behavior level ($\chi^2 = 2.63$, $df = 2$, $p = 0.269$), indicating that male and female respondents do not differ meaningfully in their distribution across low, moderate, and high financial behavior categories.

The findings show that the structures of the categories are similar, especially in the category of high financial behavior where 31,6% of men and 31,8% of women exhibited high levels of financial behavior. The most substantial difference was found in the category of low financial behavior where 16,3% of men and 21,4% of women showed low level of financial behavior. Also, male respondents were found to have more often moderate financial behavior than women (men 52,1% and women 46,81%). The results suggest that the patterns of financial behavior among young women and men in Croatia are very similar, with mild differences in the lower part of distribution.

When it comes to the level of financial education, the results revealed a statistically significant association between institution type and financial behavior level ($\chi^2 = 9.14$, $df = 2$, $p = 0.010$).

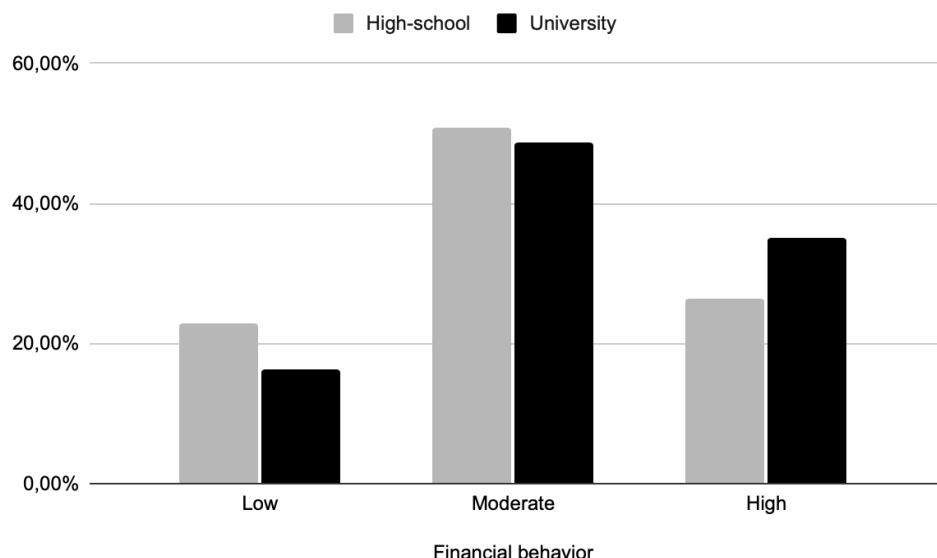


Figure 4: Financial behavior by level of education

According to the data presented in Figure 4, university students exhibit significantly better financial behavior than high-school students. High school students showed a higher proportion of low financial behavior (22.8%) compared to university students (16.2%), while university students were more likely to belong to the high financial behavior category (35.1% versus 26.4% among high school students). The proportion of respondents in the moderate category was similar in both groups. These findings indicate that university students exhibit significantly more responsible financial behavior than high school students.

4. Discussion

The findings of this research discover a complex pattern of financial behavior of Croatian Generation Z that combines cautious consumption habits with limited long-term financial preparedness. The respondents showed a relatively high level of awareness of price comparison and careful consideration before purchasing which points to a certain level of financial discipline and mindfulness. However, rather low results accomplished on items related to emergency savings and defining long-term goals indicate a lower level of financial resilience, i.e. the ability to recover from financial shocks. This imbalance between short-term prudence and limited orientation to the future implies that financial behavior of Gen Z is driven more by budget control than by systematic financial planning. These kinds of tendencies may be shaped by their life stage, limited incomes or exposure to uncertain socio-economic environments.

The results are in line with previous studies that emphasized that young people very often show responsible micro-level behavior (such as creating a budget, avoiding overdrafts) but experience difficulties with macro-level behaviors that require strategic planning, such as retirement saving or investing (Lusardi & Mitchell, 2014; OECD, 2023). Similar to findings of Xiao and Porto (2019), Croatian sample reflects a generation that recognizes the importance of managing everyday expenses, but at the same time, lacks the experience, self-confidence, self-efficacy and institutional support which is necessary for building long-term financial security. Furthermore, relatively low presence of emergency funds is in line with studies that highlight limited precautionary saving motives among the youth (OECD/INFE, 2020). This pattern emphasizes a knowledge-behavior gap, a well known challenge in behavioral finance and financial literacy research.

We also conducted the analysis of group differences using chi-square tests that offered further insight into the sociodemographic factors associated with financial behavior among Croatian Gen Z. The findings show that there is no statistically significant relationship between gender and financial behavior which suggests that young women and men exhibit similar behavioral patterns despite minor descriptive differences in the lower part of the distribution. This is in line with recent research that points to the fact that the gender gap in financial behavior and financial literacy in general is narrowing as access to financial information and digital financial tools becomes more equally distributed (OECD, 2023). In contrast, the level of education was shown to have a statistically significant relationship with financial behavior: university students had higher probability of exhibiting responsible financial behavior when compared to high-school students. This result is in line with previous research that concluded that higher levels of formal financial education, especially tertiary, are connected to higher level of financial competence (Lusardi and Mitchell, 2014; OECD, 2020). The observed differences highlight the importance of educational context in shaping financial behavior through transition in adulthood, implying that targeted financial education initiatives might be very beneficial for adolescents that still did not enter into the higher education system.

The implications of our findings extend beyond the individual behavior. For policymakers and educators, results point to the need to strengthen education on financial resilience and importance of creation of mechanisms of protection against economic shocks. Integrating topics such as risk management, emergency funds and long-term planning into the high-school curriculum might encourage a more proactive way of thinking. Financial institutions and regulators should also use digital platforms to promote transparent, available and gamified tools for financial education that resonate with Gen Z's communication style.

At the same time, public policy should focus on creating a stimulative environment that will encourage responsible financial behavior through nudge interventions (for ex. automatic saving features, default micro-saving options etc.) and inclusive financial products tailored for the needs of the youth. Collaboration between educational institutions, government agencies and the financial sector might ensure the development of financial education from a one-time educational event into lifelong learning rooted in everyday decisions. In doing so, Croatia might

strengthen financial capabilities and long-term security of the youngest generation and help them transform their informed awareness into sustainable financial action.

5. Conclusion

This study offers a concise snapshot of how Generation Z in Croatia manages money, revealing generally moderate to responsible everyday financial behavior, alongside noticeable gaps in long-term financial resilience. Differences between educational groups, but not gender, highlight the importance of educational context in shaping financial habits. Although the analysis is based on a non-representative sample, the findings provide valuable indicative insights into the financial reality of young people.

The findings highlight the need for strengthening education on financial resilience, especially in high-schools, through topics such as emergency funds, risk management and long-term planning. Digital channels still present an important opportunity which financial institutions and regulators should use with a purpose of promoting available tools that support saving, budgeting and informed decision-making. Public policies that include behavioral nudges could also further encourage creation of sustainable financial habits.

This paper contributes to the growing literature on financial behavior of young adults in several ways. Firstly, it provides empirical evidence on financial habits of Croatian Gen Z, a demographic group that is still underexplored even though its economic importance is constantly increasing. Secondly, the paper highlights the differences between short-term financial discipline and long-term vulnerability, offering insight into the knowledge-behavior gap. Thirdly, the study identifies the level of education as a relevant factor in shaping financial behavior, emphasizing the importance of early financial education and interventions.

There are several limitations of this research. First, the analysis is based on a convenience sample that mainly includes high-school students and university students and limits the representativeness and possibility to generalize the results on a wider population of Gen Z, including young people who are employed and not engaged in formal education. Second, the analysis is based on self-reported measures that may contain social desirability bias and subjective and misreporting of financial behavior. Third, cross-sectional design prevents understanding how behaviors change with age, experience and economic conditions. Forth, the research instrument is mainly focused on behavioral indicators, without the incorporation of psychological constructs (for ex. self-efficacy, optimism, locus of control, impulsivity etc.) that are well-known as predictors of financial behavior and decision-making. Finally, the paper does not analyze digital financial behavior in detail, which represents an increasingly important area of research given the Gen Z's strong orientation and exposure to digital financial content, digital tools and content on social media.

Future research should employ probability-based sampling techniques or stratified sampling in order to ensure higher level of representatives of Gen Z in Croatia; integrate longitudinal approaches in order to follow how behavior changes through time; include quantitative methods (for ex. interviews, focus-groups) to better understand motivations, emotions and social influences behind certain financial decisions; expand the analytical model by including psychological and behavioral predictors and explore cross-country comparisons within the EU to offer additional insights and support more targeted financial education and policy design.

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GOMBAR, M., SVETOZAROVA, N. & BURDOVA, A. / *The Tax System of the Slovak Republic in a Changing European Environment*

The Tax System of the Slovak Republic in a Changing European Environment

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Abstract

The paper focuses on a comparative analysis of the performance of tax systems in the countries of the Visegrad Group, with particular emphasis on the position of the Slovak Republic. The aim is to identify trends and evaluate the efficiency of individual tax systems by analyzing their structure, tax revenues, and the development of the value-added tax (VAT) gap as an indicator of tax collection performance. The research is based on secondary data obtained from international statistical databases and national ministries of finance, employing descriptive and exploratory analysis to assess long-term developments. The paper provides an overview of direct and indirect tax systems, their fiscal functions, and compares their contribution to public budgets through the tax mix. The results highlight differences in the structure and efficiency of the Visegrad countries' tax systems, with Slovakia showing a relatively stable but improvable performance, particularly in the area of VAT collection and tax compliance.

Keywords: tax system, tax policy, VAT gap, Visegrad Group, fiscal performance

1. Introduction

Tax evasion represents a long-term problem for public finances and is present across various economic systems regardless of the level of economic development. Its scale and nature influence not only the financial stability of the state but also the quality of the business environment and the overall public trust in institutions. According to Martinez and Vergeiner (1995), tax evasion arises where discrepancies exist between the legislative framework, the effectiveness of its enforcement, and the behaviour of taxpayers. This mismatch creates space for an imbalance between the

expectations of the state on one hand and the preferences of individuals or organizations on the other.

In a modern economy, fiscal stability is of key importance, and the state's ability to enforce tax compliance directly affects its revenue base and the quality of public services. As Špalek (2011) notes, the financial sustainability of public goods depends on whether the tax system is perceived as fair and functional. If the system fails to ensure equal conditions for all taxpayers, its legitimacy weakens and the willingness of subjects to participate in financing common needs decreases.

Current practice also shows that the issue of tax evasion is shaped by a dynamic environment where legislative changes, technological progress, and the development of new economic models intersect. Globalization and digital technologies create new opportunities to circumvent tax obligations, as highlighted by the OECD (2010), which calls for strengthened coordination between states and modernization of control mechanisms. These developments create a need to reassess traditional approaches to identifying and monitoring tax evasion.

At the same time, the importance of examining social, cultural, and behavioural aspects is growing. As Servátka (2007) states, taxpayers' decisions are not driven solely by economic considerations but also by the environment in which they operate, their perception of fairness, and their reactions to the behaviour of others in society. In connection with this, Pauličková (2005) warns that social tolerance of unpaid taxes may deepen the problem and normalize it within certain population groups.

In addition to macroeconomic and social aspects, corporate processes also play a significant role. Burák and Orihel (2011) point out that ineffective risk management, ambiguous internal rules, or insufficient control may create conditions that facilitate illegitimate practices. The interplay between corporate practice and legislative regulation highlights the need to seek solutions that go beyond traditional tools of tax policy.

Given these factors, the issue of tax evasion requires a comprehensive research approach that enables the identification of the main drivers of its emergence, the ways it manifests, and the limitations of current regulatory instruments.

2. Theoretical Framework

Tax evasion represents a long-studied phenomenon situated at the intersection of economics, law, sociology, psychology, and public policy. It is a problem that affects not only the revenue side of public budgets but also the quality of public administration, citizens' trust in the state, and the overall stability of the fiscal system. According to Babčák (2018), tax evasion results from the deliberate and intentional

behaviour of taxpayers aimed at fully or partially avoiding tax liability. Faltová (2018) distinguishes between tax evasion as an illegal act and tax avoidance, which exploits legal loopholes in the legislation. Both phenomena, however, have significant impacts on the functioning of the state.

From an economic perspective, tax evasion is most often explained through rational choice models. Martinez and Vergeinerová (1995) argue that a taxpayer weighs the potential benefits of avoiding tax obligations against the risk of detection and the severity of penalties. This approach draws on Becker's traditional economic theory of crime, which assumes that individuals make rational decisions by analysing potential gains and losses. Servátka (2007) adds that the degree of tax burden is also an important factor; higher taxes may increase the motivation for risky behaviour.

However, modern approaches highlight that economic rationality is not the only determining factor. Behavioural economics and psychology point to the importance of emotional, social, and moral aspects of decision-making. Coricelli et al. (2021) show that tax behaviour is often shaped by feelings of guilt, shame, or fear of reputational loss. Chmelová (2014) emphasises that individuals also make non-rational decisions influenced by heuristics and social norms. This means that tax evasion is often the result of a combination of rational calculation and emotional or group-based behaviour.

Social factors play an especially important role in post-socialist countries. Pauličková (2005) notes that societal tolerance towards non-payment of taxes and deeply rooted distrust in the state create an environment in which tax avoidance is perceived as an acceptable strategy. Jelenčová (2013) adds that the quality of public institutions is crucial; the lower the enforceability of law, the higher the likelihood of tax evasion.

From the perspective of public finance and legislation, an essential factor is the framework created by the tax administration. Burák (2016) points out that unclear laws, frequent legislative changes, and weak control mechanisms create space for tax evasion. According to Burák and Orihel (2011), internal corporate processes also play an important role - insufficient control, weak risk management, and a lack of ethical standards can enable intentional circumvention of tax regulations. The OECD (2010) stresses that effective tax administration must combine preventive, punitive, and informational tools.

International organisations, such as the OECD and the European Commission, regularly publish recommendations for strengthening tax discipline, emphasising modern tools such as digitalisation of tax administration, the use of big data analytics, and automatic exchange of information between states. These measures significantly influence the ability to detect sophisticated tax evasion mechanisms, such as carousel fraud, profit shifting, or the misuse of tax havens.

In terms of typology, authors divide tax evasion mechanisms into several categories. Faltová (2018) distinguishes between simple forms, such as undeclared income or fictitious expenses, and more complex, organised schemes requiring a high degree of

coordination. Pauličková (2005) highlights the importance of transnational tax haven structures and transfer pricing. Burák (2002) notes that legal tax optimisation can represent a boundary between lawful and unlawful behaviour, which often complicates the interpretation and sanctioning of tax practices.

Contemporary approaches therefore view tax evasion as a phenomenon with a complex cause-and-effect structure that includes economic incentives, legislative conditions, socio-psychological motives, and institutional factors. Špalek (2011) adds that an important aspect is public goods theory - willingness to pay taxes depends on how taxpayers perceive the quality of public services and the value they receive from the state.

Preventive tools also deserve significant attention, as described by Sabayová (2020). According to her, modern strategies for reducing tax evasion include behavioural interventions, improved communication with taxpayers, personalised reminders, digital platforms, and the promotion of positive tax morale. Such approaches are often more effective than traditional repressive tools based on audits and sanctions.

Theoretical foundations thus demonstrate that the issue of tax evasion is inseparably linked to the complexity of the economic and societal environment. Various scientific approaches offer different perspectives, yet collectively they emphasise the need for a multidisciplinary framework that encompasses economic, legal, psychological, and institutional aspects. On this basis, it is possible to effectively analyse the factors and mechanisms behind tax evasion and propose adequate measures for their reduction.

3. Methodology

The methodological approach employed in this study is based on the need to comprehensively analyse the performance of the tax system of the Slovak Republic within the context of the changing conditions of the European economic environment and in comparison with the other Visegrad Group countries. The aim of the research is to identify key trends in the development of tax revenues, assess the structure of the tax mix, and evaluate the efficiency of tax collection, particularly in the case of value-added tax, which represents a significant source of public revenue. The chosen research design is grounded in the quantitative analysis of secondary data and combines descriptive, comparative, and exploratory analytical methods. This approach makes it possible to capture macroeconomic linkages between individual tax systems as well as to identify differences in their long-term development.

Data collection was carried out exclusively from secondary sources, including international statistical databases (Eurostat, OECD Revenue Statistics), national budgetary and tax reports of the ministries of finance of the V4 countries, and the European Commission's annual VAT Gap Reports. These sources provide consistent and comparable data on the structure of tax revenues, their share in GDP, and the development of tax collection efficiency. Given the aim of the research, data from the

past ten to fifteen years were analysed, enabling the identification of both current tendencies and long-term stability within tax systems in the region.

The primary method used is descriptive analysis, which serves to characterize the structural features of individual tax systems and their changes over time. This analysis focuses particularly on differences in the composition of direct and indirect taxes, the share of taxes in public revenues, and the dynamics of the tax mix. Comparative analysis subsequently allows for an evaluation of the Slovak Republic in relation to the other V4 countries and for the identification of specific challenges or distinctions within the Slovak tax system. Special emphasis is placed on comparing the development of the VAT gap, which represents one of the most important indicators of tax administration efficiency and the level of tax compliance.

Exploratory trend analysis complements the preceding methods by assessing the long-term direction of tax policies and identifying structural shifts in the behavior of individual tax revenues. Particular attention is given to the development of VAT revenue, corporate income tax, personal income tax, and their elasticity in relation to economic growth. To ensure analytical comprehensiveness, qualitative information on legislative changes with potential impacts on tax system performance was also incorporated into the assessment.

4. Results

The results of the analysis point to several significant findings regarding the development, structure, and efficiency of the tax system of the Slovak Republic within the changing European environment and in comparison with the remaining V4 countries. The evidence suggests that although Slovakia has achieved a degree of stability in tax revenue generation, its tax system continues to exhibit structural weaknesses that limit its long-term performance.

A key result concerns the efficiency of VAT collection, which remains a critical indicator of administrative capacity and tax discipline. Slovakia demonstrates a gradual improvement in reducing the VAT gap over the analyzed period. Despite this progress, it still performs only moderately in comparison with the Czech Republic, which consistently achieves the most favorable outcomes within the V4. The results further show that Slovakia's improvements in VAT collection correlate strongly with the implementation of digital control mechanisms, increased automation in tax administration, and targeted anti-fraud initiatives. However, the pace of improvement remains slower than in some neighboring countries, suggesting that additional reforms, particularly in risk analysis, audit strategy, and cross-border cooperation - could further enhance collection efficiency.

Another important finding involves the overall tax burden and revenue capacity. Slovakia records the lowest tax-to-GDP ratio among the V4 countries, which underscores its relatively narrow revenue base. While this may be perceived as advantageous from a competitiveness perspective, it simultaneously constrains the

government's ability to finance public services and respond to fiscal pressures. The comparative analysis indicates that countries with a more diversified tax structure, such as the Czech Republic, achieve greater stability in revenue generation and exhibit stronger resilience during economic fluctuations. This is particularly relevant in the context of the European economic environment, where demographic changes, technological transformation, and crisis-related fiscal needs require adaptable and sustainable revenue frameworks.

The findings further highlight the imbalanced composition of the Slovak tax mix, characterized by a disproportionately high reliance on indirect taxes, especially VAT. This structural feature increases the sensitivity of public revenues to consumption cycles and contributes to the relatively regressive nature of the tax system. In contrast, countries like the Czech Republic maintain a better balance between direct and indirect taxation, while Hungary relies even more heavily on consumption-based taxes than Slovakia. This comparison suggests that Slovakia's tax structure reflects a long-standing policy preference for low direct taxation; however, such an approach reduces the redistributive potential of the fiscal system and limits options for tax base diversification.

A cross-country comparison reveals that the V4 group is far from homogeneous in terms of tax system design and performance. Poland shows the highest volatility in VAT collection efficiency, reflecting ongoing structural reforms. Hungary demonstrates high revenue intensity but relies heavily on indirect taxation and non-standard tax instruments. Slovakia occupies a middle position, neither the strongest nor the weakest performer, but its progress appears more incremental than transformative.

Overall, the results indicate that the Slovak tax system, while functional and relatively stable, lacks several features associated with high-performing tax systems in the European context. These include greater tax base diversification, stronger direct tax revenue mobilization, more consistent enforcement mechanisms, and higher administrative efficiency. The findings therefore highlight a clear potential for reform, especially in strengthening tax compliance, revisiting the balance between direct and indirect taxes, and enhancing administrative digitalization.

Table 1. VAT Gap Development in V4 Countries (source: European Commission, 2021)

Year	Slovakia	Czech Republic	Poland	Hungary
2010	29%	20%	25%	23%
2011	28%	18%	27%	24%
2012	27%	16%	30%	25%
2013	26%	15%	32%	27%
2014	24%	14%	28%	28%
2015	23%	13%	25%	29%
2016	22%	12%	22%	27%

2017	21%	11%	20%	26%
2018	20%	10%	18%	24%
2019	19%	9%	16%	23%
2020	17%	8%	14%	22%

Table 2. Tax Revenues as a Percentage of GDP in V4 Countries (source: OECD, 2020; Eurostat, 2021)

Year	Slovakia	Czech Republic	Poland	Hungary
2010	28.1%	33.8%	30.2%	38.0%
2012	28.5%	34.2%	31.0%	38.5%
2014	28.9%	34.6%	31.6%	39.1%
2016	29.2%	34.9%	32.0%	39.5%
2018	29.5%	35.1%	32.3%	39.8%
2020	30.0%	36.0%	33.1%	40.2%

Slovakia consistently records the lowest tax-to-GDP ratio among V4, indicating a lighter taxation burden and a higher reliance on indirect taxes. Hungary maintains the highest values, reflecting strong revenue from consumption taxes and social contributions.

Table 3. Structure of the Tax Mix – Share of Direct and Indirect Taxes (source: OECD, 2021; European Commission, 2020)

Country	Direct Taxes	Indirect Taxes	Social Contributions
Slovakia	22%	45%	33%
Czech Republic	25%	38%	37%
Poland	23%	41%	36%
Hungary	19%	52%	29%

Slovakia, similar to Hungary, is highly dependent on indirect taxation, especially VAT. The Czech Republic demonstrates a more balanced system with strong social contributions.

5. Conclusion

The study concludes that the tax system of the Slovak Republic is undergoing gradual, yet limited modernisation, and its performance within the V4 region is stable but not strongly competitive. Slovakia has achieved measurable progress in reducing

the VAT gap and strengthening tax administration tools; however, structural constraints continue to limit the system's ability to generate sufficient and stable revenue.

A fundamental challenge remains the imbalanced tax mix, characterised by an excessive dependence on indirect taxes. While administratively convenient, this model is less sustainable in the long run and increases vulnerability to external shocks. Similarly, Slovakia's low tax-to-GDP ratio may support short-term economic growth, but it restricts the capacity of the state to finance strategic investments and social needs.

Evidence from the V4 comparison shows that countries with more diversified tax structures and more active reform agendas - particularly the Czech Republic - achieve higher efficiency and greater revenue stability. Based on these findings, Slovakia has significant room to improve its tax system in the following areas:

- Enhancing tax collection through digitalisation, automation, and data analytics,
- Diversifying the tax mix by strengthening the role of direct taxation,
- Improving tax compliance through risk-based control models and modern enforcement tools,
- Increasing transparency, predictability, and long-term consistency of tax policy.

Shifting European economic conditions, rising public expenditure pressures, and the need for long-term fiscal sustainability underscore the importance of continued reforms of the Slovak tax system. The findings of this study highlight key areas for policy attention that could contribute to improving the system's efficiency and strengthening the competitiveness of the Slovak Republic within both the V4 region and the broader European Union.

6. Discussion

The results of the analysis confirm that the tax system of the Slovak Republic operates within a dynamically changing European economic environment. However, its adaptive capacity and overall performance remain moderate when compared with the other V4 countries. The discussion highlights that, although Slovakia has achieved gradual improvements in areas such as VAT collection efficiency and the digitalisation of tax administration, several structural weaknesses persist.

A central finding concerns Slovakia's long-standing high reliance on indirect taxation, particularly value-added tax. While this model is administratively efficient and imposes relatively low burdens on businesses, it simultaneously limits the redistributive function of the tax system, increases its regressivity, and reduces revenue stability during economic fluctuations. In comparison, the Czech Republic

demonstrates a more diversified tax structure with a stronger contribution from direct taxes and social contributions, making its revenue system more resilient. The Slovak tax model, by contrast, remains sensitive to consumption cycles and external economic shocks.

The discussion also emphasizes the importance of VAT gap development as an indicator of tax administration effectiveness. Although Slovakia has succeeded in gradually reducing the VAT gap, its progress still lags behind that of the Czech Republic, which consistently achieves the strongest results in the region. Cross-country differences appear to stem from the extent of administrative digitalization, the sophistication of data analytics, the capacity of tax authorities and differences in enforcement intensity. These results suggest that Slovakia has further potential to enhance tax collection efficiency, particularly through deeper technological upgrades and advanced risk-based control mechanisms.

Another key finding relates to Slovakia's low overall tax burden, which remains the lowest within the V4. While this may support competitiveness and investment attractiveness, it concurrently restricts the state's ability to finance essential public services and invest in long-term priorities such as healthcare, infrastructure and the green transition. The comparison with other V4 countries indicates that higher and more diversified revenue levels correspond with more robust public services and increased fiscal stability.

The analysis further indicates that the Slovak tax system shows limited flexibility in responding to economic changes. While some V4 members, such as Poland, have implemented more dynamic reforms, Slovakia's adjustments tend to be incremental and conservative. As a result, Slovakia's progress, though positive, often positions the country in the middle of regional rankings rather than among the frontrunners.

Overall, the discussion demonstrates that the Slovak tax system is functional and stable but does not yet reflect the characteristics of a high-performing tax regime. Identified weaknesses in the tax mix, administrative performance and revenue diversification point to the need for targeted reforms to strengthen the system's sustainability and competitiveness within the evolving European fiscal landscape.

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Evaluating Corruption, Money Laundering, Bribery Risk and Tax Compliance in Slovakia through International Indices

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Abstract

The paper evaluates corruption, money laundering risks, bribery exposure, and tax compliance in Slovakia through selected international indices and assessment frameworks. The study investigates long-term trends in the Corruption Perceptions Index (CPI), Basel Anti-Money Laundering index and TRACE Bribery Risk Matrix to assess the country's integrity environment and vulnerability to financial crime. A time-series analysis of secondary data over past decade provides insight into changes in institutional effectiveness, regulatory performance, and transparency standards. The results reveal fluctuating progress, with periods of improvement followed by renewed weaknesses in corruption control, anti-money laundering capacity, and tax enforcement. The study underscores the importance of continued policy commitment, institutional strengthening, and effective enforcement to support sustainable improvements in transparency and economic governance.

Keywords: Tax evasion, Corruption, Financial crime, Money Laundering

JEL Classification: H26

1. Introduction

The issue of country risk assessment in the fight against money laundering and terrorist financing has become increasingly urgent in the context of global financial integration, the digitalization of financial services, and geopolitical instability. Despite decades of developing international standards, money laundering and terrorist financing continue to undermine financial stability, weaken governance, and facilitate organized crime. Numerous studies highlight how weak public administration, corruption risks, insufficient regulation, and institutional gaps increase the likelihood

of money laundering and terrorist financing (Yarovenko et al., 2024; Slavhorodska, 2025; Pulungan et al., 2024).

In recent years, both research and policy agendas have increasingly focused on country risk assessment frameworks, which provide deeper insights into the structural factors shaping the vulnerability of economies to money laundering and corruption. These systems serve as tools for policymakers, regulatory bodies, and financial institutions to identify the highest-risk areas and implement appropriate preventive measures. Effective risk assessment requires a combination of quantitative indicators (indexes) and qualitative evaluation of a country's legislative and institutional environment. In this context, global indexes such as the Anti-Money Laundering (AML) Index, the Corruption Perceptions Index (CPI), and the TRACE Bribery Risk Matrix play a crucial role by enabling cross-country comparisons across multiple dimensions.

Money laundering is regarded as one of the main forms of economic crime (Hilal et al., 2022). According to the Cambridge University Dictionary, it is a criminal activity that involves transferring illegally obtained financial resources through banks and other institutions with the aim of creating the impression that they originate from legitimate sources.

This financial crime is particularly significant in the context of globalization and an increasingly interconnected world economy. The definition itself portrays money laundering as a process of altering or disguising the origin of unlawfully acquired financial assets—most commonly derived from drug trafficking, fraud, or tax evasion—to give such funds a legal appearance (Oliva, 2022). According to Eulaiwi et al. (2024), this process involves complex layers of transactions and financial arrangements carried out across multiple jurisdictions, which complicates oversight and detection.

The spread of corruption, the shadow economy, and organized crime creates an enabling environment for money laundering. The World Bank defines corruption as the illegal use of public resources for personal gain. According to Chang (2021), corruption constitutes the abuse of entrusted power for personal benefit. Such behavior undermines democratic governance, weakens the rule of law, and negatively affects economic development by discouraging foreign investment and slowing economic growth (Alam et al., 2023).

As noted by Wyatt et al. (2018), corruption can take various forms—the most common being bribery, embezzlement, money laundering, and tax evasion. Corruption is therefore often interconnected with other economic crimes, creating a mutually reinforcing system.

In the field of international trade, corruption frequently manifests as bribery—an exchange between government officials who demand bribes and business entities that provide them in return for access to government contracts, licenses, or regulatory advantages. Government officials may demand bribes as a precondition for providing services or may manipulate public procurement processes for their own benefit or that

of their allies. Businesses, on the other hand, may offer bribes to overcome administrative barriers or obtain competitive advantages (Dávid-Barrett, 2019).

As Dávid-Barrett (2019) emphasizes, both parties benefit from such transactions at least in the short term—the public official financially and the business entity commercially. Ultimately, however, others bear the costs: disadvantaged competitors and the broader public, who face declining quality of public services, slower economic growth, and erosion of democratic values and the rule of law.

2. Methods

The aim of the paper is to examine Slovakia's development in the areas of corruption, money laundering risk, and business bribery over the past decade. The analysis is based on secondary data obtained from three global indexes that provide relevant information on the level of integrity and risk within the business environment. The data from these indexes were processed into time series for the period 2015–2024 in order to capture the development of the individual indicators and to assess Slovakia's position in international rankings.

Line charts and combined charts were used to present the results—where the columns in the combined charts represent the index values and the line curve shows the country's ranking. This approach allows for a comprehensive comparison of both the absolute level of risk or corruption and Slovakia's relative position in an international context. A description of the selected indexes is provided in the following section.

CPI – Corruption Perceptions Index

The most commonly used index in the context of assessing corruption at the macro level is the Corruption Perceptions Index (CPI), which has been calculated since 1995 by the international organization Transparency International based on 13 studies conducted by reputable international institutions and research centers. The CPI makes it possible to evaluate countries on a scale from 0 points (corruption effectively replaces the state) to 100 points (corruption is almost non-existent), meaning that the higher the index, the better a country's position in the ranking. The CPI reflects the views of representatives of the business sector, investors, market researchers, etc., as well as the private sector's perception of the extent of corruption in the public sector of the economy. A higher score of one country compared to another does not necessarily mean that the first country has less corruption than the second; rather, it means that the first is perceived as less corrupt than the other (Transparency International, 2023; Dluhopolsky et al., 2024).

AML – Base Anti-Money Laundering Index

An interesting indicator for assessing a country's financial integrity is the Anti-Money Laundering Index (Basel Anti-Money Laundering Index, AML Index). This index

is used to measure and evaluate the risks associated with money laundering and terrorist financing across countries worldwide. The AML Index assesses the level of corruption and criminal activity that may contribute to these illegal practices, while also evaluating the risks of their emergence and development (Dluhopolskyi et al., 2024).

The index includes a wide range of risks, each with a different weight. According to the Basel Institute on Governance (2023), these components and their weights are as follows:

- quality of the anti-money laundering and counter-terrorist financing system (65%),
- corruption and bribery risks (10%),
- financial transparency and standards (10%),
- overall transparency and accountability (5%),
- political and legal risks (10%).

The assessment is carried out on a scale from 0 to 10, where 0 represents minimal risk and the best country performance, while 10 indicates maximum risk. This means that the lower the index a country achieves, the more favorable its indicators are in the area of combating money laundering and terrorist financing.

TRACE Bribery Risk Matrix

The TRACE Bribery Risk Matrix (TRACE Matrix) is an internationally recognized indicator that measures the risk of bribery in the business environment across 194 countries and territories. The index was originally developed in 2014 in collaboration with RAND Corporation and is updated annually by TRACE International (TRACE International, 2025).

A country's overall risk score is a combined and weighted score of four areas:

1. Business interactions with the government;
2. Deterrence of bribery and enforcement;
3. Government and public service transparency;
4. Oversight capacity of civil society, including the role of the media.

3. Results and discussion

To analyze the current state of corruption in Slovakia, we use the CPI (Corruption Perceptions Index). This index assesses the perceived level of corruption in a country on a scale from 0 to 100, where a value of 100 represents the lowest level of corruption and a value of 0 the highest level of corruption.

In Graph 1, we can observe the development of corruption in Slovakia based on the CPI index values. The graph shows that from 2015 there was a gradual improvement in the corruption situation; however, in 2017 a deterioration occurred. According to Lendvorský et al. (2022), the government period of 2016–2020 was the most challenging for Slovak society in terms of mapping corruption. Many anti-corruption

measures—such as preventing conflicts of interest in the allocation of state subsidies, material responsibility in the management of public resources, or measures related to reporting antisocial conduct—were implemented insufficiently or not applied in practice at all (Beblavý and Sičáková-Beblavá, 2014). These factors, together with the political situation of the period, contributed to an increase in the level of corruption.

From 2021 to the present, a significant improvement in the corruption situation in Slovakia can be observed, which Lendvorský et al. (2022) attribute to a change in government and its different approach to fighting corruption. In 2023, Slovakia achieved 54 points out of 100, indicating a positive development in this indicator.

However, in the most recent period observed, namely in 2024, the value of the index decreased again to 49 points, which is the lowest value in the monitored period. This decline indicates a worsening perception of corruption and signals the need to reassess current anti-corruption policies.

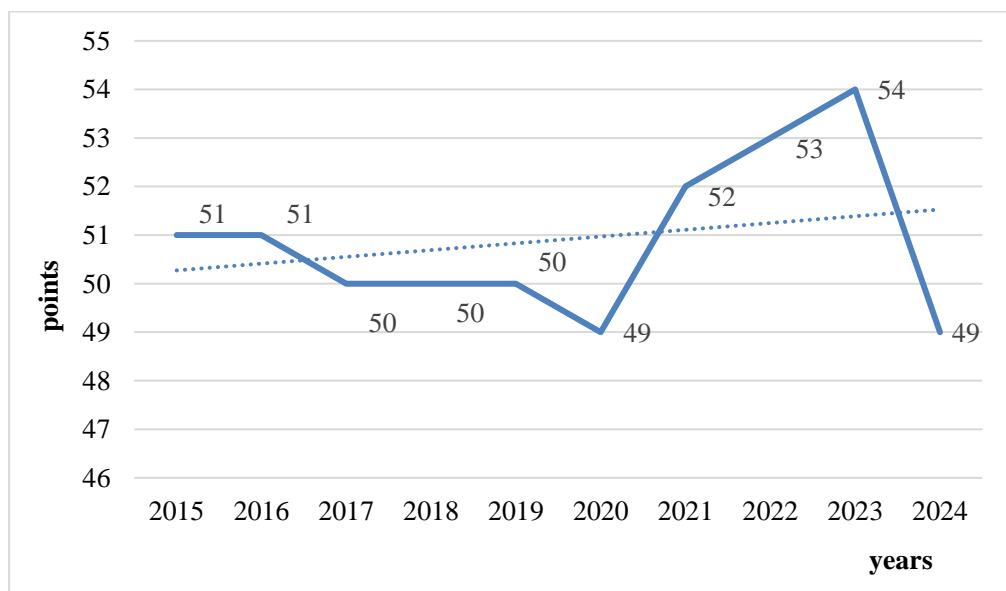


Figure 1. Development of Corruption in Slovakia During the Years 2012-2024 (source: own processing based on CPI index data)

According to Jančíková and Pásztorová (2018), although the legislation of the Slovak Republic in the area of combating money laundering complies with international and European standards, there are still visible shortcomings in practice. These deficiencies are also reflected in Slovakia's assessment according to the AML Index, which is rated on a scale from 0 to 7, where 0 represents the lowest risk of money laundering and 7 the highest.

Slovakia's development based on the Anti-Money Laundering Index is illustrated in Graph 2. In the first year analyzed (2015), Slovakia achieved a score of 4.66 and ranked

126th. In the following year, 2016, the score increased slightly to 4.88, which contributed to Slovakia moving to 116th place in the ranking. However, it is important to emphasize that according to the AML Index methodology, the higher a country ranks, the lower its assumed risk of money laundering and related financial crimes. Conversely, a lower ranking indicates higher risk and thus a less favorable position in the international assessment.

The period from 2017 to 2019 brought only minor changes. In 2017, the score decreased slightly to 4.78 and Slovakia moved to 120th place. In 2018 and 2019, the score gradually improved to 4.13 and 4.04, with Slovakia ranking 110th and 109th. This development indicates an improvement in Slovakia's score; however, its relative position compared to other countries did not improve significantly, as many states progressed at a more substantial pace.

In 2020, the score worsened to 4.95 and Slovakia returned to 120th place. The period 2021–2023 brought another slight improvement, as the score decreased from 4.37 in 2021 to 4.22 in 2023. Despite this, Slovakia's overall placement in the global ranking shifted from 90th place (2021) to 123rd place (2023), suggesting that other countries progressed less significantly, resulting in Slovakia's improvement in the international rating.

In the AML Index for 2024, which evaluated 164 countries worldwide, the Slovak Republic ranked 126th with a score of 4.39. This result places Slovakia in the lower half of the ranking, meaning among countries with a moderately increased risk of money laundering. For comparison, the poorest-rated countries that year were Myanmar (8.17 points) and Haiti (7.92). These countries belong to those with the highest risk, reflecting their long-term problems with weak institutions, corruption, and low levels of financial transparency.

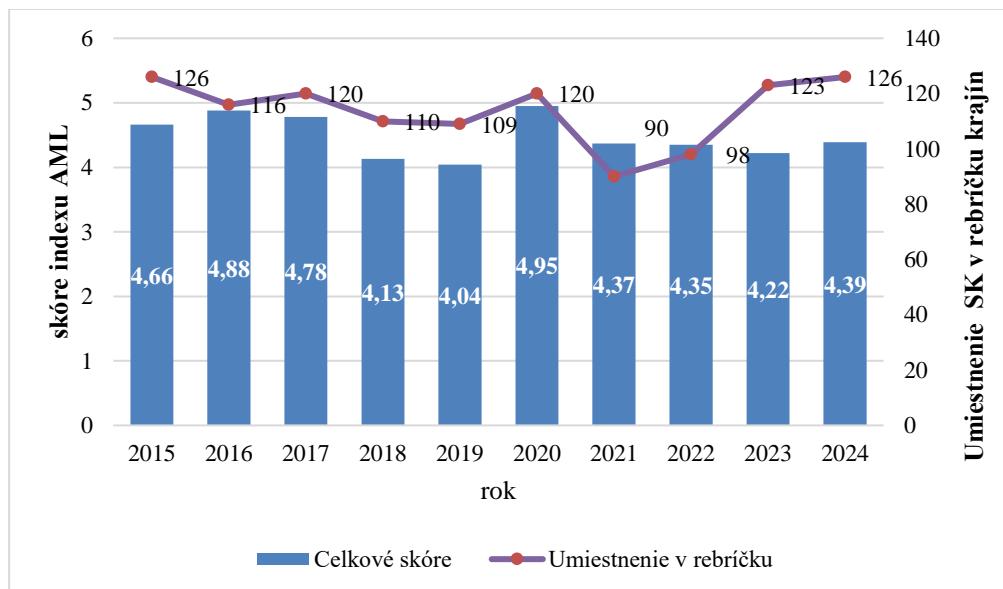


Figure 2. Development of Money Laundering in the Slovak Republic According to the AML Index (source: own processing based on AML index data)

On the other hand, the best-rated countries—such as Finland (3.07), Sweden (3.45), and Denmark (3.50)—show the lowest risk of money laundering, which places them at the top of the ranking (162nd–164th positions). Compared to them, Slovakia still faces persistent challenges in the effectiveness of supervision, implementation of legislative measures, and interdepartmental cooperation in combating money laundering.

According to data from the TRACE Bribery Risk Matrix, it is possible to observe the development of bribery risk in business in Slovakia from 2016 to 2024. The values of the overall risk score fluctuated between 33 and 43 points, with higher scores indicating a higher risk of bribery.

In 2016, Slovakia reached the highest score of the monitored period, 43 points, and ranked 37th among the evaluated countries. In the following years, the score slightly decreased and fluctuated — in 2017 it reached 33 points, in 2018 it increased to 38 points, and in 2019 it rose to 40 points.

In 2020, Slovakia achieved its highest ranking placement among other countries, namely 52nd place, even though the risk score decreased compared to the previous year. In the period from 2021 to 2024, the score ranged between 35 and 33 points, and in the most recent year it returned to the minimum value previously recorded in 2017.



Figure 3. Development of Bribery Risk in Business in the Slovak Republic According to the TRACE Index (source: own processing based on TRACE index data)

The graph clearly shows that Slovakia experienced a slight decline in bribery risk in recent years, although its position in the international ranking fluctuated depending on risk developments in other countries as well. This trend suggests that although Slovakia is reducing its absolute bribery risk, its relative ranking among countries is changing, and there remains room for improving transparency and oversight of business interactions with the public sector.

4. Conclusion

The analysis of Slovakia's development in the areas of transparency, corruption, money laundering, and business bribery during the period 2015–2024 provides a comprehensive picture of the dynamics of integrity and risk within the business environment.

The country has achieved a positive trend in the perception of corruption and in reducing the risk of money laundering. However, the risk of bribery in the business sector continues to fluctuate, indicating that gaps in ethics and transparency remain in certain areas of business activity.

The results show that progress in these areas is important not only for reducing corruption but also for maintaining the competitiveness and stability of the business environment. The contribution provides an overview of trends and highlights areas where targeted measures are needed, which can help policymakers, entrepreneurs, and the public better understand the risks and opportunities for improvement.

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Surviving under Pressure: Frugal Innovation as a Strategy for Microbusiness Sustainability Amidst Limitations

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Abstract

This study analyze the influence of resource constraints, cost efficiency, and market demand on the sustainability of microbusinesses in Indonesia through frugal innovation, as well as to examine the role of organizational capability as a moderating variable. Using a quantitative approach with a survey method of microbusiness actors in Central Java Province, and the data were analyzed using *Partial Least Squares Structural Equation Modeling* (PLS-SEM). The results show that resource constraints and market demand have a significant positive effect on frugal innovation and the sustainability of microenterprises. Conversely, cost efficiency does not have a significant effect on either frugal innovation or business sustainability. Frugal innovation plays an important role in bridging the influence of resource constraints and market demand on business sustainability, indicating that frugal innovation is an adaptive strategy for microbusinesses facing environmental pressures and capital constraints. In addition, organizational capability strengthens the relationship between frugal innovation and micro-business sustainability, confirming that internal capacity is a key factor in optimizing efficient and sustainable innovation. Overall, the findings of this study confirm that frugal innovation and organizational capabilities are the main drivers of micro-business sustainability amid resource constraints, while cost efficiency has not yet shown a significant role in this context.

Keywords: frugal innovation, microbusinesses, resource constraints, cost efficiency, market demand, organizational capabilities, business sustainability.

JEL Classification: L26, O31, Q01, M21, and L21.

1. Background

Microenterprises play an important role in the Indonesian economy, particularly in terms of job creation, income distribution, and poverty reduction. Based on data released by the Central Statistics Agency (2024), microenterprises have successfully

absorbed 52.08% of the national workforce. This demonstrates the ability of microenterprises to support the economy of the lower class in various regions. Microbusinesses are highly vulnerable to changes in the business environment, economic crises, and market pressures, especially given the limited resources they have. The limitations of microbusinesses can be seen from various perspectives, such as finance, labor, and access to technology, which make it difficult for microbusinesses to grow (Keupp and Gassmann 2013) .

Frugal innovation emerged among microbusinesses as an unintended response to limitations. This concept is known as *frugal innovation*, which is the spirit of producing simple yet effective solutions without incurring large costs (Radjou and Euchner 2016) . Simula et al. (2015) explain frugal innovation as a concept that arises from limitations such as finance, knowledge, raw materials, technology, and others with the aim of meeting the needs of underserved communities. Marchi et al. (2022) explain that frugal innovation has a broad impact on business sustainability, taking into account social, environmental, and economic aspects. The concept of frugal innovation in microenterprises acts as a bridge between internal limitations and evolving external needs (Felipe et al. 2020) .

Frugal innovation practices are widely applied by micro-entrepreneurs in Indonesia, such as modifying makeshift equipment, utilizing raw material leftovers, and serving local markets by adjusting product prices for local markets. These practices are often found in various types of businesses such as handicrafts, small workshops, home-based tailors, small-scale agriculture and livestock farming, and are generally carried out intuitively and are not documented systematically. Resource-based theory (RBV) emphasizes competitive advantage in business competition, depending on the ability to manage valuable, scarce, inimitable, and non-substitutable resources (Wernerfelt, 1984) . This argument develops the concept of *resource position barriers*, similar to *entry barriers*, where companies that have certain resources can maintain their advantage by preventing competitors from obtaining similar resources. Through the concept of *resource position barrier*, Barney (1991) developed RBV theory into a more detailed modern business strategy, including introducing VRIO theory and expanding the concept of RBV. This theory is not sufficient to explain how small organizations can survive and thrive. This situation has led to frugal innovation becoming an important tool that turns limitations into competitive strengths. To gain a deeper understanding of this issue, the theory of dynamic capabilities (DCT) must be included (Teece et al., 1997) . The use of DCT helps explain the role of business actors in developing learning capacity, adjusting their strategies, and exploring market opportunities flexibly (Teece et al., 1997) .

Previous studies have yielded inconsistent results regarding the influence of resource constraints, cost efficiency, and market demand on innovation and business sustainability. Some studies emphasize that cost efficiency is a driver of innovation, while other studies show the opposite results. The addition of the variable of organizational capability as a moderating variable in the relationship between frugal innovation and sustainability is still minimal and empirically inconsistent (Sengura, Mu, and Busumabu 2024; Abbas et al. 2025) .

Based on these gaps, this study seeks to analyze the influence of resource constraints, cost efficiency, and market demand on the sustainability of microenterprises through the application of frugal innovation, as well as to examine the role of organizational capability as a moderating variable. This approach is expected to contribute theoretically to the development of RBV and DCT integration in the context of microenterprises in developing countries, as well as provide practical implications for entrepreneurs to manage resource constraints adaptively.

Research Questions

1. Do resource constraints, cost efficiency, and market demand affect the sustainability of microenterprises through the application of frugal innovation?
2. Does frugal innovation mediate the influence of resource constraints, cost efficiency, and market demand on the sustainability of microenterprises in Indonesia?
3. Does organizational capability moderate the influence of frugal innovation on the sustainability of microenterprises in Indonesia?

2. Literature Review

This study integrates the *Resource-Based View* (RBV) and *Dynamic Capability Theory* (DCT) with the aim of explaining the sustainability of microenterprises amid resource constraints. The RBV theory emphasizes the importance of managing valuable and difficult-to-imitate internal resources as the basis for competitive advantage (Wernerfelt, 1984). However, the limitations faced by microenterprises, such as capital, technology, and managerial capacity, provide a different perspective for DCT, which emphasizes the organization's ability to adapt to environmental changes, innovate, and reorganize resources (Teece et al., 1997). The integration of these two theories confirms that sustainability is not only determined by resource ownership but also by the adaptive capacity of organizations to manage them efficiently and creatively.

The literature shows that resource constraints, cost efficiency, and market demand are the main factors affecting the sustainability of microenterprises. Resource constraints are defined as a lack of financial resources, technology, and skilled labor that hinders innovation (Keupp and Gassmann 2013). Cost efficiency describes a company's ability to control expenses without compromising quality (Niță and Ștefă 2014), while market demand reflects external pressures that drive companies to tailor their products and strategies to customer needs (Küçüksayaç 2015). These three factors encourage micro-enterprises to use frugal innovation that utilizes limited resources to produce simple, cost-effective, yet high-value solutions (Bhatti and Ventresca, 2012; Kun, 2022). Frugal innovation acts as an adaptive strategy that bridges the influence of internal and external factors on the sustainability of micro-enterprises in Indonesia.

Business sustainability is defined as an organization's ability to maintain economic, social, and environmental performance in the long term (Rezaee 2016). Meanwhile, organizational capability is described as the ability to adapt, collaborate, and change,

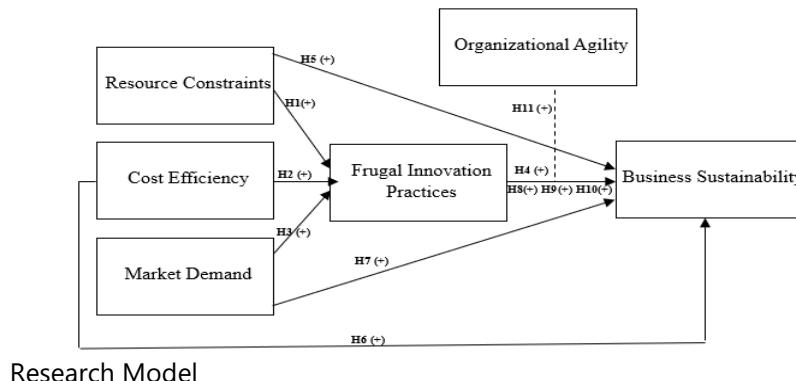
which strengthens the role of frugal innovation and business sustainability(Omoush et al. 2024; Perdana and Syah 2023) , so that the limitations experienced by microbusinesses are not seen as obstacles but rather as drivers for the implementation of frugal innovation. With the support of dynamic organizational capabilities, this can become a source of sustainable competitive advantage for microbusinesses in Indonesia.

3. Methodology

This study uses a quantitative approach with a survey method to examine the relationship between resource constraints, cost efficiency, market demand, the application of frugal innovation, organizational capabilities, and business sustainability. This approach was chosen because it can explain the direct, indirect, and interactive effects between variables simultaneously. Data analysis was performed using Partial Least Squares-based Structural Equation Modeling (PLS-SEM) with the help of SmartPLS software, as it is suitable for predictive models involving latent constructs.

The population in this study was micro-enterprises operating in Central Java Province, Indonesia, because they represented characteristics relevant to frugal innovation, resource constraints, cost efficiency, and market demand dynamics in micro-enterprises, which were the core of this study. Reviewing data from(2024) , Central Java Province ranks second with 19.17% of the total number of microbusinesses in Indonesia, after East Java Province with 21.72%. The data released by Central Statistics Agency (2024) regarding the number of microbusinesses in Indonesia indirectly represents the face of Indonesia in this study. The sampling technique used purposive sampling with a total of 240 micro business actors, in accordance with the *10 times rule* criteria (Hair et al. 2022) . The sample criteria included: (1) microbusinesses that are actively operating in the region, both formal and informal; (2) facing resource constraints such as capital, labor, and technology; (3) have or are currently implementing simple innovations in products, processes, or services that fall under the category of *frugal innovation*; and (4) are willing to complete the research questionnaire online. Data were collected through a five-point Likert scale questionnaire.

This research instrument was developed based on four indicators validated in prior studies, namely: resource constraints (Keupp and Gassmann 2013) , cost efficiency (Niță and Ștefăea 2014) , market demand (Küçüksayraç 2015), frugal innovation and business sustainability (Kun 2022) , and organizational capability (Omoush et al. 2024)). Validity and reliability tests were conducted through *an outer model* using *factor loading* values, *Composite Reliability* ($CR \geq 0.7$), and *Average Variance Extracted* ($AVE \geq 0.5$). Hypothesis testing was conducted through *bootstrapping* 5,000 resampling with a significance level of 5%, according to the criteria (Hair et al. 2022) .



Research Model

Source: Author's processed data (2025)

The research model was developed based on the integration of *Resource-Based View* (RBV) and *Dynamic Capability Theory* (DCT). This research model positions micro-enterprises with limited resources, cost efficiency pressures, and market demand dynamics as the main challenges that require an innovative approach. Frugal innovation is positioned as a mediating mechanism that bridges these external pressures with business sustainability, through the creation of cost-effective and high-value solutions from limitations. Meanwhile, organizational capability acts as a moderating variable that strengthens the effectiveness of frugal innovation in creating sustainability, because only organizations with adaptive capabilities are able to manage frugal innovation optimally. This model is not only empirically predictive but also provides a theoretical contribution in explaining the ability of micro-enterprises to achieve sustainability through the integration of efficiency, adaptation, and change processes using frugal innovation.

4. Results and Discussion

Data

Data collection in this study was conducted through an online questionnaire distributed using various social media platforms, such as *Instagram*, *Facebook*, *Telegram*, and through micro-business groups on the *WhatsApp* application. In addition, the questionnaire distribution process also received support from classmates, the PK LPDP network, and fellow lecturers from the alma mater who are currently pursuing doctoral studies in Central Java Province. The data collection process was carried out in two stages. The first stage was piloting, which began on June 16, 2025. The second stage was carried out on August 10, 2025, with a broader

coverage. In total, 696 respondents returned the questionnaire. From this number, data tabulation and filtering were carried out. A total of 183 respondents were excluded because their business locations were not in Central Java Province (Yogyakarta and Bandung), and there were 2 respondents who did not complete their age data.

Thus, the number of respondents that met the research criteria was 240 respondents, in accordance with the minimum sample size requirements as recommended by Hair et al. (2022). However, to maintain data quality and reduce potential uncertainty in the analysis, the researcher added nine respondents who also met the criteria, bringing the total data used in this study to 249 microbusiness respondents. The researcher found that there was diversity in the education levels of the microbusiness actors who were respondents in this study. The data obtained in this study were distributed across several districts, such as Magelang District (60 respondents), followed by Boyolali District (47 respondents) and Klaten District (36 respondents). A number of respondents also came from other districts in Central Java, such as Banjarnegara, Demak, Pati, Rembang, Grobogan, Karanganyar, and Temanggung, with smaller numbers. This distribution shows that the research respondents are geographically heterogeneous, although they remain within the scope of Central Java Province. The questionnaire also found that the educational level of micro-business actors in this study was dominated by high school/vocational school graduates (130 people), diploma (D1–D3) graduates (40 people), bachelor's degree (S1) graduates (46 people), junior high school graduates (28 people), elementary school graduates (4 people), and 1 person who did not complete elementary school.

The data shows that the culinary sector dominates with 132 respondents, or half of the total respondents in this study. Apart from the culinary sector, there were 41 businesses in the service sector (such as sewing, laundry, salons, and others), followed by 24 businesses in the trade/food stall/small shop sector, handicrafts, and 11 businesses in the small workshop and vehicle service sector. Meanwhile, businesses in the agriculture, plantation, livestock, and fisheries sectors are only run by a small number of respondents, with only 15 businesses contributing to this study.

Descriptive analysis

Table 1 Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
KSD	249	12,00	17,00	15,0120	1,38390
EB	249	9,00	16,00	14,5261	1,82730
PP	249	12,00	16,00	14,5622	1,61306
FI	249	11,00	18,00	14,6747	1,92254
KB	249	10,00	16,00	14,3534	1,81714
KO	249	12,00	16,00	14,6787	1,50576
Valid N (listwise)	249				

Source: SPSS 29 output for this study

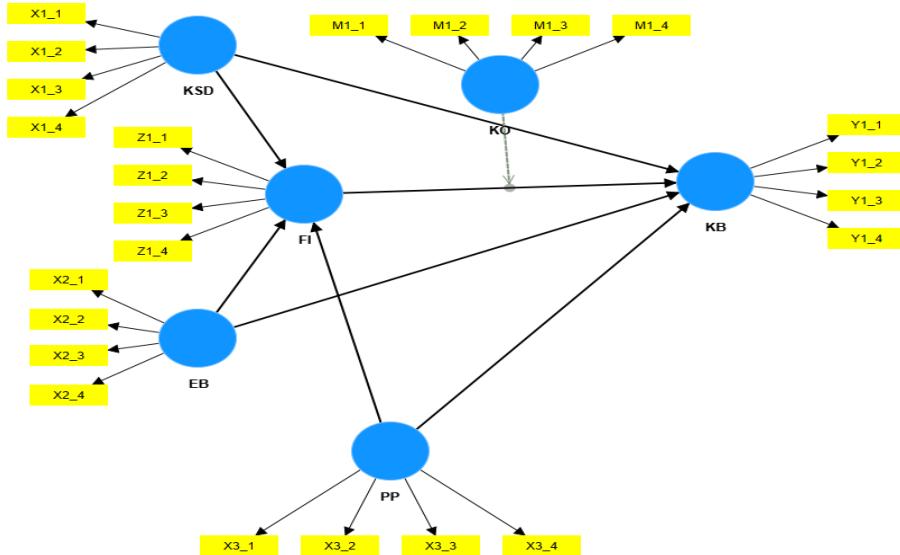
The results of the descriptive statistical analysis in this study found that the resource limitation variable had an average value of 15.01 with a standard deviation of 1.38, indicating that most microbusinesses face limitations in capital, labor, and technology in their operations, although some are able to overcome this through innovative work methods. The cost efficiency variable had an average of 14.52 and a standard deviation of 1.82, illustrating differences in the implementation of cost-saving strategies; some businesses still had difficulty managing their finances, while others had been able to reduce costs through the use of local materials or production based on demand. The market demand variable has an average of 14.56 with a standard deviation of 1.6, indicating that micro-enterprises are generally adaptive to changes in consumer needs, although some are still slow to read market trends.

Furthermore, the frugal innovation variable shows an average of 14.67 with a standard deviation of 1.92, indicating that most microbusinesses have begun implementing frugal innovations relevant to their business fields, such as culinary, crafts, and services. The business sustainability variable has an average of 14.35 and a standard deviation of 1.81, indicating business actors' awareness of maintaining sustainability through adaptive strategies, although some still face capital constraints and market uncertainty. Finally, the organizational capability variable shows an average of 14.67 with a standard deviation of 1.50, indicating that most microbusinesses have fairly good organizational capacity, such as task distribution and simple financial record keeping, although some are still not optimally structured.

5. PLS Model Analysis Results

PLS Path Diagram

Path Diagram



Source: SmartPLS 4 output for this study

Table 2 Outer Loading

ITEM	Latent Variable 1	Latent Variable 2	Latent Variable 3	Latent Variable 4	Latent Variable 5	Latent Variable 6
X1_1	0.787					
X1_2	0.898					
X1_3	0.843					
X1_4	0.860					
X2_1		0.916				
X2_2		0.818				
X2_3		0.757				
X2_4		0.830				
X3_1			0.757			

X3_2	0.868
X3_3	0.909
X3_4	0.709
M1_1	0.756
M1_2	0.778
M1_3	0.733
M1_4	0.892
Y1_1	0.755
Y1_2	0.878
Y1_3	0.759
Y1_4	0.867
Z1_1	0.935
Z1_2	0.679
Z1_3	0.935
Z1_4	0.783

Source: SmartPLs 4 output for this study

The results from 249 microbusiness respondents show that all indicators have outer loading values > 0.5 , meeting the criteria for Convergent Validity (Hair et al. 2022). These results indicate that the indicators have a sufficiently strong correlation with the latent constructs they measure and consistently represent the research variables. No items were eliminated because all met the validity threshold, so the measurement instrument was deemed suitable for use. The cost efficiency indicator (X2.1) showed the highest outer loading value of 0.916, confirming cost control as the most representative aspect in measuring the operational efficiency of micro businesses. Conversely, the organizational capability indicator (Z1_2) had the lowest outer loading value of 0.679, but it was still above the minimum threshold and remained acceptable. The range of outer loadnings for the independent variables was between 0.757 and 0.916, the mediation variables between 0.733 and 0.892, and the moderation variables between 0.679 and 0.935, confirming that all constructs were measured consistently and reliably.

Table 3 Discriminant Validity

	cost efficiency	frugal innovation practices	business sustainability	organizational capability	resource constraints	market demand
cost efficiency	0.832					
frugal innovation	0.851	0.840				
practices						
business sustainability	0.883	0.891	0.817			
organizational capability	0.914	0.888	0.890	0.792		
resource constraints	0.873	0.847	0.880	0.855	0.848	
market demand	0.921	0.881	0.885	0.925	0.864	0.815

Source: SmartPLS 4 output for this study

The results of discriminant validity testing using the Fornell and Larcker (1981) approach show that all constructs in the research model meet the criteria for discriminant validity. The output results show that the square root of the Average Variance Extracted (\sqrt{AVE}) value of each construct is on the diagonal of the table, and its value is greater than the correlation between other constructs. For example, the Cost Efficiency construct has an \sqrt{AVE} of 0.832, which is higher than its correlation with Resource Constraints (0.873) and Market Demand (0.921). Similarly, the Business Sustainability construct has an \sqrt{AVE} of 0.817, which is still greater than its correlation with Frugal Innovation (0.891) and Organizational Capability (0.890). The Frugal Innovation construct also has an \sqrt{AVE} of 0.840, which is above its correlation with other variables, although the difference is relatively small.

These results confirm that each construct in this study is unique and can be clearly distinguished from other constructs. Theoretically, the *resource-based view* Wernerfelt, (1984) explains resources as the weaknesses and strengths of a business

organization and can be defined as assets (tangible and intangible) that are semi-permanently tied to a particular organization and are not easily replaced. For example, resource constraints, market demand, and cost efficiency cannot be equated because each plays a unique role in influencing microenterprise strategy. From the perspective of Dynamic Capabilities Theory Teece et al., (1997), the differences between constructs are also important to emphasize that organizational capabilities are a distinct adaptive capacity, which differs from cost efficiency and market demand pressures.

Thus, the results of the *discriminant validity* test not only meet statistical validity but also confirm the conceptual clarity between variables in the context of microenterprises in Indonesia. This provides a strong basis for subsequent structural analysis, as each construct has been proven to represent unique yet complementary dimensions in explaining the sustainability of microenterprises through frugal innovation.

Table 4 Construct Reliability and Validity

	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
cost efficiency	0.850	0.865	0.900	0.693
business sustainability	0.833	0.848	0.889	0.667
organizational capability	0.801	0.830	0.870	0.627
Resource constraints	0.869	0.877	0.911	0.719
market demand	0.829	0.856	0.887	0.664
Frugal innovation practices	0.856	0.897	0.904	0.705

Source: SmartPLS 4 output for this study

The outer model analysis results show that all indicators for 249 microbusiness respondents in Central Java meet the validity and reliability criteria. The *outer loading* values for all items are above 0.50, with a range of 0.679–0.935, so all indicators are declared valid. The highest indicator was found in cost efficiency (0.916), which reflects cost control as a major aspect of operational efficiency, while the lowest was in organizational capability (0.679), which is still acceptable.

Cronbach's Alpha values (0.70–0.90) and Average Variance Extracted (AVE > 0.50) indicate good internal consistency and convergent validity. The constructs of cost efficiency (AVE = 0.693), frugal innovation (0.705), business sustainability (0.668), and organizational capability (0.652) are all reliable and explain more than half of the variance in their indicators. These results support the *Resource-Based View* (Barney, 1991) and *Dynamic Capabilities Theory* (Teece et al., 1997), which state that efficiency

and adaptive capabilities form the basis of competitive advantage for micro-enterprises.

The *discriminant validity* test using the Fornell-Larcker criteria also shows that the square root of AVE (\sqrt{AVE}) value of each construct is higher than the correlation between variables, indicating that there is no measurement overlap. Thus, all constructs are declared valid, reliable, and conceptually consistent, making them suitable for testing structural models at the *inner model* stage.

Structural Model Analysis (Inner Model)

In structural model analysis, it is necessary to pay attention to the R^2 results, as specified by the , several criteria such as $R^2 > 0.75$ = strong; $0.5-0.75$ = moderate; < 0.25 = weak. In this study, the business sustainability variable has R^2 value of $0.872 > 0.75$ as determined by (Hair, et al. 2022) , so it is considered strong and shows that 87.2% of the variation in business sustainability can be explained by the independent variables used in the study, while the remaining 12.8% is explained by other variables outside the model. Meanwhile, the R^2 value for frugal innovation practices is 0.806, indicating that 80.6% of the variation can be explained by resource constraints, cost efficiency, and market demand, while 19.4% is explained by other variables not included in this study.

The Adjusted R^2 values for business sustainability (0.869) and frugal innovation practices (0.804) are relatively close to their respective R^2 values, so it can be concluded that the model is stable and does not experience a significant decline after adjusting for the number of predictors. Thus, the results of this structural test confirm that the model constructed has strong and stable explanatory power and is able to accurately predict the relationship between variables. These findings support the theoretical relevance of the *Resource-Based View* and *Dynamic Capabilities Theory* in explaining how frugal innovation plays an important role in maintaining the sustainability of microbusinesses through the management of limited resources.

Predictive Relevance Test (Q^2) and Effect Size (f^2)

The results of the predictive relevance (Q^2) test using the blindfolding method show that the business sustainability variable has a Q^2 value of 0.557, while frugal innovation practices have a value of 0.562. A Q^2 value > 0 confirms that this research model has strong predictive power (. Thus, the proposed model is not only theoretically consistent but also has high *explanatory power* and *predictive relevance* for the phenomenon of micro-enterprises in Central Java. Theoretically, these results reinforce the Resource-Based View (RBV) framework, in which the effective utilization of internal resources—through cost efficiency, resource constraint management, and organizational capability strengthening—is empirically proven to explain most of the variation in frugal innovation and business sustainability. Meanwhile, from the perspective of Dynamic Capabilities Theory (DCT), the high R^2 and Q^2 values indicate that the organization's dynamic capabilities, such as the ability to adapt, integrate, and transform resources according to business environment demands.

The analysis results show that the relationship between the cost efficiency variable and frugal innovation practices has an f^2 of 0.007, and the relationship between cost efficiency and business sustainability has an f^2 of 0.001, which explains that cost efficiency does not yet contribute practically to frugal innovation and business sustainability. Another result on the effect of frugal innovation on business sustainability has an f^2 of 0.142, which has a moderate and most dominant effect in the model. The effect of organizational capability on business sustainability ($f^2 = 0.019$) shows a small but relevant effect, while the moderating interaction of organizational capability on the relationship between frugal innovation and business sustainability ($f^2 = 0.251$) shows a strong effect, confirming that organizational capability strengthens the influence of frugal innovation in maintaining micro-business sustainability. Overall, these results indicate that frugal innovation and organizational capability are key factors in strengthening the sustainability of microenterprises, while cost efficiency and resource constraints play a weaker and indirect role in the research model.

Hypothesis Testing

After determining that the measurement model (*outer model*) showed good validity and reliability and the data also proved to be valid and reliable, the next stage of testing was carried out, namely the structural model (*inner model*), which was calculated using SmartPLS 4 *bootstrapping*. After *bootstrapping*, we tested the hypotheses using path coefficients and indirect effects.

The results of hypothesis testing (H1–H11) using the *bootstrapping* method (5,000 resampling, $\alpha = 0.05$) showed variations in the influence between variables in the research model.

H1 shows that resource constraints have a significant positive effect on frugal innovation ($\beta = 0.224$; $t = 4.112$; $p = 0.000$). This means that constraints encourage micro-enterprises to innovate in a resource-efficient manner. **H2** (cost efficiency → frugal innovation) is not significant ($\beta = 0.071$; $t = 1.221$; $p = 0.222$), indicating that cost efficiency is not yet a major driver of innovation. **H3** (market demand → frugal innovation) is significantly positive ($\beta = 0.312$; $t = 5.587$; $p = 0.000$), confirming the importance of market pressure on the emergence of simple innovations.

For the direct effect on business sustainability, **H4** (resource constraints → business sustainability) is significantly positive ($\beta = 0.121$; $t = 2.412$; $p = 0.016$). **H5** (cost efficiency → business sustainability) is not significant ($\beta = 0.078$; $t = 1.446$; $p = 0.149$). Meanwhile, **H6** (market demand → business sustainability) is not significant ($\beta = 0.076$; $t = 1.201$; $p = 0.230$), indicating that market demand does not directly increase the sustainability of micro businesses. Furthermore, **H7** (frugal innovation → business sustainability) is significantly positive ($\beta = 0.467$; $t = 7.005$; $p = 0.000$), indicating that frugal innovation is a major factor supporting sustainability.

H8–H10 show that frugal innovation partially mediates the influence of resource constraints and market demand on business sustainability, but does not mediate the relationship of cost efficiency. Finally, **H11** (moderating organizational capability) is

significantly positive ($\beta = 0.214$; $t = 3.744$; $p = 0.000$), indicating that organizational capability strengthens the relationship between frugal innovation and micro-business sustainability. Overall, the results of H1–H11 confirm that frugal innovation and organizational capability are the dominant elements in explaining the sustainability of microbusinesses, while cost efficiency and market demand have weaker indirect effects.

6. Conclusion and Implications

This study confirms that frugal innovation plays an important role in bridging resource constraints and market pressures on the sustainability of microenterprises in Indonesia. Based on the results of testing 249 microbusiness respondents in Central Java Province using a quantitative approach based on *Partial Least Squares-Structural Equation Modeling* (PLS-SEM), it was found that resource constraints and market demand have a significant influence on frugal innovation and microbusiness sustainability, while cost efficiency does not show a significant influence. Frugal innovation has proven to be an adaptive strategy that transforms the limitations of microbusinesses into adaptive strengths, while organizational capabilities can strengthen the relationship between frugal innovation and the sustainability of micro businesses.

These findings confirm that cost efficiency is not sufficient to maintain the sustainability of microbusinesses, thus requiring a transformation into simple innovations that add value to products or services in line with market needs. The integration of Resource-Based View (RBV) and Dynamic Capability Theory (DCT) provides a comprehensive understanding of how microbusinesses can manage constraints through adaptive organizational capabilities. Thus, limitations are not always obstacles, but can become a source of sustainable innovation if supported by strong organizational capacity.

Theoretically, this study expands the literature on frugal innovation by placing it as a mediating variable in bridging internal and external factors to the sustainability of microbusinesses. The research also provides empirical evidence from the Indonesian context, which confirms that organizational capabilities play an important role in strengthening the effectiveness of frugal innovation as a micro business adaptation strategy. In practical terms, the results of this study provide micro entrepreneurs with an overview of how to utilize limitations as opportunities for innovation rather than merely as cost efficiencies. The government and supporting institutions need to develop empowerment programs that focus on strengthening organizational capacity, simple from of digitization, and the development of innovations based on local resources. Support for frugal innovation also has the potential to increase the economic empowerment of the lower-middle class, expand employment opportunities, and strengthen the resilience of micro-enterprises in the face of market uncertainty.

Limitations and Recommendations

As with prior studies, this research is far from perfect due to limitations such as: First, the geographical coverage only includes microbusinesses in Central Java Province, so the results do not represent the national situation. Second, the use of quantitative survey methods can lead to perception bias and is considered insufficient for exploring the dynamics of innovation in depth. Third, the research variables are limited to resource constraints, cost efficiency, market demand, frugal innovation, and organizational capabilities, without considering other factors such as government policy, digitization, or access to financing.

Future research should expand the data collection area, use a *mixed methods* approach, and add contextual variables such as social networks, policy support, and access to technology. Longitudinal research is also recommended to understand long-term changes in microenterprise sustainability strategies.

Overall, frugal innovation supported by adaptive organizational capabilities has proven to be an important strategy for strengthening the sustainability of microenterprises amid resource constraints and market dynamics in developing countries such as Indonesia.

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